Thames Tideway- Aspects of fish benefit.

Executive summary

On the basis of the evidence below it is concluded that

1. The objective of the UWWTD is to protect the environment from the adverse effects of waste water discharges. Since it is recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species. The objective is to limit ecological damage by ensuring that fish species are sustainable.
2. The TTSS carried out trials on a representative suite of fish to establish their response to dissolved oxygen conditions. Salmon were the most sensitive. From these trials a table of dissolved oxygen standards was established.
3. The two big fish kills in 2004 & 2011 were primarily due to Mogden STW overflows.
4. Mogden STW has now been upgraded. Spill frequency has dropped from about 110 spills a year to about 20 spills a year, the limit proposed by the EC. Fish kills as a result of its overflows should not occur in future.
5. Beckton and Crossness STW are currently being upgraded to remove the chronic low dissolved oxygen conditions in the middle/lower Tideway and these are due for completion in 2014.
6. The sustainable mortality of various species depends on the factors such as length of life and a sustainable mortality. For salmon it was found to be 30%.
7. Further major investment could only be warranted by the need to provide sustainable conditions for the most sensitive fish species that will be present for sufficiently long to warrant the expenditure.
8. Migration and spawning conditions for salmon in the Thames catchment are not favourable but are being improved.
9. Salmon numbers have reduced to an average of less than 10 a year, 2013 3. They are considered by the EA as not sustainable in the Tideway in the short, and medium term and the Dr Friedland model shows that salmon would not be sustainable in the long term, primarily because of adverse temperature and marine conditions.
10. Salmon are the most sensitive fish species so if they are no longer sustainable then they need to be replaced by a similar species or the D.O.Table reconsidered. The additional fish species mentioned are all more tolerant of low dissolved oxygen (DO) than salmon and/or not sufficiently established. Thus the D.O. table needs reconsidering.
11. A meeting on 31st May 2012 discussed fish but the notes contain points that were not heard at the meeting and the notes were subsequently challenged.
12. In earlier years over 300 salmon migrated through the Tideway, so adverse dissolved oxygen conditions would have had limited effect on migration.
13. The 2011 analyses by TW of CSO and water quality conditions in 2021 were based on increasing dry weather flows in the sewers, and thus show deteriorating Tideway D.O. conditions. The 25 year Thames Water (TW) Water Resources Management Plans show reducing water delivered and reducing leakage, hence sewer dry weather

flows will be reducing. Hence the conditions predicted in the models for future years are worse than would actually occur. Consequently the models need re-running with the latest information.

14. Storm runoff will be affected by climate change. The Met Office has said that during winter increases in heavy rain may start to be discernible in the 2020s whilst any changes in summer are not expected to be discernible for many decades. Also middle rainfall events will get smaller. TW has assumed that water temperature increase will be 0.4C more than the air temperature increase. No justification has been provided for this odd assumption which would adversely affect dissolved oxygen conditions. Any re-run of the models should include the latest climate change information.
15. Dr Turnpenny has developed a Tideway Fish Risk Model. This multiplies the proportion of stock in each river zone by month by the probability of standard breach to arrive at a risk factor. This is then multiplied by the mortality to assess the population effect. This is a powerful tool.
16. The Tideway Fish Risk Models risks for salmon were described as "precautionary" in the challenged roundtable meeting notes, hardly a strong basis for supporting a £4.2bn project.
17. TFRM output descriptions state FARL "*not sustainable incidences zero*." Tideway Fisheries Review 2010 "*Tideway fish populations should already be sustainable*."
18. The post tunnel TFRM are based on increasing sewer flows in 2021 and are thus not robust.
19. The AMP4 TFRM assumes that all salmon are present in the Tideway for 7 months of the year. In reality they are assumed to take about two weeks to migrate through the Tideway over a 3 to 4 month period. Thus only a small proportion would be affected by any one spill. Thus, at the time of any one spill, there will be those who have not yet entered the Tideway and those that have already arrived in freshwater prior to the spill.
20. The AMP4 post current works dissolved oxygen plot for Threshold 2 shows 1.15 dissolved oxygen failures a year on average. It would, on average, take about three weeks for a failure plume to exit the Tideway, thus failure conditions could last for the equivalent of less than a month a year on average. Salmon migrate over a three to four month period in the summer. Combining these factors, then the population level effect would be less than the 30% impact which is the limit of sustainable conditions for salmon.
21. Thus the AMP4 conditions, prior to construction of the tunnel, would indicate that, in the unlikely case of there being sufficient salmon, the salmon would be sustainable.
22. Thus, post the current works, fish in the Tideway would be sustainable and, subject to the future conditions not worsening, no further works would be required to meet ecology sustainability.

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1 Introduction

This note considers the information available about historic fish kills, the fish trials and the establishment of fish sustainability criteria, the selection of various fish species, the method of analysis adopted, and the extent to which, post the current works, fish in the Tideway would be sustainable.

2 Objectives

The objective of the Urban Waste Water Treatment Directive in Article 1 is "*to protect the environment from the adverse effects of the above mentioned waste water discharges."* The UWWTD makes no reference to any actual level of protection or any numerical standards.

The UWWTD does not take account of the quality or size of the discharge water, for instance whether it is almost entirely sewage or almost entirely rainwater derived stormwater, or of the size or quality of the receiving water, whether it is a small stream or an ocean. Thus the TTSS decided to set specific objectives for the Tideway to achieve. The broad aspirational aim is to work towards "*To reduce the impact of intermittent sewage discharges, and to further improve water quality in the Thames tideway, to benefit the ecosystem and facilitate use and enjoyment of the river."*, Steering Group report February 2005. Page 19.

For the **ecology** objective the Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that **fish are the most sensitive indicator** of ecological quality, the decision was taken to derive standards that are protective of relevant fish species."*

Thus the objective is to limit ecological damage by ensuring that fish species are sustainable.

The Water Framework Directive requires that rivers achieve Good Ecological status. As the Tideway is a heavily modified water body this is good ecological potential. The Tideway Fisheries Review, 2009 states that the Tideway status is currently Moderate Ecological Potential. On page 37 it states that "*good status will not be met in the middle reaches, even with the solutions in place*." In this context middle reaches are from Vauxhall to Crossness STW.

3 Previous fish kill events

Let us look more closely at the fish kills that have occurred in recent times. In December 2011 I asked the EA for reports on all the relatively recent fish kill events but I have received evidence of just two. There was a serious fish kill in August 2004 and another fish kill in June 2011.

3rd August 2004 event

The Steering Group report 2005 states "*A joint Thames Water/Environment Agency report identified that the fish kill was due to the combination of storm discharges from Mogden STW and the CSOs at the head of the Beckton catchment (principally Hammersmith pumping station) ."*

Four significant rainfall events occurred over the London catchment and Mogden catchment between mid June and later August but without apparent fish kill problems. However on 3rd August 28.7mm fell over the Mogden STW catchment. The rainfall over the London catchment was reported as 12.3mm. At the time rainfall events, and resulting suspended solids loads were being measured at the Acton Storm Tanks. There were events there on 22nd June 2004 and 24th August but on 3rd August no event was measured at Acton and no high flow was recorded there. Thus there must be doubt as to the overflows from the Tideway CSOs in this reach on 3rd August 2004.

The Thames Water bubblers were deployed and hydrogen peroxide was injected to raise the river oxygen levels . The Daily Telegraph of 5th August reported that "*Thames Water's oxygenation vessels were unable to reach the most polluted part of the river at the uppermost limit of the tidal reaches because of low flows...The pavement uncovered by the tide at Kew was strewn with dead 1 ½ inch flounder and bass fry...Among the adult fish found dead were carp, chub, bream, sea lamprey, dace, and tench... The Environment Agency said it was the worst sewage pollution in the river since 1986."* The Guardian reported that 10,000 fish had been killed, see text below with a couple of adult dead fish Maxine Clement of the EA had collected.

Storms kill 10,000 fish in Thames

THAMES FISH IN POISON DISASTER

The EA report Tideway Pollution Event August 3, 2004 states "*The circumstances that made the August 3 event more significant in terms of the severity of the fish kill were probably due to the very high flows received by the Mogden sewage treatment works, causing exceptional operating conditions at the works and leading to large discharges of partially treated sewage....this reinforces the view that the discharge from Mogden STW was a principal contributory factor to the fish mortality. "*

The partially treated sewage is probably activated sludge. Activated sludge is particularly "hungry" for oxygen and is capable of greatly reducing the oxygen content in the river. This appears to be supported by the statement in Solutions Working Group Report Vol 2 December 2006, page 12 *"Due to the poor performance of the final tanks and thereby to minimise the amount of solids discharged to the River Thames, the works currently has a reduced consent flow of 690,000m3/d."* The design flow to full treatment was 810,000m3/d.

It is interesting that on 4th May 2004 a storm with three times the discharge volume occurred but with a much greater proportion over the Hammersmith catchment than the Mogden catchment. I have been unable to find any report of fish kills for this event. Thus it would appear that fish kills are much more dependent on Mogden STW overflow than from downstream CSO overflows.

Although the Hammersmith pumping station may have contributed to the lowering of the dissolved oxygen level, with the main storm being over the Mogden STW catchment, dead fish being found at Kew, a short distance downstream of the Mogden outfall but several kms upstream of the Hammersmith pumping station, and the oxygenation bubblers not being able to reach the most polluted part of the river at the tidal limit which is well upstream of the Mogden outfall, all indicate this was an event primarily generated by Mogden STW.

It is important to remember that Mogden STW has its own sewerage catchment and is not related to the Beckton catchment or the main interceptors. It would not be affected by the proposed changes to the Beckton sewerage system or the Thames Tunnel. The Mogden system is being currently dealt with by the Mogden STW upgrade work.

Impact of the 2004 event

The sustainability of the 2004 event was reviewed by the person who led the fish trials Dr Turnpenny in the report Thames Tideway Strategy: Fish and Ecological Objective, August 2005. "*The Tideway Strategy Steering group Report refers to the August 2004 event, in which large numbers of fish were believed to have died, as a vindication of the proposed scheme....The results of the Tideway Fish Risk model study indicated that for some species, even though the 1.5mg/l standard was breached, mortalities at the Tideway population level were below or around the 10% sustainability benchmark, and that for other species where this was exceeded (e.g. dace salmon), the life-history characteristics of the species may mean that the predicted mortality levels are sustainable."*

In September 2004 fish counts were done in the vicinity of Beckton, many kms downstream of the fish kill area. *"Instead of finding a significant reduction in fish in the area*" compared to September 2002 "*numbers had increased five-fold. It is surmised that some fish may have been able to run ahead of the hypoxic front and were forced downstream, thereby protecting them. In this case, the fish might be expected to gradually spread back into the affected regions when conditions became more favourable."* Thames Tideway strategy: Fish and Ecology Objective August 2005.

This indicates that more fish may be able to survive such conditions and that even the 2004 fish kill may have been sustainable. Thus, with the improvements to the Mogden STW currently under construction, the river would be more likely to be sustainable for all fish without the need for the tunnel.

June 2011 event.

There was another fish kill reported in June 2011. I have been told by Thames Water and the EA that no report has been complied on this event. TW have also told me that the impact of this event was primarily due to Mogden STW but with a contribution from Hammersmith Pumping Station. It seems surprising that, since fish deaths due to too low dissolved oxygen content in the river is stated to be a major driver for expenditure of some £4bn of capital

works, that a major event such as the 2011 event does not have a formal report to support the case for the scheme.

The EA have provided me with two press releases they issued. "*The incident happened after the heavy rain over the weekend caused the release of more than 250,000 tonnes of storm sewage into the river from combined sewer overflows and at least 200,000 tonnes of storm sewage from the Mogden Sewage Treatment Works in Isleworth...fish deaths along a kilometre of river."* The press release some three weeks later stated*. "More than 26,000 fish were killed along a 2 kilometre stretch of the river between Barnes and Chiswick."* Thus the fish kill occurred over a 1-2km stretch, roughly between Chiswick Bridge and Barnes Bridge, which are 1 to 2kms apart. This is downstream of the Mogden STW outfall but significantly, about 3km, upstream of the Hammersmith Pumping Station outfall. Thus it is difficult to conclude that the Hammersmith pumping station outflow had a significant effect on the fish kill.

"*Thames Water has dosed the polluted water with hydrogen peroxide from three different locations to add oxygen to the water. Its oxygenation vessels* " the mobile bubblers" *have also been deployed to the area and can inject 30 tonnes of oxygen a day into the water."* Thus, under the tidal conditions at the time, the TW bubblers were able to reach the Chiswick/Barnes area. CEH monthly report for June shows the flow at Kingston as about 30 m3/sec and the TW reservoirs increasing from 93% to 95% full by the end. This would indicate that TW were likely to have been abstracting from the Thames and thus the flow over Teddington weir would have been likely to be the normal minimum of about 800Ml/d. Thus the bubblers would have been able to reach the Chiswick/Barnes area under these conditions.

I believe that, over the last ten years, there may have been some other smaller fish kill events but I have not been able to obtain any records of them. I have asked the Environment Agency for the records of other fish kills but none have been provided yet.

Conclusions

Thus one could conclude that the prime cause of both these events would be final tank effluent overflow from Mogden STW.

4 Mogden STW upgrade

The text below is from the Thames Water website. It states "*We are carrying out a £140m upgrade at Mogden Sewage treatment Works in west London to extend treatment capacity by 50%. This will significantly reduce the amount of storm sewage overflows into the tidal stretches of the River Thames after the site becomes overloaded during heavy rainfall. The improvements will also help us to meet tighter quality standards for the effluent we discharge."*

Thus it would seem reasonable to assume that the Mogden STW upgrade would mean that such fish kill events would not occur once the upgrade has been completed, in March 2013.

Sewage Works Upgrades

Mogden Sewage Treatment Works

We are carrying out a £140m upgrade at Mogden Sewage Treatment Works in west London to extend sewage treatment capacity by 50 per cent.

This will significantly reduce the amount of storm sewage that overflows into the tidal stretches of the River Thames when the site becomes overloaded during heavy rainfall.

The improvements will also help us to meet tighter quality standards for the effluent we discharge.

So how much has the situation improved?

The TW Sewage Discharge Notifications show there have been 15 spills from Mogden STW between 1st April and the 31st December 2013. Thus it would appear that the Mogden STW upgrade means that the spill frequency has reduced from about 110 times a year to about 20 times a year. All those involved should be congratulated. Interestingly it is at the limit of 20 times a year suggested by the European Commission, and presumably accepted by the EA.

The much reduced spill frequency means that the more polluting first flush goes to storage. Thus not only has the volume of spill reduced dramatically, but also that which is spilled is the less polluting later storm water. This is demonstrated by the large rainfall event on 28th May 2013. This was a heavy rainstorm such that the storm tanks filled but the STW became tide-locked by a very high spring tide and no normal discharge could take place. Some 80,000 m3 of storm flow was discharged into the river. However the EA reported that "*the discharge did not have a significant effect on Tideway water quality. This was evident from the water quality monitoring of the estuary: Dissolved Oxygen saturation in the upper Tideway remained above 80%, which as we know is pretty good. We did not receive any reports from the public of any of the normal polluting effects that we might expect to be associated with discharges, such as fish in distress, or dead."* Darryl Clifton-Dey email 6th September 2013. 80% dissolved oxygen content would be about 8 mg/l (depends also on temperature), well above the threshold of any of the objectives, the highest for mortality being 3mg/l. Further, the critical time of year for dissolved oxygen sags is the summer when the water temperatures are higher, and hence the river would be more sensitive to DO sags, and the river flow lower. This spill occurred at a time when conditions would have been close to such a period. I understand that the spills on 30th July and 24th August also did not cause any fish mortalities.

Thus the previous associated low dissolved oxygen conditions, the main source of fish kills in the Upper Tideway, has been dealt with even though the spill frequency is about 20 spills a year.

With the improvements to the Mogden STW the upper Tideway appears now to be sustainable for fish.

Further the general water quality of the river should improve, thus raising the dissolved oxygen content in the river generally and reducing the health impact.

5 Fish kills due to CSO overflows

The WTP show card states that post the STW upgrade there would be t to 2 fish kills due to CSO spills into the Tideway. This conforms generally with the water quality analyses shown in the water quality plots where there are about 38 failures in 34 years.

I have no record of any such events. I have searched various web sites, so far without success, only finding fish kills on tributaries due to other causes and the fish kill in the River Crane in October 2013 caused by a contractor fracturing the sludge pumping main from Mogden STW to Iver..

On 18th December 2013 I asked the Environment Agency for any records of such events. On 23rd December I was promised that the information would be provided. Once this is provided I will incorporate into this note.

6 Fish based dissolved oxygen standards

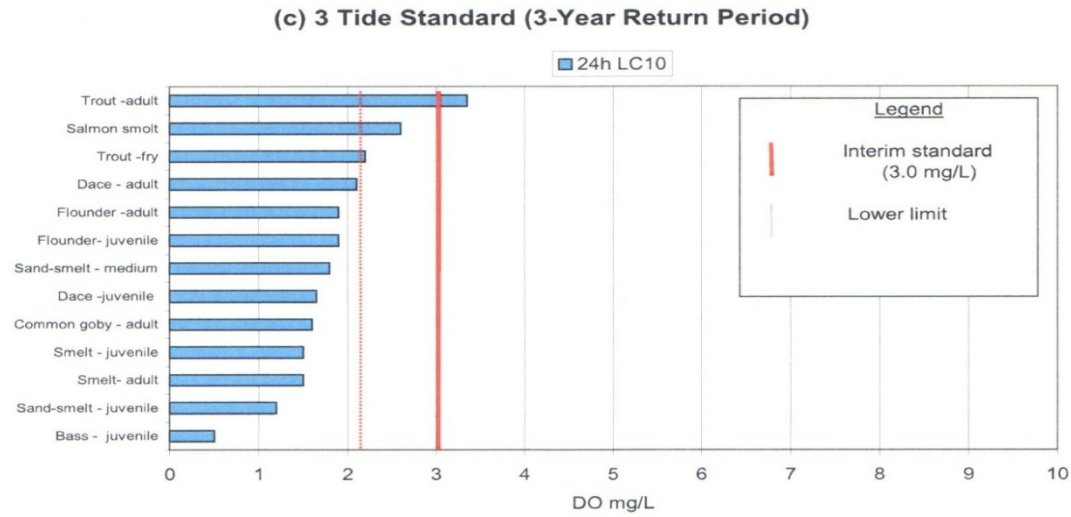
It was necessary for the TTSS to set environmental standards for the Tideway. "*it is expected that, since fish are relatively sensitive to hypoxia compared to other aquatic organisms, compliance with standards ""* aimed at maintaining water quality whereby fish kills are reduced or eliminated"" will also protect other fauna." Thames Tideway Strategy : Fish & Ecology Objective August 2005.

This is supported by the Thames Water report 2006 Tackling London's Sewer Overflow vol 1 page 6 which states "**since it is generally recognised that fish are the most sensitive indictor of ecological quality, the decision was taken to devise standards that are protective of relevant fish species.**"

A suite of fish were chosen to be representative of the fish found in the Tideway. This included dace, flounder, common goby, smelt, sand smelt, bass, and salmon. "*The seven species investigated here were chosen to represent a spectrum of fish sensitivities and to stand as indicators for the 118 or so fish species that have been recorded in the Tideway."* Report on the trials page 83. However salmon specimens for testing could not be obtained, so trout were taken as a surrogate for salmon.

Fish trials were conducted to establish the sensitivity of various fish species to dissolved oxygen conditions.

Thus each representative fish species was tested in turn. The test results shown below, Threshold 2 is the highest dissolved oxygen that was considered to cause mortality.



These test results were converted into a table of dissolved oxygen conditions, see table below, but, as can be seen in the test results, this was heavily influenced by the sensitivity of salmon.

The Thames Water report Objectives and Compliance Working Group Report 2006 is "*To limit ecological damage by complying with the DO standards specified in the table above.*" The Table above is shown below.

Dissolved oxygen threshold 1

FARL page 75 states *"The basis of the proposed standards was as follows:*
The one week standard (4mg/l, 1 per year, 29 tides) was selected to ensure protection against chronic effects; these include eg effects such as depression of growth and avoidance of hypoxic areas."

The 24h standard (3mg/l,3 yrRP,29 tides) and the 6h standard (2mg/l, 5 yr RP, 1 tide) were selected to provide protection to stocks by managing the scale and frequency of mortalities. It was accepted that greater mortality would occur with the more severe of the two standards, but intended that for both standards, fish loss would be fairly limited."

Since the table is representative of those fish actually in the Tideway it is focussed on the

Dissolved Oxygen (mg/l)	Return period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1
Note: The objectives apply to any continuous length of river >=3km. Duration means that the DO must not fall below the limit for more than the stated number of tides. A tide is a single ebb or flood. Compliance will be assessed using the network of Automatic Quality Monitoring stations (AQMS)		

specific conditions of the Tideway.

The table was established prior to the TFRM being developed but was clearly intended to provide sustainable mortalities. However its fundamental weakness is that it takes no

account of the different sustainable mortalities of the various fish species. Thus the TFRM is a much more reliable tool for assessment of fish sustainability.

The notes of the meeting of 31st May 2012 states in relation to the fish suite "*the Chair raised the important question of whether the presence or absence of salmon in the Thames Tideway is important. It was concluded that this is not."* No evidence is provided to support this statement. Further, I was present at the meeting and never heard those words spoken and challenged the notes as soon as they were issued. Looking at the impact histogram above it is clear that salmon are by far the most sensitive fish species in the representative mix. Thus if salmon are not included then either salmon should be replaced by another species or the standards should be revised. All the potential additional fish species mentioned are considered below in this note. However all are either more tolerant of low dissolved oxygen conditions and/or are not sufficiently established in the Tideway. Thus the conclusion in the notes is not supported by the evidence, and the absence of salmon would lead to reasons to reconsider the dissolved oxygen table.

However the standards "*were made on the basis of avoiding fish kills and not on maintaining sustainable fish communities"* Thames Tideway strategy: Fish & Ecology August 2005.

The Jacob Babite review dated February 2006 had on its team Dr Andy Turnpenny who had carried out the TTSS fish trials. This says on page 15 "*we consider there is scope to apply these standards less rigorously or to apply them spatially to reflect the sensitivity of local fish populations or their ability to swim away from areas deficient in oxygen."*

There was a CSO event in August 2004 in which large numbers of fish died. Turnpenny reports in 2005 "*An opportunity was taken was taken to attempt an assessment using the Tideway Fish Risk Model (TFRM). The results of the study indicated that for some species, even though the 1.5mg/l standard was breached, mortalities at the Tideway population level were below or around the 10% sustainability benchmark and that for other species where this was exceeded (dace, salmon) the life-history characteristics of the species may mean that the predicted mortality levels are sustainable."*

"Another interesting observation was that trawl surveys were carried out in the vicinity of Becton STW before and after the" 2004 fish kill *" event. Instead of finding a significant reduction of fish in the area, numbers had increased fivefold. It is surmised that some fish may have been able to run ahead of the hypoxic front and were therefore forced downstream, thereby protecting them. In this case, the fish might be expected to gradually spread back into the affected regions when conditions became more favourable."* Whilst not all fish species exhibit avoidance and there are few offline temporary refuges, consideration of this avoidance phenomena needs to be included in the analysis of sustainability.

Thus, as the aim is to limit ecological damage by ensuring that fish species are sustainable, it is important to consider the sustainability of fish populations rather than the slavish reliance on a specific table. This is considered by the Tideway Fish Risk Model and this, along with its output, is considered later in this note.

7 Additional fish species

The EA notes of the meeting on 31st May 2012 state "*It must be remembered that fish are a surrogate for ecology as a whole. They are particularly suitable as they are mobile and therefore reactive. A suite of seven species of fish having a range of physiological types and DO tolerances was used. These are present in the Thames Tideway and are in the top 15 most abundant species present today.*"

The EA meeting notes state "*The group concluded that: the species chosen to derive the standards are a good physiological spread in terms of: salinity sensitivity, bottom and mid water species; types of life history and would therefore be protective of other species of conservation concern Northerly and southerly species currently occur in the UK, examples of both of which are at the limit of their viability. In the long term southerly species may move into the UK in response because of climate change, but they will replace species with the same ecological function and will replace these within the ecological community. Ecological niches will be filled as species tolerances are exceeded."*

The standards would need to consider the characteristics of the relevant species. for instance if more sensitive species became relevant the standards would need to become tighter. However northerly species such as smelt, salmon, and sea trout are more sensitive to both high temperature and low dissolved oxygen (DO) than the southerly species which could replace them such as lamprey, eel and twaite shad. Thus the standards might not need to be as rigorous in the future.

It could be argued that the fish species should have included those fish species that, with improved oxygen conditions, should be able to colonise the Tideway. I cannot remember this being discussed by the TTSS specifically. However the Report on the Trials Appendix 7 quotes some species including Twaite Shad as "*not strongly established*" and sea trout were not included in the "*discussion on fish of conservation interest*."

The trials report states on page 4 about the Test Fish species "*A number of other Habitats Directive designated species are of conservation interest although they are presently not strongly established within the Tideway and were consequently not used in the experimental work. These include sea lamprey...river lamprey... and the Allis and twaite shads. Such species are difficult to procure and are protected in law but will need to be considered further in the future, probably in a national rather than a Thames Tideway context."*

Salmon are a species which is more sensitive to low dissolved oxygen conditions. If salmon become naturally unsustainable in the Tideway are there other similar species that should replace them?

Some of these aspects were discussed at the fish Roundtable meeting on 31st May 2012 at which I was present. In my view the notes do not represent what was said and agreed at the meeting and I challenged them as soon as they were received. I asked for a number of reports to support statements made at the meeting but only the BEEMS report on temperature tolerance has been received. I have incorporated that into this note. I have also added further information about shad and sturgeon into this note.

Before these species could be considered as drivers of major capital investment it would need to be found out how established they were in the Tideway, how much of their life cycle they spent in the section of the Tideway affected by CSO spills, how affected they would be

by low dissolved oxygen conditions, and whether they could spawn to the extent of becoming a representative species.

In response to my challenge on fish based dissolved oxygen standards in my Project Justification Review, the defra Summary of Responses February 2012 states " *The standards are appropriate to protect sensitive and vulnerable fish species...such as sea trout, eels, river and sea lamprey, and twaite shad."* All these species are migrants who would only spend part of their life cycle in the area affected by the Tideway CSOs.

Eels

Eels are tolerant of low dissolved oxygen conditions. Maes in his report on the Scheldt quotes eel Dp50 of 1.3 mg/l. Eels are one of the most tolerant fish species to low dissolved oxygen conditions.

Appendix 7 to the Fish Trials report 2004 states "*Elvers and eels are common throughout the estuary all year.*" Thus elvers and eels were tolerating the then current dissolved oxygen conditions.

In 2013 the EA informed me *"the excellent number of elvers entering the freshwater tributaries of the Thames in 2013, probably has been helped by the good water quality."*

Therefore eels and elvers are not a species of concern regarding dissolved oxygen conditions which will improve further on completion of the current works.

Lamprey

The EA meeting briefing note states on page 8 that "*There is no doubt that significant pollution can eliminate whole populations of sea lamprey from rivers and there are several examples where this has happened in the past, including the River Thames. Maitland 2003"* Maitland 2003 is EN 5. The text continues " *In such cases, it is usually severe pollution in the lower reaches that prevents upstream migration and kills downstream migrants."* Indeed, from the early 1800s to about the 1960s, the Thames was effectively dead with no residual oxygen for long stretches and this killed off all fish species, including lamprey. This is the situation to which the text is referring. Since then, dissolved oxygen conditions have improved considerably and consideration of the previous horrendous conditions is no longer relevant.

Current situation

The notes of the meeting on 31st May 2012 states "*Sea and river lamprey are already in the Tideway and are probably increasing in abundance. For example post spawning dead sea lamprey have already been found at Battersea in some years."*

I have been told a few dead lamprey were seen near Barnes about 2001. "*presumed spawning site in Kew Barnes area*" , FARL Appendix 7.The adults may have come from France.

There are few reports of either species in the Tideway. None were reported in the 2004 fish kill. The few in the Tideway could mostly be strays born elsewhere. The Environment Agency say they have no data of their own on lampreys in the Tideway, the information they have coming from the Zoological Society of London (ZSL) who collect data in areas such as

power stations. The ZSL , Mowat email 25th April 2012 states "*We have very few recordings of lamprey in the Thames*." Although I have asked for the ZSL information on lampreys, none has been provided.

Thus the evidence appears to show that lamprey are occasional visitors and occasionally spawn.

Spawning

Conserving Nature 2000 Rivers by English Nature (EN 5) states" *Mature lamprey* " returning to spawn " *require a migration route free of obstacles- natural such as water falls or man-made for example weirs, in order to reach their spawning grounds ."* EN 5 page 11. "*Weirs presently deny lamprey access to many valuable spawning grounds....any significant alteration or management of channels that removes resting cover or creates stretches of fast flowing water must be avoided all along migration routes*" EN 5 page 15.

Thus it would appear that lamprey would be unable to ascend the Thames weirs, thus their spawning grounds would be limited to the Tideway. With the encroachment of the sides of the Tideway by successive development of wharves and sea walls both resting places would be lost and much of the Tideway would appear to have a tidal velocity in excess of that required for lamprey.

Dissolved oxygen tolerance

For sea lamprey "*Low oxygen is rarely a factor limiting the distribution of larvae for two reasons. First ammocoetes can tolerate low oxygen levels because of low metabolic activity, their blood characteristics and brancial pumping ability.*" "*some pollution in the lower reaches of rivers appears to be tolerated and migrating adults can pass through such waters to reach their spawning grounds in cleaner water upstream."* EN 5 page 43.

The text book by Hollick states about sea lamprey *"the adults often pass unscathed through heavily polluted water during their spawning migration"* River lampreys *"They are able to survive water with only 9.5% air saturation for at least 4 days."* This would appear to be less than the level 4 Threshold standard of 1.5 mg/l for one tide only once in 10 years. Thus they would meet the dissolved oxygen standards and not would not be a critical fish species.

River lamprey "*larvae can tolerate low oxygen tension, and may remain in their burrows for some time under these conditions*."EN5 page 14. "*Adults..some pollution in the lower reaches appears to be tolerated."* EN 5 page 15.

Conclusions
Habitat is not conducive to lampreys and lampreys should be able to tolerate dissolved oxygen conditions appreciably worse than in the standards.

Sea trout
Sea trout are a migratory species that, like salmon, returns to fresh water to spawn.

Numbers

In the Background note for the round table meeting on May 31st, page 7 the EA states that "*sea trout are becoming increasingly common".* However the records of returning sea trout in

the Thames over recent years provided by the EA show the numbers of returning sea trout since 1994 to have been variable but with no overall change, bar one year, at about 5 to 15 per year. 2013 had 25. Some smaller sea trout may escape from the trap so the actual numbers could be somewhat higher. However it would be reasonable to assume a similar mix each year, in which case the numbers are sensibly steady.

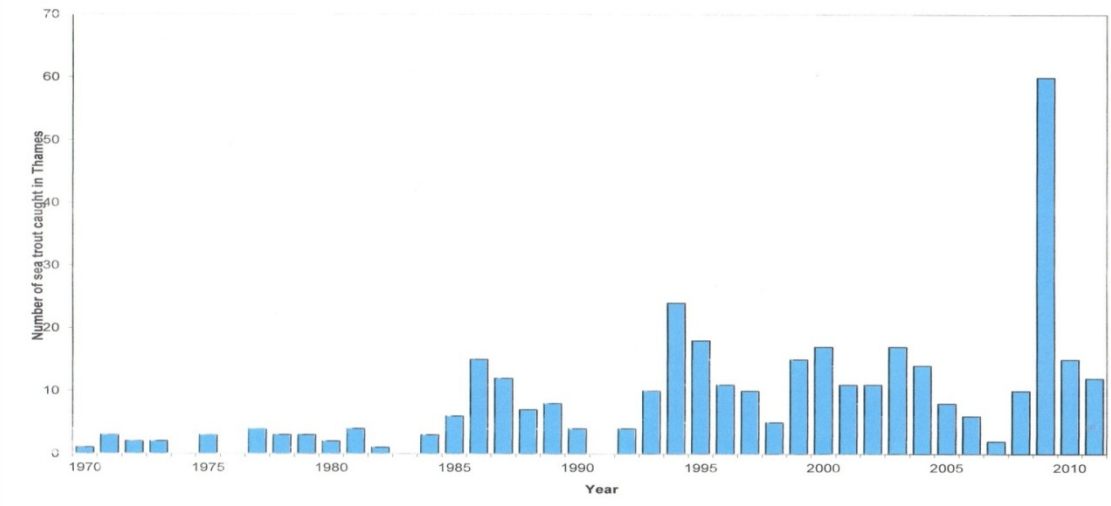
Spawning

Daryl Clifton Dey of the EA, has told me that, some years ago, a single sea trout redd was found well down the river in Deptford Creek, part of the Ravensbourne river. He believes that spawning may be occurring occasionally in the River Colne. The RBMP shows the River Colne as having moderate ecological potential status. Sea trout are known to enter non-natal rivers and it is probable that most of the numbers seen come from another river. Clifton- Dey said that they tag the fish they catch and they have caught the same fish more than once. DC-D did state that the occasional sea trout smolt had been observed. This would increase the likelihood that some sea trout are returning to a natal river. However if that were to be the case, then one would expect to see a significant increase in numbers as a greater number of sea trout returned to their natal river to spawn. That could explain the increase in 2009 but the numbers returned to the general level in the following years

At the meeting, and in my note of the meeting, I requested a copy of any note of when sea trout smolts were observed but none has been provided.

Consideration for inclusion in the fish suite

The FARL studies in 2004 considered that the numbers were not sufficiently numerous to be specifically considered for inclusion in the fish suite. They were not included in the discussion on "*Test Fish Species*", page 4 nor in Appendix 7,"*Notes on the main fish species*"



The Thames Tideway Strategy Steering Group (TTSS), of which the EA was the lead member on this topic, in 2003 considered the sea trout numbers too small a population to be included as a fish of conservation interest. The numbers since then, bar one year, are very similar. I heard no challenge to this view at the meeting on 31st May 2012. I have asked in

my notes of the meeting "**Thus is there any reason to change that decision? "** I have had no response.

Temperature

The BEEMS report says in Table 19 on page 42 that the maximum sea surface temperature in September at the latitude that the species are found is 24.6C. However in Appendix C the marine temperature tolerance of sea trout is shown as lethal 22.5C with a maximum preferred of 17.5C. The latter source would appear more reliable.

The EA state in The thermal biology of brown trout and Atlantic salmon on page 34 that the tolerance of brown trout, the same species as sea trout, to temperature "*appears to be about 2C*" less than salmon. This is different from the BEEMS analysis where sea trout and salmon have the same figures.

The EA state in The thermal biology of brown trout and Atlantic salmon on page 34 that the tolerance of brown trout, the same species as sea trout, to temperature "*appears to be about 2C*" less than salmon.

However sea trout return earlier than salmon, starting in May with the main run in June and a few in July. Being earlier than salmon means the river water temperature will be lower but rising than for the salmon run later. Taking May and June as the key months and studying the HPA water temperature plot for 2005 and 2006, then the early May temperature is about 15C with the beginning of June about 17.5C and the end of June temperature about 21C. Thus, at present, sea trout can enter the Tideway during May and early June before reaching presumed adverse temperature conditions.

The long term situation

By 2050 the water temperatures are predicted to rise by about 1.5C, thus squeezing the time for spawning.

The EA Science report The thermal biology of brown trout and Atlantic salmon states on page 31 "*The models for 27 rivers...For brown trout the model suggests that...15 rivers* "would be" *uninhabitable by 2050 under the high global warming scenario."* For salmon these are mainly in the south and east so one would presume similarly for sea trout. Thus the Thames is likely to be uninhabitable by sea trout by about 2050. There was no challenge to this view at the meeting of 31st May 2012.

Conclusion

There are few sea trout returning each year. Whilst spawning probably has happened, it appears infrequent and not every year. Sea trout are likely to become unsustainable in the long term due to climate change induced temperature rise. They were not considered by TTSS to be sufficiently numerous to be considered for the original fish suite. The numbers are still similar. My notes concluded "*Thus there appears no new reason to change the FARL/TTSS view that sea trout are not a species sufficiently established...."*

Shad

Current population

In the FARL fish trials report Twaite shad were described as "*not strongly established within the Tideway*" and no notes of their biology were provided on them in Appendix 7 My understanding is that they do appear on occasion.

The Environment Agency say that the only data they have on Twaite Shad comes from the Zoological Society of London. They say that the ZSL "*collect data in areas such as power station screens in the east of the estuary.*" If so then information from ZSL may well be outside the area of concern. Anyway ZSL have stated, Mowat email of 25th April 2012, that "*they have very few recordings of shad".*

Migration route

Shad are reported to be unwilling to migrate past weirs with turbulent flow and" *need easy access to spawning grounds*" EN Shad page 10.

"*the critical habitat requirements are : a clear migration route to the spawning grounds, with suitable river flows and no barriers."* EN 3 page 12.

"Apart from actual barriers, any significant alteration or management of channels which remove resting pools or creates stretches of fast flowing water or very shallow water must be avoided all along the migration route." EN 3 shad page 14.

The Tideway is heavily altered and channelised with resting pools removed by encroachment of wharves and river walls and historical dredging for navigation and stretches of fast flowing water driven by the tide. Thus the Tideway channel does not appear to be a favourable habitat for migrating twaite shad. Such conditions will not change, so the migrating habitat is unlikely to be favourable in the future.

Spawning conditions

"*Spawning takes place in flowing water over stones and gravel, among which the eggs sink*." EN 3 page 11.

BEEMS page 74 states that "*Twaite shad spawn in the River Usk about 10km above the tidal limit."*Thus it would appear the preferred spawning is well upstream of the tidal limit, in this case Teddington Weir.

"*In practice the location of spawning grounds is often limited by obstacles to migration. Such obstacles include man-made dams and weirs."* EN shad page 13 Thus Teddington Weir would be an obstacle to shad migration further upstream.. *"fish passes are not often effective because shad avoid confined spaces and areas of turbulent flow."* EN shad page 14.

"Habitat in those stretches used for spawning should remain diverse, with deep pools and overhanging banks for rest and shelter before and after spawning, and adjacent areas of suitable gravel over which to spawn." EN3 page 16. Due partly to extensive river barge traffic in historical times, the upper Tideway is largely canalised with tow paths, artificial bank protection, and man-made features. I believe there are few, if any, deep pools or overhanging banks for rest and shelter.

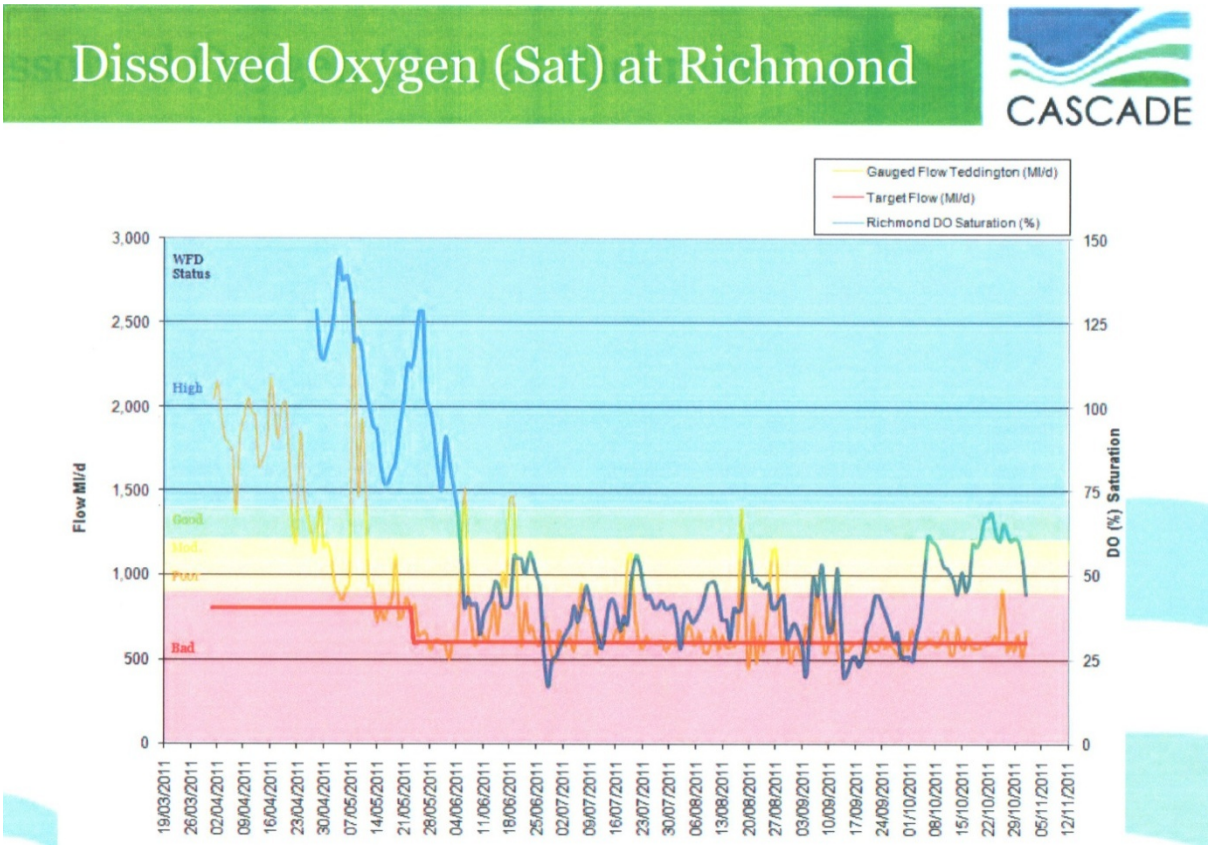
I was told at the meeting on 31st May 2012 that recent habitat sampling work shows extensive areas of gravel substrate in the upper Tideway which could make a spawning ground for twaite shad. Good. However I was also told that these beds are subject to sediment build up during low flows. This is unsurprising as the tidal Thames is a very silt laden river, as can be seen by its colour, especially during spring tides.

For spawning shad require "*clean, well oxygenated substrate is required for successful hatching of eggs and survival of young larvae*(Maitland & Hatton-Ellis)" Background note. Maitland & Hatton Ellis is the EN 3 publication.

The Cascade LTOA report provides information on oxygenation levels at Richmond for 2011 where there are gravels and this shows good oxygenation in May but an average of about 50% in June, presumably too low to be "well oxygenated", see image below. Thus the spawning beds would have had poor oxygenation. However this was a period of unusually low rainfall and river flow. Further, it is not known how much influence the Mogden STW would have had on dissolved oxygen conditions in the Richmond pound. With the upgrading of Mogden STW this adverse effect on dissolved oxygen would significantly reduce. However there are a number of STW upstream of Richmond which would have effected the Richmond Pound. Thus care should be used in interpretating the actual figures. I cannot find any more up-to-date data. However the plot does indicate that dissolved oxygen conditions are unlikely to be good during the hatching and larval stages of shad.

The Cascade LTOA study also reported that these places are often sedimented and this occurs once the winter floods have ceased to flush out the accumulated sediment.

Thus the habitat would not appear to be optimum for Twaite shad spawning.



Dissolved oxygen tolerance

The Environment Agency email of 4th April 2012 states *" FARL discovered tests on the related American shad by Chitendon (1973) which suggested that shad are more tolerant*" of low dissolved oxygen" *than salmon*." The fish trials report page 6 shows American shad as having a 24 hour Lc10 of 1.58 mg/l. This would indicate that shad, as a species, may be relatively tolerant of low dissolved oxygen, "*this genus is more tolerant than Salmo spp*." Trials report page 7.

Thus shad are unlikely to be either in the Tideway in significant numbers or, if they were, to be affected by low DO in the same way as salmon.

Sturgeon

There are several species of sturgeon some of which can tolerate UK waters. However they are either endangered or critically endangered and are extremely rare. They are one of the most threatened of European species thought to have only a few scattered populations on the Atlantic coast.

The notes of the meeting on 31st May 2012 state p4 "*It is possible that adolescent European Sturgeon will be seen in the future due to recent French stocking activity."* My understanding is that the French stocking referred to are the trial stocking of a aquaculture centre to try to rear sturgeon to produce caviar. With the high value of caviar, great care would have been taken.

However the trials were not in the nearby rivers of Normandy but in the Gironde River near Bordeaux. Thus the water climatic conditions would be appreciably different to those in UK.

Climate change conditions would not result in similar conditions in the Thames for many decades, if not a century.

Two sturgeon have been caught in recent years in the south of England but both are thought to be escapees from the UK pet trade, Talk of the Thames winter 2013. There are a few aquaculture farms in Europe that breed sturgeon for caviar so they could have escaped, in some form, from there.

Conclusion

Thus sturgeon are endangered or critically endangered and are extremely rare in UK waters. They are not sufficiently established, or likely to become so, to be considered as a representative species.

Conclusion on all the species

Thus it would appear that these species are either more tolerant of low dissolved oxygen than salmon and/or are not sufficiently numerous to be considered a representative species. Thus, were salmon to be classified as unsustainable and not appropriate for the fish suite, then the dissolved oxygen table would need reconsidering.

8 Salmon sustainability

No salmon has spawned naturally in the Thames catchment for about 150 years. In 2013, after the upgrade of Mogden STW improved the water quality of the Upper Tideway, only 3 salmon were trapped at Molesey weir. They do not occur between the Esk and the Itchen.

Spawning areas

The Environment Agency investigated the habitat for spawning in the Kennet and Lambourn. " *There appears to be little "text-book" spawning habitat and sedimentation is clearly an issue in many areas." " The results suggest that the Kennet system provided marginally suitable Atlantic salmon and brown trout spawning habitat ."* [1]Having only marginal spawning habitat is clearly a serious disadvantage to re-establishing a naturally sustainable salmon stock.

The EA by email 11th June 2012 stated "*Since the Kennet and Lambourn were designated as SSSI and SAC there has been a perceived decline in the quality of their habitat. This is the firm view of anglers, river keepers and many other people, and we have no reason at all to doubt this, although there is very little tangible evidence for it. The generally held view is that the decline is due to the canal, changing farming practices, the invasion of non-native crayfish, predation by cormorants, over-abstraction from groundwaters, and inappropriate river management. These may all contribute and the canal is a particularly favoured "culprit" because at places such as Copse Lock it is possible to clearly see sediment being re-suspended by boat propellers. However, this will have no bearing on the habitat in the Wilderness Fishery, which is upstream, or the Lambourn, which is not connected to the canal."*

[1] RFERAC September 2010 page 6.

"In 2006 the EA tasked a contractor to carry out some freeze coring of the gravels in the Kennet and Lambourn to assess whether they were of a composition suitable for salmon spawning. This looked at the size of the substrate and the amount of fine sediment within it (fine sediment clogs up the interstices in the gravels and prevents oxygen from reaching buried eggs). The results did show that some areas were quite marginal for salmon spawning. Subsequently we carried out some work burying eggs within the gravels to assess true survival, and got quite encouraging results. I think that the overall conclusion was that there was habitat for salmon spawning, but that it could be improved. The improvements to habitat are being carried out."

"The River Kennet still has a number of challenges, some such as crayfish, interactions with the canal, and abstraction are pretty large, but they are being looked at and overcome wherever possible."

Kennet & Avon canal.

The Kennet and Avon Canal was reopened about 1990. Upstream there are a number of nutrient sources including agriculture and sewage treatment works. I am informed that in essence the problem is nutrients and sediment settling in the canal in winter when it is hardly used and getting re-suspended by the propellers of boat traffic. From Kintbury down to Reading the canal and river share a channel in a number of places causing sedimentation, turbidity and algal growth in what should be a gin-clear chalk stream. This problem built up over several years after the re-opening of the canal. A solution to part of the problem would be separation of the canal and river. The EA Kennet catchment Plan 2010 states "*this is very expensive at Copse Lock....Once the canal and river re-join in Newbury there appears to be no other location downstream of Newbury where separation is possible."*

Thus the problems of the water quality, habitat and adverse weirs of the River Kennet would need to be overcome before successful salmon spawning could take place.

Effect of Thames weirs

Between 1996 and 2004 radio tracking was done to establish the efficiency of the fish passes on the Thames. The results are set out below.

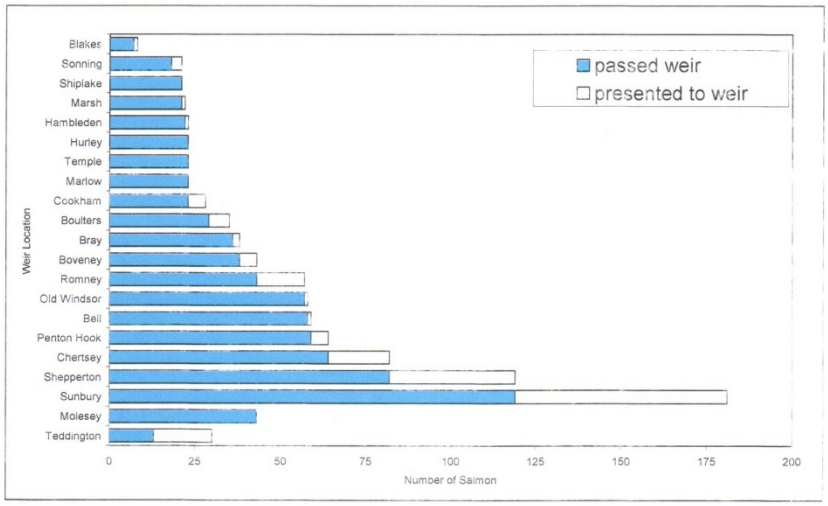


Figure 3 Results from salmon radio tracking programme on River Thames 1996-2004

The River Basin Management Plan 2009 states on page 17 "*Barriers to fish passage are one of the big issues affecting the ecology of rivers in the Thames River Basin District.*

The report of the Regional Fisheries, Ecology, and Recreation Advisory Committee of 2010 September 2010 states "*Under these efficiency rates, for every 100 salmon that make it into freshwater, only nine will reach and successfully swim over Blakes weir, the first on the river Kennet."* Thus the weirs on the River Thames are major obstructions to salmon sustainability.

Since the radio tracking study, new fish passes have been constructed at 7 weirs, including Sunbury and Shepperton, to improve fish passage and more are planned at most other weirs. Some of these are to alleviate the impact of Archimedes screw hydropower development. Some fishermen are concerned that the turbulent flow from such turbines may attract migrating salmon, thus delaying or impeding migration.

The notes of the meeting on 31st May 2012 state on this topic "*The chair concluded that, as improvement measures are now being designed and implemented to support a spread of species, salmon as an individual species is less important to drive action than in TTSS days."* The meaning of this is not clear to me. I presume that it means that as there is now great doubt about the longer term sustainability of salmon, then improvements to habitat to reach good ecological status, and measures such as improvements to weirs, need to be supported by the needs of other species.

The report of the Environment Agency Regional Fisheries, Ecology and Recreation Advisory Committee dated 20th September 2010 states on page 2 that "*However the two key targets relating to the return of adult salmon and their successful breeding in the Thames have not been achieved. ..Without significant progress on these two key elements, it is very unlikely that a self sustaining salmon population is viable in the Thames over the short to medium term (ie next ten years)."*The return figures are shown below and show minimal returning salmon. *"We have no evidence of successful salmon spawning in the River Kennet, and given the low numbers of returning salmon, it seems unlikely that any successful salmon breeding has occurred."*

Salmon returns

The paper to the Regional Fisheries, ecology and recreation advisory Committee meeting on 20th September 2010 included a graph of recorded salmon catch and this is shown below.

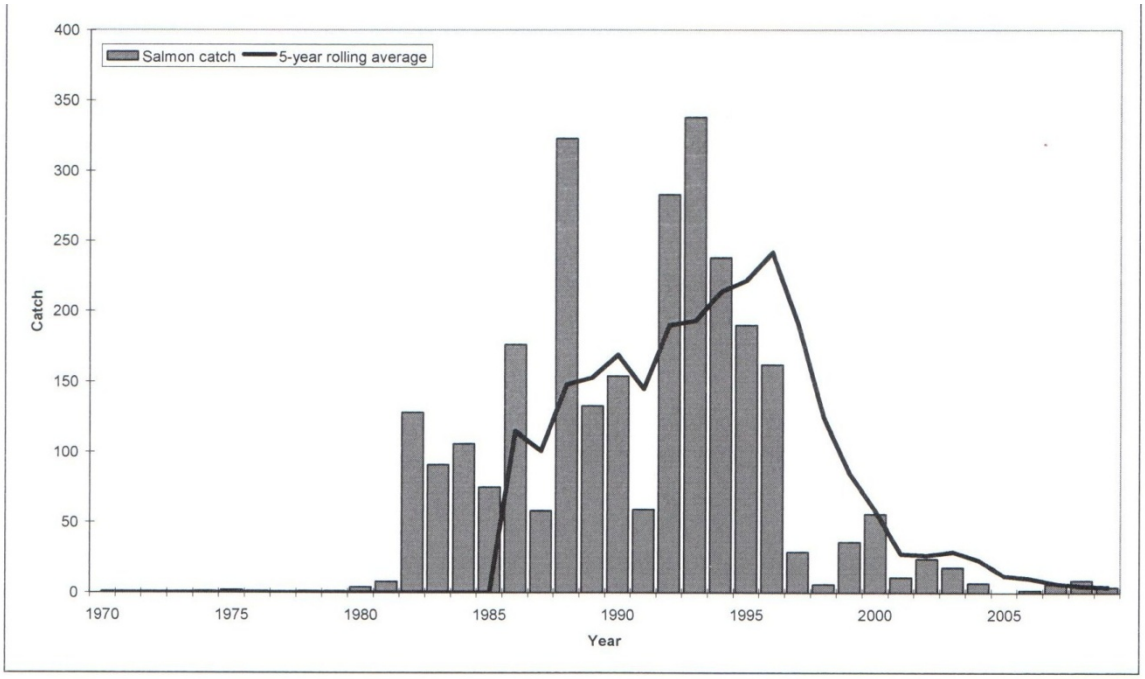


Figure 1 - River Thames recorded salmon catch and five year rolling average

David Solomon in his report River flow and salmon migration in the River Thames at Molesey 2011 states that "*There are three factors that may explain the falling returns. First marine conditions have changed since the 1980s, reducing overall marine survival. This is clearly illustrated by the recorded return rate of hatchery smolts to the river Shannon...There can be little doubt that generally reduced marine survival has contributed to the reduction in returns to the Thames...The second factor is the change in stocking stategy as a result of a review in 1994."* I believe from the lower non-tidal Thames " *to target the River Kennet....The third factor may be implicated is reversal in the trend of using returning fish as bloodstock."*

The notes of the meeting on 31st May 2012 state "*S Colclough noted that CSO events in the middle estuary appear to have been instrumental in stopping salmon runs."*

I have been unable to identify any significant worsening of the dissolved oxygen conditions in the Tideway. Looking at Solomon's table 2.6 Monthly mean dissolved oxygen levels at Cadogan pier 1986-2008, between 1987 and 1992 every year had at least two months when the mean monthly dissolved oxygen level was below 5 mg/l. Between 1993 and 2007 inclusive, 15 years, there were only 3 years when this occurred. "*Improvement and expansion at Beckton and Crossness STW, completed in 2005, has improved the situation..."*[2]

[2] Solomon page 28.

Thus changes in dissolved oxygen conditions in the Tideway are most unlikely to have caused the reduction in salmon returns. I have not been able to find any evidence that CSO events have stopped salmon runs. Even if they had then the spill plume would still have cleared the middle Tideway within about three weeks compared to the salmon run period of about three months. In any case, when dissolved oxygen conditions were worse, several hundred salmon a year migrated upstream to be caught in the Molesey trap.

Salmon post 1996

However post 1996 the salmon numbers crashed despite continued stocking by the Environment Agency. The average in recent years for those in the Molesey Weir trap has been less than 10/year. In 2013, despite the considerable improvement from the up-rating of Mogden STW , the number of salmon caught in the Molesey trap was 3.

Medium term salmon sustainability

Thus there are effectively almost no salmon in the Tideway. The EA state "...*it is very unlikely that a self sustaining salmon population is viable in the Thames over the short to medium term (ie next ten years)*." The EA have now "*halted current annual rearing and stocking of juvenile salmon."*

Effect of temperature

"*Species such as salmon are already close to their physiological limits due to the interaction between temperature and oxygen....Warmer water temperatures, an expected impact of climate change, will exacerbate this*.." TTT vol 1 page 8. Post 2023 adverse temperature conditions would affect any returning salmon.

According to Turnpenny and Liney,2006 the lethal temperature for salmonids is 27.8C but the Freshwater Fish Directive says for salmonids the temperature should not exceed 21,5C.

The minutes of the meeting on 31st May 2012 states "*SC: thermal standards have not been set for transitional waters, but a report published last year (BEEMS SAR.008, 2011) suggested that the good/moderate boundary should be 23oC compared to 21.5oC previously suggested. Knowledge of salmon's thermal physiological limits is improving and the species appears to be more tolerant than was previously thought."*

Re salmon the upper lethal temperature, is quoted in BEEMS on page 49 as 28C. However in Table 19 on page 42 the maximum sea surface temperature in the latitude where salmon are found is quoted as 23.5C. In Appendix C temperature tolerance of fish is quoted as lethal to salmon at 22.5C with a preferred maximum of 17.5C. The latter figures appear more realistic.

This is described on BEEMS page 51 "*Summer temperatures in the warmest southern English estuaries (eg the Thames) can reach 23-24C. For most warm water species ULTs in the high twenties to thirties degrees centigrade provide adequate headroom for survival under these conditions, although the situation is more marginal for some cold-water species such as salmonids and probably smelt."*

"Brett's classic study of the thermobiology of sockeye salmon demonstrated that the preferred temperature in this species (15C) coincided with optimum conditions ...Magnuson

found that most fish will spend two-thirds of their time within +-2C of their temperature preferendum and all of their time within +-5C."

BEEMS Table 22 summaries data on fish temperature preference. For salmon the paper by Alabaster 1986 states preference 9-17C. For avoidance their latest paper 1991 states "*21.5C Thames migration ceased."* This is in conflict with Rosten 2010 which states "*no effect of temperature on entry into the Thames: controlled by DO only."* Unfortunately there is no record of the highest temperatures reached during this study so it does not allow one to put a number on the temperature limit found.

BEEMS page 64 quotes the Solomon and Sambroo (2004) study of the Avon as a *"case less susceptible to low oxygen, where the effects may be more closely related to temperature"* 433 fish were tagged. "*The data suggest that the onset of thermal avoidance in salmon probably does not occur below a value of 19 C*" However no tagged salmon entered the river within 10 days when the temperature was 21 C.

Thus, one conclusion could be that although salmon can tolerate water temperatures up to about 22.5C, they are unlikely to migrate upstream to spawn when the temperature exceeds

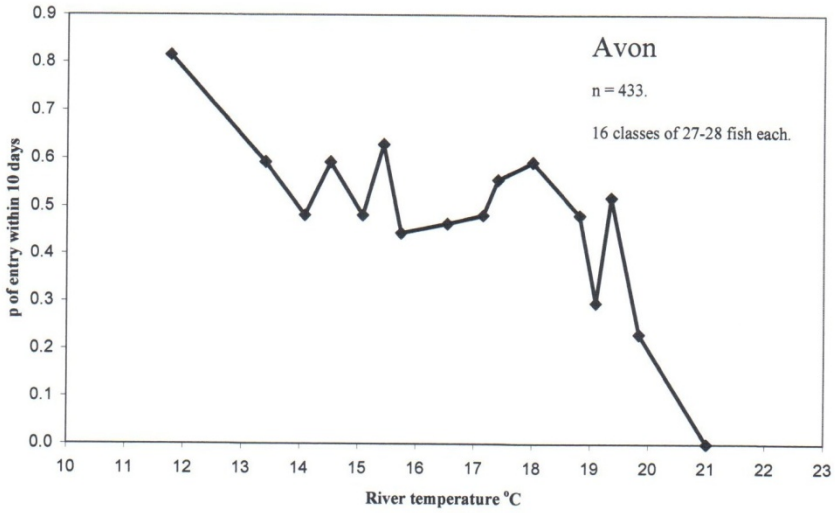


Figure 8.1. Relationship between river water temperature at 09:00 hours on the day of tagging of salmon at the entrance to the estuary of the Hampshire Avon, and the probability of passing the tidal limit within 10 days of tagging.

about 21C.

Solomon(2011) analysed the relationship of temperature and migration. ""Migration is under-represented at temperatures above about 22.5 C in July, 22 C in August, and 19 C in September. " page 24.

Solomon has shown that salmon did not enter the Avon River when the temperature was above 21C. In the Thames "*Migration is under-represented at temperatures above about 22.5 C in July, 22 C in August, and 19 C in September."* Solomon 2011. Turnpenny et al 6-14 says "*Summer temperatures in the ...Thames can reach 23-24 C. "* With climate change temperatures are likely to rise 2 to 3C in the long term.

The only years for which I have regular temperatures is in the HPA report on The Thames recreational users study which shows the temperatures for the years 2005 and 2006.This shows, for the summer three months, temperatures around 20C with occasional spikes to about 22 C and one to about 23.5 C. More importantly it shows that for those three months for at least one of them temperature would have affected migration.

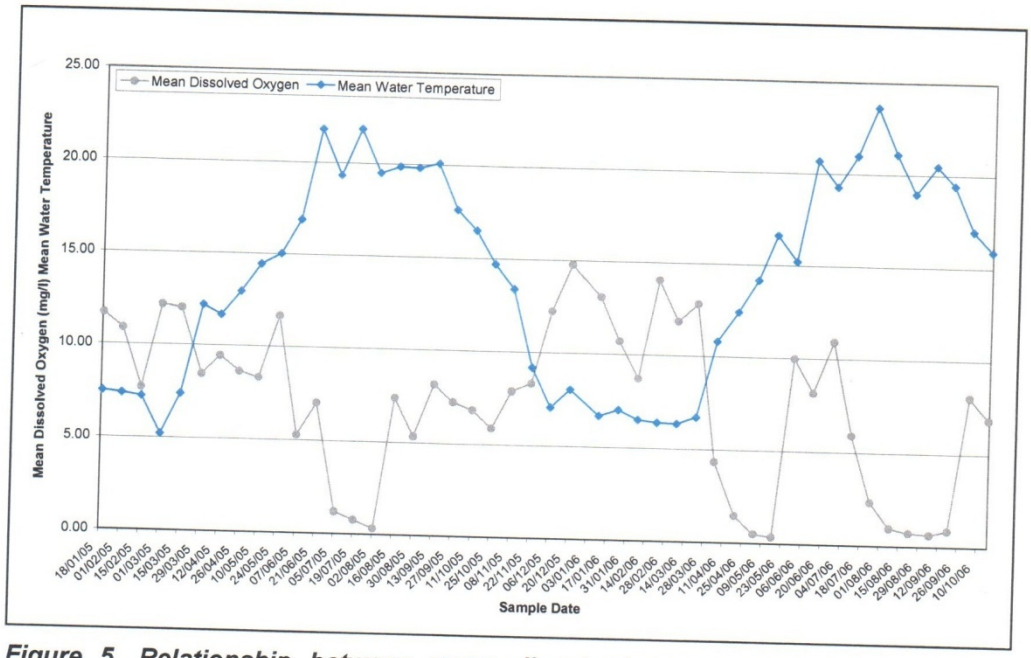


Figure 5. Relationship between mean dissolved oxygen and water temperature. Thames tideway January 2005 October 2006

Cascade in their studies on the LTOA 2011 Technical Appendix D page 43 have plotted maximum annual temperatures for the River Thames from 1991 to 2005.. This shows that during this period the annual maximum has risen from about 22C to about 23.5C. This is a remarkable rise in just 14 years. Whilst annual maximum do not directly link with general temperatures during the salmon migration season, it does indicate the general trend of summer temperatures in the river and it is likely that general temperatures during the summer will have increased by a similar amount.

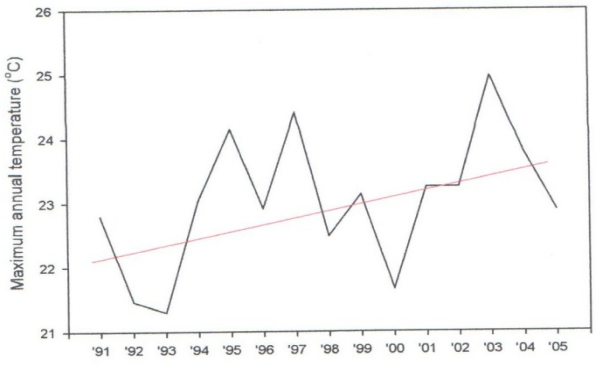


Figure D.6 Maximum Annual Temperature of the River Thames, 1991-2005

Thames Water have provided me with figures for the monthly temperature increase for the Tideway. For July this shows a rise of 1.5C by 2050 and 2.4C by 2080.

Thus one would expect that future temperatures would more and more restrict salmon migration.

Long term salmon sustainability

The image below is of a river thought to have little outside influence on salmon numbers. As can be seen, returns of salmon in recent years have reduced considerably

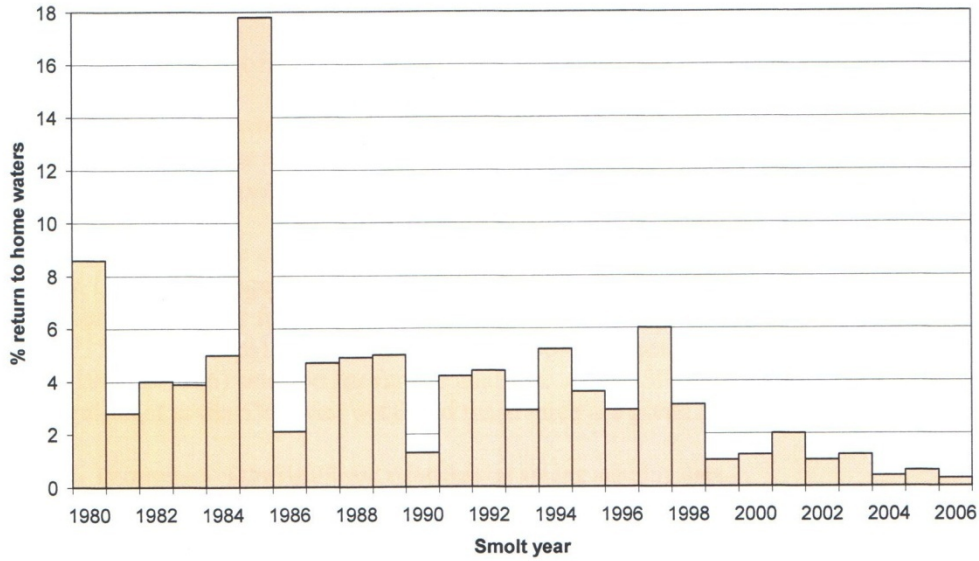


Figure 3.3. Rate of return to home waters of one and two year old hatchery smolts released in the River Shannon in 1980 to 2006. Source: 2008 Report of the ICES WG on North Atlantic Salmon.

Solomon (2011) analyses salmon sustainability in his report on page 17. "*There can be little doubt that generally reduced marine survival has contributed to the reduction in returns to the Thames*."

The Environment Agency in its December 2001 report for Defra "The case for change-current and future water availability "page 23 states "*Protecting the water environment in the future*" in this case 2050 *"With changes to the amount and distribution of rainfall and an increase in temperatures, it is inevitable that the water environment of the future will be different to the environment seen today. Some species will be better suited to future conditions and thrive. But there is a risk that some important species and habitats could be lost. Iconic species such as* ***Atlantic salmon and brown trout, which need cold water to thrive, may struggle to survive in some rivers."*** My emboldening.

Below is the temperature uplift for 2050 and 2080 .

Results of calculated monthly uplift values for River Thames temperature (°C) in the 2050s and 2080s for Medium emissions p50

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2050	M	p50	2.1	2.0	1.5	1.6	1.6	1.6	1.5	1.3	2.0	2.2	2.2	2.1
2080	M	p50	2.8	3.0	2.2	2.3	2.3	2.2	2.4	2.1	2.9	3.0	3.0	3.0

These temperatures are mean monthly so there may be periods when the temperature change will be more or less. Further, I have been informed by TW that they have assumed that water temperature would be 0.4C higher than the air temperature quoted above. I have asked for substantiation but none has been provided.

The EA science report states on page 34 that models show that, "*Under the scenario of high global warming, they predicted that 12 of the 27 rivers would be uninhabitable by Atlantic salmon by 2080, mainly those in the south and east*." It would appear likely that this would include the Thames.

BEEMS page 90 Regarding global warming "***Atlantic salmon*** *populations in southern British rivers can be regarded as being at* ***particular risk,*** *especially in estuaries such as the* ***Thames,*** *where low DO levels reduce metabolic headroom (Rosten 2010)"* My emboldening

One conclusion could be that, although salmon can tolerate water temperatures up to about 22.5C, they are unlikely to migrate upstream to spawn when the temperature exceeds about 21C. This compares with the current Tideway summer temperature of 20C to 22C. However the climate change increase in summer water temperature by 2050 is about 1.5C, resulting in a projected river temperature in 2050 of 21.5C to 23.5C, indicating that, at times, the river temperature will generally exceed the highest temperature at which salmon will run up, 21 C, and also at times exceed the limit of tolerance of salmon, about 22.5C. By 2080 the river temperature in the summer is projected to be 22.4C to 24.4C, generally well beyond the runup cut off temperature found by Solomon of 21.C.

In March 2010 the Atlantic Salmon Trust held a conference on "Managing River Flows for Salmonids: Evidence-based Practice. This states on page 74 concerning the climate change effect on the freshwater environment "*An increase in the water temperature will accelerate*

embryonic and alevin development during the winter and lead to earlier emergence of fry from the gravels. Survival of eggs and alevins in upland rivers could be reduced should expected higher winter rainfall generate more frequent river spates resulting in wash-out of the embryos...Reduced flows and increased river/estuary temperatures will inhibit and delay the movement of adult spawning salmon into freshwater environment. Increased temperatures will reduce the amount of suitable thermal habitat for returning salmon. Reproductive success and fecundity may be reduced at higher water temperatures... There is also reason to expect northward movement of the thermal niche of anadromous salmonids with decreased production and ***population extinction in the southern part of the distribution areas.****"* My emboldening.

Regarding the marine environment it states "*A mis-match in prey availability during entry into the marine environment may reduce post-smolt survival and growth. Changes in sea surface temperatures may also reduce the amount of suitable thermal habitat required for suitable growth and development of salmon in the sea.."*

In October 2011 a Salmon Summit was held at La Rochelle to discuss the latest scientific findings of the SALSEA project. Dr Kevin Friedland gave a paper on behalf of the ICES North Atlantic Salmon Working group, entitled "How climate and post-smolt growth control marine mortality in Atlantic salmon: the potential effects of a changing climate on the marine survival of Atlantic salmon."

Dr Friedland concluded "*Ocean thermal conditions in key post-smolt nursery areas are expected to continue to change,* ***making marine survival unsustainable*** *for segments of the stock complexes from both north America and Europe*." My emboldening.

To my question by email asking if the stocks referred to included southern England, Dr Friedland replied on 16th December 2011 "*The analysis was for southern tier European Stocks , so that would include stocks from England."*

"*With predicted continuing background temperature rises associated with climate change****, it is not clear that there is any real chance of salmon runs improving in the future*** *although the STW upgrades may improve the situation.*"Tideway Fisheries Review Appendix F Needs case 2010 page 11.

The notes of the meeting of 31st May 2012 states ***"...there is currently no evidence to challenge the hypothesis that salmon may not be sustainable in the longer term due to climate change."*** My emboldening.

Conclusion on salmon

Thus salmon have been designated by the Environment Agency as not sustainable in the short to medium term. Even with the benefit of the £140m Mogden STW upgrade, only 3 salmon were caught in the Molesey trap in 2013.

They are obstructed by adverse conditions at some weirs in the River Thames and also in the River Kennet, have adverse spawning conditions in the Kennet river, and are projected to be not sustainable in the longer term due to post smolt marine conditions and are classified by Dr Friedland as not sustainable in the long term.

Thus it would not seem warranted to spend large sums of money in the hope that salmon might return in adequate numbers for a limited number of years.

Conclusions on fish species

It would seem axiomatic that major investment could only be warranted by the criteria needed to provide sustainable conditions for the most sensitive fish species that will be present for sufficiently long into the future.

The notes of the meeting of 31st May 2012 states in relation to the fish suite "*the Chair raised the important question of whether the presence or absence of salmon in the Thames Tideway is important. It was concluded that this is not."* No evidence is provided to support this statement. Looking at the impact histogram above it is clear that salmon are by far the most sensitive fish species in the representative mix. Thus if salmon are not included then either salmon should be replaced by another species or the standards should be revised. All the potential additional fish species mentioned are either more tolerant of low dissolved oxygen conditions than salmon or are not sufficiently established in the Tideway. Thus the absence of salmon would provide a strong reason to change the table.

When I received the notes of the meeting it contained many statements that I did not hear said at the meeting, and in particular the conclusions. I challenged the notes at the time. Some of the alleged conclusions of the meeting on 31st May 2013 were that

"*...there is currently no evidence to challenge the hypothesis that salmon may not be sustainable in the longer term due to climate change*." True. My emboldening. But in that case, how can the conclusion be reached in the challenged notes of the meeting of 31st May 2012 that "The *choice of species used to derive the Thames Tideway DO standards remains appropriate." ?* If salmon are not sustainable then why should they be retained in the representative fish suite? Should they not be replaced by another sensitive species?

"...a fully functioning community of species tolerant to temperatures that will be present in the Thames Tideway long term will require sufficient DO to do so." It is reasonable to base standards on the most sensitive representative fish species.

"*The DO standards are based on a detailed understanding of the fish ecology within the Thames Tideway. This reduces uncertainty and the need for precautionary factors to be applied.*" The fish ecology is considered in detail earlier in this chapter and in the Tideway Fish risk model.

"*The DO standards ...have been set to adequately protect species, not "gold plate"*. But if the most sensitive species is salmon, as shown in the FARL trials, and salmon are not sustainable, then they are set to protect an unsustainable species, and thus may be "gold plate", until a replacement sensitive species is identified. All the fish species proposed at the meeting are either less sensitive to low dissolved oxygen conditions than salmon and/or are not, and probably wont in the future be, present in sufficient numbers to warrant inclusion in the fish suite.

"DO standards may need to be reviewed long term once evidence of the effects of climate change on species is seen." This section has looked at all the alternative species to salmon and found that climate change is unlikely to result in any fish species as sensitive as salmon

becoming sufficiently numerous in the Tideway to warrant consideration as a representative species.

"*Until this time the Thames Tideway DO standards remain justified*." This statement seems highly questionable. If salmon are not in the representative fish mix then they must either be replaced by another species or the standards be modified to the next most sensitive representative fish species tested, dace.

Whatever, the conclusion must be that, dissolved oxygen standards that are based primarily on a sensitive species, salmon, which appears to be agreed that it is unsustainable cannot support major expenditure. The alternative species to salmon that have been proposed are either more tolerant of low dissolved oxygen and/or are not sufficiently numerous in the Tideway. Until the dissolved oxygen standards are reconsidered they could be considered as "gold plated". The Coalition in its Our Programme for government section 2 Business has stated "*We will end the so-called "gold-plating" of EU rules, so that British business are not disadvantaged relative to their European competitors."* In this case the disadvantage would be the cost on business and people in paying the substantially increased sewerage charges.

Criterion for the rest of this note

However, despite this evidence, the rest of the note assesses the situation should salmon be considered to continue to be a representative species in the Tideway. It may however be required to meet other criteria such as spill frequency.

9 What Mortality Rates are Sustainable?

Page 76 of the FARL report, when discussing mortality, states " 6.4 *This is a difficult question, which, in the absence of detailed scientific population data on Tideway fish stocks, must rely heavily upon expert judgement.*

All fish populations can cope with a degree of mortality without the long-term population level being affected. This is a principle that underlies the commercial exploitation of fisheries, in which sustainable fishing mortality rates of 50+% are not uncommon (see e.g. Van Winkle, 1977). Mortalities are best withstood in the early juvenile phase, where natural mortalities are already high (typically 5-10% per day for pelagic larval stages). Hence, a 10% loss in the early fry stages is unlikely to be detectable and a 10% loss even at the adult stage is likely to be sustainable in a population that is not commercially exploited and under pressure already. Annual mortality rates of this magnitude would probably cause little or no detectable change
in the population relative to one in an unexploited, unimpacted population in a pristine environment.

In reviewing the Interim Standards, it must be appreciated that the percentage mortality figures shown are unlikely to apply to the entire Tideway population of any species but only to those that are exposed to the DO sag. It is difficult to be specific about this, as CSO discharges can vary considerably in terms of volume, origin and dispersion but under any circumstances, the proportion of a population exposed is likely to be considerably less than 100%. "

Dr Turnpenny, in his response to the TTSS comments on the Babtie report, see TFR page 48 states "*Fish in the Tideway are generally scattered through a number of Tideway zones and therefore, while suffering high mortalities in the grossly polluted reaches, the bulk of the population may survive. This can mean that there will be heavy fish kills but that mortalities over the Tideway as a whole would still be sustainable. Sustainability in this context I have previously proposed as meaning 10% or less mortality per annum for short lived species such as gobies or smelt and 20% or more for multi-spawning class species such as salmon, flounder or bass."*

The 2010 Tideway Fish Review Appendix F to the Thames Water 2010 report states on page 23 *"Further refinement was made to the sustainable mortality values for some species, as it was considered after discussion with EA fishery experts (S. Colclough, D. Clifton-Dey) that the marginally sustainable (blue type face) had been overly generous in some cases in the original Turnpenny et al (2004) analysis. Table 3-4 shows the revised figures used in more recent analyses.*

Table 3-4 ***Values used for sustainable mortality. It is assumed that fish with more reproductive year classes are able to sustain a higher mortality in a single year.***

Species	No. of Reproductive Age classes	Sustainable Mortality %
Salmon	3	30
Bass	10	30
Sand smelt	2	10
Dace	4	20
Smelt	2	10
Flounder	7	30
Common goby	2	10

In the notes of the meeting on 31st May 2012 it is said "*It was noted that there is no data to support the use of the mortality rate quoted by CB and use of this would not be scientifically supported or justifiable."* This is not explained as to what rates are being referred to or why they are not justifiable. The mortality rates taken by me are those found in the FARL trials and the table above as set out in the 2010 Fish Review Appendix F to the Thames Water Needs report. This was raised with the EA but no response has been received.

10 Fish risk model analysis

Page 76 of the FARL report, when discussing mortality, states "*All fish populations can cope with a degree of mortality without the long-term population level being affected. This is a principle that underlies the commercial exploitation of fisheries, in which sustainable fishing mortality rates of 50+% are not uncommon (see e.g. Van Winkle, 1977). Mortalities are best withstood in the early juvenile phase, where natural mortalities are already high (typically 5-10% per day for pelagic larval stages). Hence, a 10% loss in the early fry stages is unlikely to be detectable and a 10% loss even at the adult stage is likely to be sustainable in a population that is not commercially exploited and under pressure already. Annual mortality rates of this magnitude would probably cause little or no detectable change in the population relative to one in an unexploited, unimpacted population in a pristine environment.*

In reviewing the Interim Standards, it must be appreciated that the percentage mortality figures shown are unlikely to apply to the entire Tideway population of any species but only to those that are exposed to the DO sag. It is difficult to be specific about this, as CSO discharges can vary considerably in terms of volume, origin and dispersion but under any circumstances, the proportion of a population exposed is likely to be considerably less than 100%. "

Dr Turnpenny, in his response to the TTSS comments on the Babtie report, see TFR page 48 states "*Fish in the Tideway are generally scattered through a number of Tideway zones and therefore, while suffering high mortalities in the grossly polluted reaches, the bulk of the population may survive. This can mean that there will be heavy fish kills but that mortalities over the Tideway as a whole would still be sustainable. Sustainability in this context I have previously proposed as meaning 10% or less mortality per annum for short lived species such as gobies or smelt and 20% or more for multi-spawning class species such as salmon, flounder or bass."*

As part of the fish studies and trials a fish risk model (TFRM) was set up "*to better assess the risk of hypoxic (low DO) events. It takes account of the fact that CSO events do not affect the whole of the Tideway equally and that a breach of a standard is likely to affect some zones more than others. For instance, if a species were uniformly distributed throughout the Tideway but the LC10 (lethal concentration for 10% of the population was exceeded in only 20% of the Tideway habitat, then only 2% of the population(not 10%) would be likely to die. The TFRM applies this concept using the EA Tideway water quality Zones to estimate for any given month of the year, for each species/lifestage, what proportion of the Tideway population are likely to be present in a particular zone. Water quality (DO) data are then compared against lethality data to estimate the mortality by species/lifestage and Zone."* Thames Tideway Strategy :Fish & Ecology Objective, 2005

Basis of risk factor calculation

The general basis of the Risk Factors is set out in the FARL report page 85. This multiples the proportion of stock in each river zone by month by the probability of standard breach to

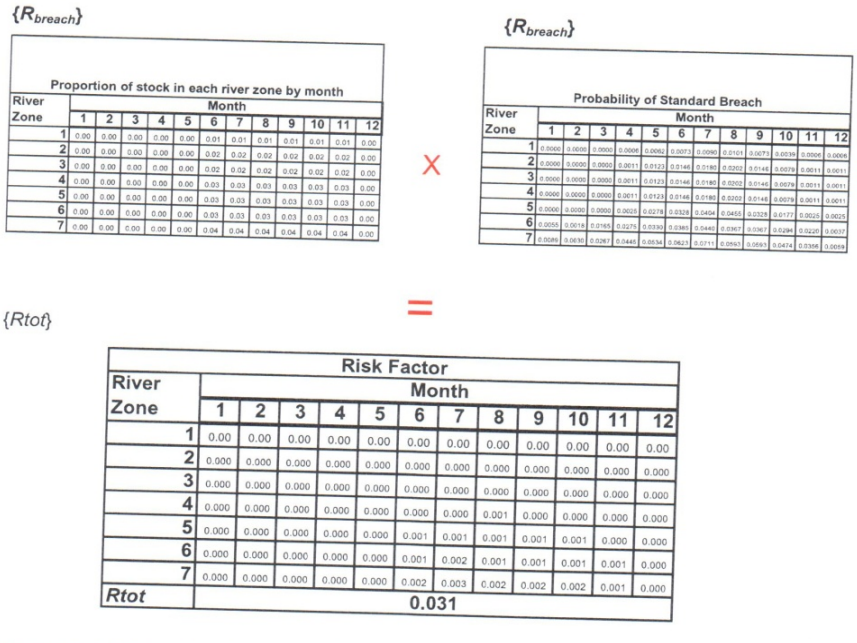


Figure 6.2 Example of matrix {Rbreach} and {Rbreach}. : {Rbreach} represents the relative probabilities of a standard breach for different river zones and months, while {Rbreach} represents the proportionate distribution of the fish stock along the Tideway zones in different months. The corresponding cells are multiplied together to generate the Risk Matrix {Rtot}. The

arrive at the Risk Factor. The example is shown above.

Fish risk assessment

"The TFRM therefore provides the means to assess the effect of a particular water quality scenario on Tideway fish populations as a whole. This is potentially much more realistic than using a standards-only approach, which requires compliance across the whole Tideway, since we can now apply the 10% mortality figure as a sustainability threshold for the whole population. Put another way, we can allow the standards to be breached in parts of the Tideway, provided that mortality in the population as a whole does not exceed 10% per annum." Thames Tideway Strategy :Fish & Ecology Objective, 2005.

11 TFRM output for the original conditions

The current baseline conditions referred to here are the pre STW upgrades and pre the Lee tunnel as at the time of the analysis those works had not been authorised.

"If maintaining a sustainable fish community is an acceptable objective, then this would require much less investment, according to the Tideway Fish Risk Model results. Based on the August 2004 modelling investigation, ***the existing conditions are at least close to allowing for sustainable fish populations.*** *With proposed capital improvements at Beckton and Crossness"* STW*" under AMP4,"* now nearing completion*" the DO-profile predictions given in the Steering Group report indicate that the* ***baseline condition should improve considerably,*** *and the impact of CSO spills on DO status in the Tideway's middle reaches will be greatly ameliorated by these measures alone."* In addition the Lee tunnel is under construction, thus the future CSO spill volumes would more than halve. *" Additional protection appears to be provided by the ability (larger fish at least) to avoid low DOs."* Thames Tideway Strategy : Fish & Ecology Objective, August 2005. My emboldening.

For the current situation, the FARL report Experimental studies on the dissolved oxygen requirements of fish 2004 states on page 91, assuming a 1.5mg/l minimum condition, "*This is seen to reduce the number of "****not sustainable" incidences to zero***". Page 95 "*a 1.5mg/l minimum standard"* as now adopted " *however appears to create a* ***sustainable outcome***." My emboldening.

Similarly "*Using the revised 1.5mg/l base standard, red figures were eliminated, indicating that the fish populations would be "sustainable" (black type) or "marginally sustainable (blue type face). The fact that this state is achieved with the large number of standards breaches associated with the Current Baseline can be taken to imply that* ***Tideway fish populations should already be sustainable,*** *which potentially undermines the case for improvements."* Tideway Tunnel Fisheries review Appendix F to the Needs case 2010. p 16.My emboldening.

Appendix F Tideway Fisheries review to the Needs Report 2010 states on page16

"Under Current Baseline conditions a number of limitations exist

1 Populations of some species remain "marginally sustainable ". This means there is some scientific uncertainty about how much more mortality these species could withstand..I consider these in the section on AMP4.

2 Substantial periodic fish kills may occur without affecting sustainability, provided that they affect only a relatively small proportion of the Tideway Habitat.

3.While fish mortalities may not be at unsustainable levels , fish are likely to be stressed by sub-optimal DO conditions , with possible adverse consequences for growth and reproduction.
4 Current predictions are that, without intervention, the frequency of CSO events is likely to increase in the future." This applies to the TFRM output in future years and I will consider the sewer flows used in future years in a later section, suffice to say here that they appear to have been done on incorrect assumptions and are not robust.

12 TFRM for AMP 4 conditions.

The AMP4 conditions are once the Mogden, Crossness and other Tideway STW have been upgraded, at a cost of about £600m. The Mogden STW up-rating was completed in March 2013 and the spills reduced from about 110 a year to about 20/year, and the associated part of the upper Tideway now appears to meet favourable dissolved oxygen conditions.

Beckton and Crossness STWs are also being considerably up-rated to cope with the previous chronically poor dissolved oxygen conditions in the Middle/Lower Tideway and meet the 4 mg/l background level, the one currently with most failures, in the middle/lower Tideway. The Beckton STW contract completion date is March 2014.

Below is the TFRM analysis from the Tideway Fisheries Review Appendix F to the 2010 Needs report page 21 for AMP4 conditions.

It is noteworthy that the salmon risk factor has increased from 0.52 at the "current baseline" to 0.63 for the AMP-4 conditions. The three STWs would now be much improved, with the Mogden spill volume reducing by about 5 Mm3/year (no firm figures are available) and the Greenwich CSO spill reducing from about 8 M3/year to about 4 Mm3/year as a result of the upgrading to Crossness STW. It would appear that the allowance for increasing sewer dry weather flow and the allowance for climate change are assumed by the modellers to exceed these benefits. I show in the later section that this assumption is not robust. However I have analysed the TFRM as presented.

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Table 6.10 Expected fish mortalities with the proposed AMP 4 Solution in place, at the proposed Interim Standard levels of 1.0,2.0, 3.0 and 4.0 mg DO L⁻¹

AMP 4														
Species	Lifestage	Effect of Proposed Standard on Predicted Fish Mortality												
		1.0 mg L^{-1}	1.5 mg L^{-1} (6h in 10y)	2.0 mg L^{-1} (6h in 5y)			3.0 mg L^{-1} (18h in 3y)			4.0 mg L^{-1} (1 wk per y)			No. of >10% PL Effect @1.0mgL^{-1}	No. of >10% PL Effect @1.5mgL^{-1}
				Mortality Rate	Risk Factor	Population Level Effect	Mortality Rate	Risk Factor	Population Level Effect	Mortality Rate	Risk Factor	Population Level Effect		
Salmon	Smolt	100%	100%	100%	0.00	0.0%	10%	0.00	0.0%	10%	0.05	0.5%	4	4
	Adult	100%	100%	100%	0.35	35.4%	90%	0.63	56.8%	10%	0.53	5.3%		
Bass	Young Fry	10%	10%	10%	0.00	0.0%	10%	0.00	0.0%	10%	0.00	0.0%	0	0
	Juvenile	10%	10%	10%	0.35	3.5%	10%	0.63	6.3%	10%	0.53	5.3%		
Sand smelt	Egg/fry				0.00			0.11			0.00		2	0
	Juvenile	50%	10%	10%	0.35	3.5%	10%	0.63	6.3%	10%	0.59	5.9%		
	Adult	75%	10%	10%	0.35	3.5%	10%	0.63	6.3%	10%	0.87	8.7%		
Dace	Egg/fry	100%	100%	85%	0.00	0.0%	10%	0.00	0.0%	10%	0.00	0.0%	3	2
	Juvenile	50%	30%	10%	0.53	5.3%	10%	0.29	2.9%	10%	0.11	1.1%		
	Adult	50%	10%	10%	0.53	5.3%	10%	0.29	2.9%	10%	0.11	1.1%		
Smelt	Egg/fry				0.00			0.00			0.00		3	3
	Juvenile	100%	40%	40%	0.35	14.2%	10%	0.63	6.3%	10%	0.59	5.9%		
	Adult	100%	40%	40%	0.25	10.0%	10%	0.88	8.8%	10%	0.87	8.7%		
Flounder	Egg/fry				0.00			0.00			0.00	0.0%	2	2
	Juvenile	50%	50%	15%	0.35	5.3%	10%	0.63	6.3%	10%	0.56	5.6%		
	Adult	50%	40%	15%	0.25	3.8%	10%	0.83	8.3%	10%	0.83	8.3%		
Common goby	Egg/fry				0.00			0.00			0.00		2	2
	Juvenile	50%	40%	10%	0.35	3.5%	10%	0.63	6.3%	10%	0.53	5.3%		
	Adult	50%	40%	10%	0.00	0.0%	10%	0.00	0.0%	10%	0.00	0.0%		
										Total PL Effects occurrences >10%			16	13
										Total PL Effects 'not sustainable'			4	0

[1], modified by the Fish Risk Model. The effect of a 1.5 mgL^{-1} Minimum Standard is also shown.

The FARL report states that for the TFRM the numbers in "*blue show possible marginal sustainability"* and the numbers in red "*are considered to indicate that the population may become unsustainable."*

It should be noted that no TFRM for the post Lee tunnel condition has been produced.

I look below at the two species that show marginal failure, salmon, and smelt at threshold 3, 2mg/l.

13 Smelt

Smelt are a fairly short lived species so the sustainability level is set at 10%.

At the roundtable meeting on 31st May 2012 Dr Turnpenny said that sustainability levels had been taken on the assumption that none of the adult stocks were commercially exploited. It now appears that there was some limited commercial exploitation of adult smelt. However Dr Colclough stated that there is now a Marine Conservation Zone in the Thames Estuary that included smelt in its designation in which case the taking of smelt is likely to be banned. The TW document "Why does London's river need the Thames Tunnel?" states on page 6 "*..smelt are the subject of Species Action Plans under the UK Biodiversity Action Plans. This means that there are specific targets set by the Government to conserve these species.*" I have been unable to confirm either statement so I have had to assume that the 10% sustainability level for smelt remains.

The TFRM table above shows smelt being marginal at the Standard 3, 2.0mg/l because the mortality rate is shown as 14% against a sustainable mortality of 10%. However the FARL fish trials report shows on page 59, see Annex B, that the LC10 6 hours for smelt was found to be 1.8mg/l at Fawley and 1.4 mg/l at Chiswick. Thus if smelt can tolerate at a sustainable level of 10% down to these numbers then the 14% population level effect against the 2mg/l

standards should be less than 10%. Also the histogram on page 78 of the FARL report shows no difference in mortality between adult and juvenile smelt.

Similarly at standard 4, the 1.5mg/l for one tide, the adult mortality is taken to be 40% with a risk factor of 0.76. This gave a marginal failure. However the Chiswick LC10 is 1.4mg/l . The FARL report states on page 69 "*the Chiswick tests used Thames water and are therefore a better reflection of Tideway conditions. In general, it was considered that Chiswick data should be used where possible, with Fawley data only being used to fill in where Chiswick data were missing, sparse, or considered unreliable."* There is no comment that the Chiswick data is considered unreliable. Thus, using the Chiswick data, smelt would be sustainable at threshold 4.

In the TFRM current conditions the marginal failure for smelt is shown as not 14% but 10.3. Since, as shown later, the dry weather sewer flow effect is overstated and the STW are improved there is good reason to conclude that the smelt population level effect of 10.3 would be acceptable

Further page 11 of Appendix F 2010 shows that juvenile smelt exhibit avoidance at about 3.5 mg/l so would avoid low dissolved oxygen conditions whenever possible.

There is also the issue that the dry weather flow and climate change increase in spills are assumed in the analysis to more than balance out the STW water quality improvements. For reasons set out below this is most unlikely.

Thus smelt appears to be sustainable overall under the AMP 4 TFRM conditions.

14 Assessment of salmon sustainability

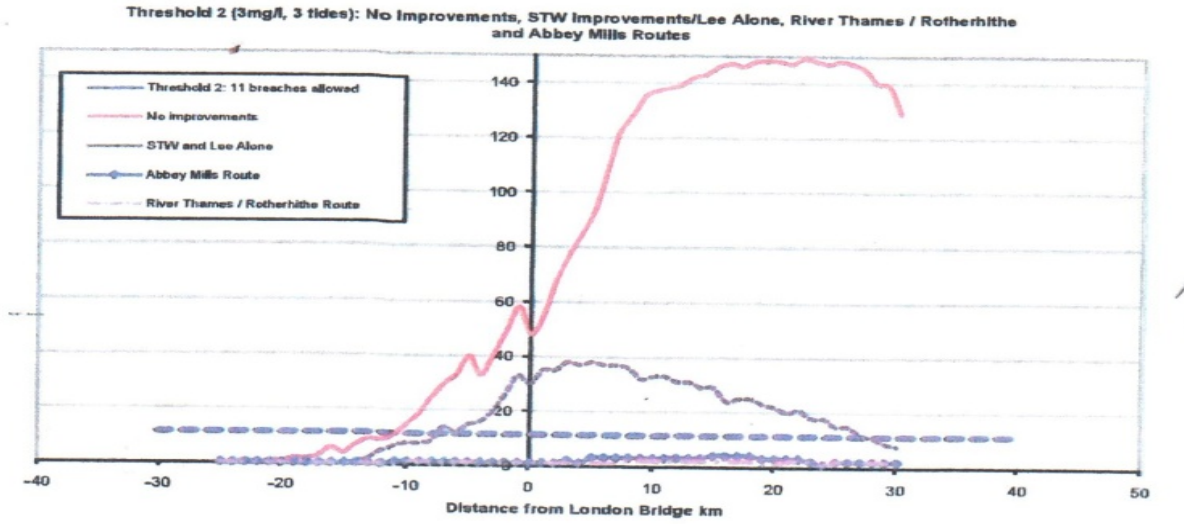
The TFRM shows that the main sustainability marginal failure of any fish species is salmon at threshold 2 , 3mg/l for 3no 6 hour tides, ie for 18 hours, every 3 years.

Frequency of dissolved oxygen failures.

Annex B shows the plots of the number of failures of the dissolved oxygen standards in the 34 years of record up/downstream of London Bridge. The upper red line shows the preworks condition with many failures in the region of the Beckton and Crossness ST outfalls.

These plots, see the mauve line, show the immense improvement as a result of the STW upgrades and the Lee tunnel, due for completion in 2014. Whilst the modelling continues to show failure of the DO standard this does not take account of the variation of mortality of the representative fish species, ie their sustainability. Threshold 1 is for hypoxia avoidance so there would be no fish kills. The worst situation is Threshold 2 3mg/l 3 no 6 hour tides once every 3 years standard. In my view, because the model assumes increasing sewer dry weather flow, the sewer and water quality models overestimate the number of failures, see section below, but let us take the numbers shown.

The graph reads as 38 failures in the 34 years of record. This is the equivalent of 1.15 failures each year on average.



Timing of failures

Salmon migrate largely during the period June to August inclusive. The arrival at the Molesey trap shows significant delay but this is probably due to salmon lying up close to the tidal limit as considered by Solomon. Whilst this is the main time of modelled dissolved oxygen failure there are a number that occur at other times of the year. The FARL study split the Tideway in two about 5km downstream of London Bridge. As can be seen from the plot above, with this classification, the majority of failures occurred in the lower Tideway. The FARL figure 6.3b shows the split of failure by month of the year and this is shown below.

The table shows that about half the failures occur outside the main migration period of June to August inclusive.

Lower Tideway

Standard	Average Monthly Proportion of Failures, 1990-2002												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
DO <4mg/l	0.02	0.01	0.06	0.09	0.11	0.13	0.15	0.12	0.12	0.1	0.07	0.01	1.0
DO <3mg/l	0.03	0	0.01	0.04	0.1	0.13	0.16	0.2	0.14	0.13	0.04	0.01	1.0
DO <2mg/l	0.03	0	0	0.03	0.07	0.1	0.14	0.24	0.17	0.14	0.03	0.03	1.0
DO <1mg/l	0	0	0	0	0	0	0	0	0	0	0	0	N/A

Time for plume dispersal

The Threshold 2 failure occurs over 3no 6 hour tides, ie 18 hours. Thus failures could last as short as this.

Thus a failure can last less than 1 day to a maximum of the period that the plume takes to leave the Tideway. This will vary depending on river flows and the location of the spill, thus spills in the lower Tideway would disperse sooner. Also as the plume moves backwards and forwards it will mix with higher DO water and thus the sag would weaken. I understand that an average period of dispersal of about three weeks would be appropriate.

Mortality

The TFRM AMP4 at threshold 2, 3mg/l for 18 hours, shows 90% mortality , for salmon.

Rough analysis

A rough analysis would be that the average period of impact, assuming all CSO failures occur during the migration period, and that the DO sag is continues to breach the failure condition throughout this period, would be 21 days X 1.15 = 24 days/year on average. Assume that all salmon migrate uniformly over the migration period then that would be 92 days. Thus the salmon at risk of impact would be 26%. This is somewhat below the allowable 30% average mortality allowed, see table of sustainable mortality. Further salmon avoid hypoxic zones. Thus the actual mortality rate would be lower rather than higher. This is supported by there being many more dissolved oxygen failures predicted by the water quality model under recent conditions but few, if any, reports of salmon mortality in the Tideway.

Presence of fish species in the stretch affected by low dissolved oxygen conditions.

FARL report 22004 page 76 states *"In contrast to resident estuarine species, it is unlikely for salmon, and other species that migrate between the river and the sea, that the whole population would be caught in the Tideway in the event of a short-term hypoxic event."*

The presence of each fish species is shown on table 6.7, of the FARL report shown in annex A to this note. For fish species this is split by month and life stage and upper or lower Tideway. However for salmon the TRFM shows a factor of 1.0 for the months June to December, see Annex A to this note. The implication of this is that all the salmon are in the section of the river affected by CSO spills and low dissolved oxygen conditions throughout the period June to December. That would be true for fish that are resident in the Tideway throughout that time. However salmon migrate through the Tideway to spawn in the freshwater section. Applying the 1.0 to them would mean that all the salmon would enter the low DO affected part of the Tideway at the beginning of June and stay there until the end of December. This is clearly an error as what is needed, as shown in the tables above, is the proportion of stock in each river zone by month. For instance those salmon that have migrated in July cannot be in the Tideway from August onwards. Thus the calculation for salmon does appear wrong.

Salmon migration period

Solomon has shown in his Fisheries Issues paper 2012 that salmon migrate upstream in June, July, August, with some in September and October

The challenged notes of the meeting on 31st May stated "*AT pointed out that a precautionary position was taken on this as it had been demonstrated elsewhere that salmon and sea*

trout can spend a long time in the estuary before running into the river and that during the whole time they could be at risk."

Surely the need for an expenditure of £4.2bn needs to have a more robust basis than "precautionary".

Reviewing the distribution of arrival dates at Molesey Weir trap, see the image in my Measures report from Solomon's Thames fisheries report, the arrival dates are reasonably uniform during July to November with a greater preponderance in July.

Salmon waiting area.

The notes of the meeting on 31st May 2012 as *"salmon and sea trout can spend a long time in the estuary before running into the river and that during this whole time they could be at risk (eg they enter the Solent/Southampton Water in June but do not enter the rivers until autumn.*"

The Solent study was carried out by David Solomon. On the Thames, analysis by Solomon, River flow and salmon migration in the River Thames at Molesey, *"summer fish tended to migrate readily for up to ten days after radio tagging in the estuary and then tended to lie up until the secondary phase of migration from October onwards.*

Page 3 states, "*The trap is not ideally located as an indicator of fish passage through the estuary as it is situated some 6km above the tidal limit at Teddington Weir. Radio tracking studies elsewhere indicate that salmon may spend considerable periods (up to several months)* ***in the upper tidal reaches and lowermost non-tidal reaches of rivers."*** My emboldening.

The dissolved oxygen conditions shown on the failure plots show that, post the Lee tunnel completion, no failure dissolved oxygen conditions would occur beyond 30km downstream or about 8km upstream of London Bridge at half tide. Thus any salmon waiting outside the zone of influence would not suffer mortality or hypoxia. Further the FARL tests showed that salmon would avoid hypoxic areas.

This is supported by the fact that none of the fish kills incident reports for the Tideway that I have been able to find include any dead salmon. Thus, those salmon that do wait in the estuary, appear to do so outside the mortality zone.

The salmon trapped later in the year might well have entered the river earlier and waited somewhere. Dr Solomon is one of the top consultants in salmon in the country and clearly his experience is that salmon wait in the **upper tidal and lowermost non-tidal stretches**. This makes sense as this gives them time to adapt to the change from marine conditions to freshwater conditions.

This would mean that salmon could well wait in the stretch from Molesey, 6km above the tidal limit, possibly down to about the Barn Elms, about 18 kms from Teddington. Whilst it would be possible for CSO spill to travel upstream under tidal conditions, the DO model shows that post Lee tunnel completion, there would be no mortality failure upstream of Barn Elms and anyway salmon are known to avoid hypoxic conditions and could move ahead of the hypoxic zone. Thus the distance where salmon could wait without risk of mortality would be about 24 km.

As supporting evidence, no salmon were reported killed during the August 2004 and June 2011 fish kill events. These events were during the salmon migration period. These two events killed many species with more low dissolved oxygen tolerance than salmon, thus any salmon present and remaining would have been killed. The area of fish kill was broadly from Isleworth Ait down to near Hammersmith. Thus it is unlikely that salmon were present in this stretch. This provides some support for the Solomon view that salmon would have been waiting further upstream, close to the tidal limit or, in avoiding the hypoxic zone, would have escaped downstream .

Analysis based on records of arrivals at Molesey trap.

Time of travel

I have been unable to find any information on the travel time of salmon up the Tideway.. There is some evidence from Solomon's work on the Exe that would indicate salmon might normally take about ten days to cover such a distance. However an assumption that it would take on average about a month seems not unreasonable and would be conservative.

Records of salmon migration

Examining the report on salmon caught at Molesey Weir, as reported by David Solomon, ref River Flow and salmon migration in the River Thames at Molesey, 2011,page 15 shows salmon arriving at the weir from the beginning of June to the end of November. Below is the frequency of trap catches at Molesey weir.

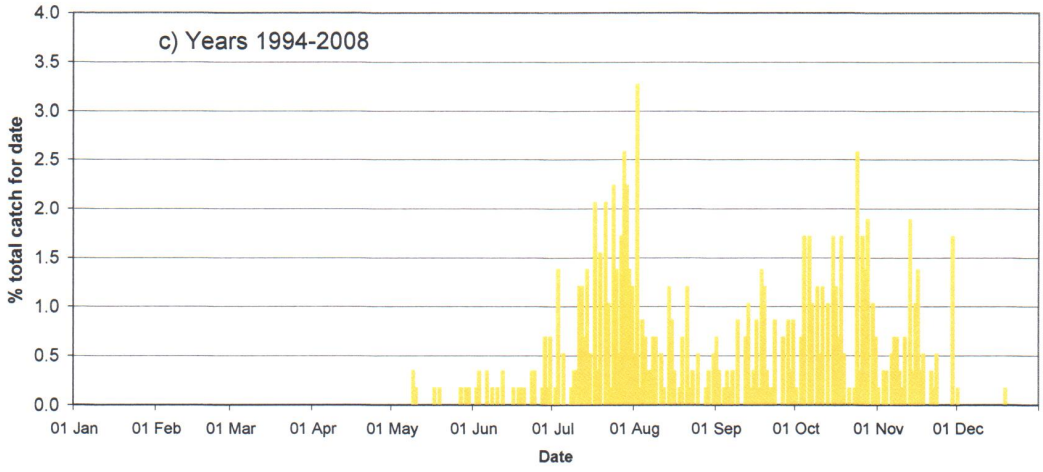


Figure 3.1. Seasonal pattern of trap catches at Molesey, totals for date. a) 1986-1996, b) 1986-1993, and c) 1994-2008.

Looking by eye at the Solomon histogram by month, the split would appear to be about;

July	0.30
August	0.15
September	0.20
October	0.2
November	0.15

These numbers then need to be multiplied by the “probability of standard breach”. Taking the numbers in the table on FARL page 85 then the Risk factor would be 0.17. Thus the 1.0 Risk Factor does not seem credible. This applies also to the Thrshold 3 and 4 calculations.

The mortality factor is 0.9.The “Risk Factor” is then multiplied by the “Mortality” to obtain the “Population Level Effect”. Thus 0.9 x0.17 = 15%. This is significantly below the 30% allowable for sustainability.

Alternative risk factor calculation assuming salmon lie up.

I have tried an alternative approach as well. The Solomon report on salmon migration at Molesey states on page 3 “*Radio tracking studies elsewhere indicate that salmon spend considerable periods (up to several months) in the upper tidal reaches and lowermost non-tidal reaches of rivers.”* The lowermost sections of the non-tidal reaches would be upstream of Teddington Weir and probably downstream of Molesey weir. Similarly the upper tidal reaches might be expected to be no more than 15kms downstream of the tidal limit, ie upstream of Hammersmith. Thus the interpretation of this would be that most of the salmon would migrate through the estuary and then lie up in the area upstream of about Hammersmith, ie upstream of that shown on the model as affected by low dissolved oxygen conditions. If so then the only salmon at risk from low dissolved oxygen would be those in transit up to the” waiting area” for the length of time they were in this zone.

David Solomon does state on page 30 of his Molesey report."*Most of the fish running in July, and to a lesser extent August, are newly returned to the estuary and are inclined to migrate." "summer fish tended to migrate readily for up to ten days after radio tagging in the estuary and then tended to lie up until the secondary phase of migration from october onwards.*
"By October, falling temperatures and the approach of the spawning season render the fish more likely to move again in response to often stimulation that would not have interested them a month or two earlier. This is termed secondary migration period by Solomon and Sambrook(1999)."

To test out the likely Fish Risk Factor under this scenario, a reasonable assumption might be that 70% of the summer run of salmon stock pass through the estuary in June and then wait in the Teddington area before ascending to the Molelsey weir in July, August and September. Thus at Standard 2, 3mg/l, there would be 70% of the salmon at risk in June. This is the highest risk month in the upper Tideway. I have taken the numbers for the average number of failures from the FARL report Figure 6.3a, 0.8/year. This is for the historical period 1990 to 2002. There are no figures provided for the post Lee tunnel condition so I have prorated them on the basis of the graphs of failures on page 53 of the TW Needs report, for the current condition/post Lee tunnel condition 40/150. This gives a risk factor of 0.15. The September run with the catch at Molesey in October and November results in a Risk Factor of 0.02. Thus, based on my assumptions, the total Risk Factor would be about 0.17, as found in the previous study.

Conclusion

Thus salmon, if present, would appear to be sustainable in the AMP4 conditions, 2014. Thus, unless there are particular reasons why conditions would deteriorate beyond then,

there would appear to be no reason for the tunnel to be implemented for fish and the ecology.

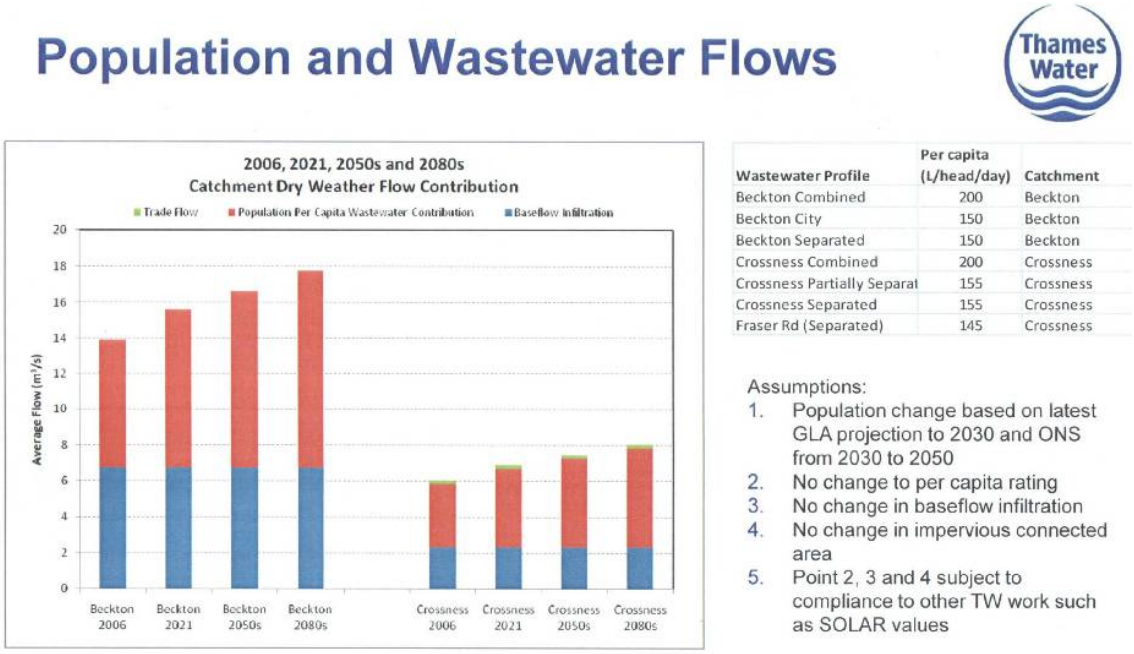
15 Sewer flows used in the model in future years

Were dry weather flows to increase or climate change induce larger rainfall events, then spill frequency would increase and this is referred to as one of the concerns about the Tideway Fish Risk Model in future years.

TFR 2010 states on page 23. *"It was considered more realistic for the assessments to consider a baseline for the year 2020 (earliest date of Tunnel project completion) taking into account forecasts of STW loading based on predicted 2020 population size (expanded) and any effects of climate change on water quality*." That seems a sensible approach.

Projected sewer dry weather flow changes

However TW have assumed that the dry weather flow in the sewers would reflect population growth with a constant per capita usage.



Thames Water have given figures for dry weather flow (DWF) for 2011, 2021, and 2031.However the only basis I can find is on image 13 of the presentation given to me on 30th September 2011. This shows the Beckton dwf rising from about 13.9 m3/sec in 2006 to about 15.8m3/sec in 2021 and about 17.8 m3/sec in 2080s. Crossness shows a similar proportional increase. To the side the image states "*no change to per capita rating*." Further the image says *"No change in baseflow infiltration".* Infiltration is made up of both leakage and rainwater/groundwater infiltration.

This is an increase of about 14% by 2021 and 30% by 2080. This was reported to lead to a "*near continuous CSO overflow*" in the later years and is one of the reasons provided by the EA for the requirement for the full tunnel.

It would appear that these sewer flows are the ones used in the TW sewer modelling. As an illustration see the spill volume from the Falcon brook pumping station, see Appendix A, that due to the increasing population from 2006 to 2021 the spill volume increases from 709,000 to 779,000, a 10% increase.

Sewer and interceptor flows are driven by flows going into the sewers and this is due to household use, leakage, and non leakage infiltration. The last is likely to be driven by rainfall and to be largely similar on an annual basis. Thus sewer dry weather flow should correlate with water delivered to households and with leakage .

The area sewered to the Tideway interceptors is similar to, but somewhat smaller than that, supplied by Thames Water with water, so, judging by eye, a factor of about 85% of the water delivered ending up in the sewers would seem to be a reasonable assumption.

The analysis of water projected to be supplied by Thames Water is given in the Thames Water Water Resources Management Plans (WRMP) 09 and dWRMP14, table WRP4-FP. This takes account of reducing customer water demand due to water appliances becoming more water efficient, more customers being metered in future, (a reducion of about 10% on average), and incentive tariffs. This shows water delivered in 2007/8 as 1633 Ml/d and in 2024/5 1537 Ml/d, a 100Ml/d reduction. Therefore the water delivered, and hence reaching the sewers, is projected to go down during this period rather than up as in the TW sewer analyses and publicity material.

It is not possible to reliably split sewer infiltration from rainfall and from leakage. An analysis of the inflow to Beckton STW does seem to indicate that when TW reduced leakage then the inflow to Beckton went down by a not dissimilar amount, see analysis in my Project Justification Report. This concludes that infiltration from leakage is larger than that from rainfall.

The leakage in 2007/8 was reported by TW for London as 590 Ml/d. In the dWRMP in 2024/5 it is projected by TW to fall to 478 Ml/d, a reduction of about 110 Ml/d. The draft WRMP14 states that the reduction in London during the plan period up to 2024/5 would be 53 Ml/d but the revised draft rdWRMP page 28 says this is increased to 105 Ml/d. No tables are provided but I believe that this would be mostly in London where there is a significant supply/demand deficit. Thus the leakage reduction over the period from 2007/8 to 2024/5 in the London WRZ is projected to be about 160 Ml/d. This would be a drop of some 25%.

Thus a reasonable assumption would seem to be that, by 2021 or thereabouts, sewer dry weather flows would have decreased by about 10%. This is in contrast to the about 13% increase assumed by TW in its modelling of the sewer system. Thus, instead of spill volumes and frequency increasing as shown in the TW model results, spill frequency and volumes would actually decrease, and hence water quality in the Tideway improve.

Thus, in my view, the future, ie 2021, design condition, the spill frequency analysis, water quality failure analysis and TFRM analysis for 2021, as done previously and displayed in the reports, over assesses spill frequency, water quality failures, and hence TFRM failures. Thus the analyses cannot be considered as robust. The sewer flow analysis, the water qualaity analysis and the TFRM for 2021 should be re-run taking account of the dry weather flow conditions projected by TW in its WRMPs.

Climate change

I have been unable to identify what allowance was made for climate change in the CSO modelling done in March 2009 for the Putney modelling in Appendix E and for the Table of Performance dated June 2011. The then guidance was probably based on UKCIP02.

At the CIWEM conference on 17th November 2011 entitled " Climate Change and the Water Sector, Integrating Adaptation and Mitigation in Practice", the Senior Climate Extremes Scientist of the Met Office Hadley Centre, Dr Elizabeth Kendon, gave a paper entitled "Will heavy rainfall increase in the future over the UK? Implications of the latest climate science." It was clear that the Hadley Centre had done much work since UKCP09 had been published and that its views had changed. She wrote

"There is observational evidence of increasing heavy rainfall on continental scales due to human-induced global warming. On smaller scales, however, any changes in heavy rainfall cannot yet be distinguished from natural variability. In particular, for the UK, it is unlikely that changes in heavy rainfall will emerge above natural variability in the next decade.

Current understanding suggests increases in heavy rainfall during the winter across the UK may start to become discernible in the 2020s whilst any changes in summer are not expected to be discernible for many decades."

I understand that the size of non-heavy rainfall events are expected to reduce. This would probably reduce the spill frequency of events greater than about 10 spills a year significantly. If so this would help to reduce the spill frequency of the frequent spilling CSOs. However heavy winter events would increase in spill volume.

It is to be noted that TW considers winter rainfall events are not critical for dissolved oxygen conditions in the river because higher river flow and lower temperature mean that dissolved oxygen conditions are not adverse and they have not quoted the figures of rainfall change for the winter months. However, summer events, when the river temperatures are higher and the river flows lower, are considered the most critical for dissolved oxygen. In late 2011 I was provided with rainfall adjustment figures for 2080. For 50% both the number of events and the depth reduced significantly for June/July/August. For the 90% event there is a significant increase. I understand that a report on climate change rainfall based on the CP09 weather generator was provided to TW in late 2011 and that this was used in an updated analysis of CSO spill frequency. However I believe the output is not in the public domain.

Climate change will also increase temperature. Increasing river temperature would also adversely affect summer dissolved oxygen conditions. There are known numbers for the increase in air temperature which at P50 are in summer in 2050 about 1.5C and 2080 about 2.3C. However I was told by Thames Water in a meeting on 30th September 2011 that the assumption in the models is that the water temperature would rise by a further 0.4C. It seems odd that the water temperature is expected to rise by more than the air temperature as one would expect water temperature to be driven by air temperature. Further the one large fully water cooled power station in the catchment, Didcot A, has now been closed and, under the planning conditions, the cooling towers are due to be demolished. I asked TW for an explanation for this difference in temperatures at our meeting on 30th September 2011 but none has been provided. This does need further investigation. M.

It would be helpful to know both the substantiation for the increased water temperature above that for air, and the outcome of CSO and river quality analyses when revised for both changes in dry weather flow in the sewers and climate change. Until that is provided then the support for worsening conditions in the Tideway and the TFRM in the future is not robust.

Comparison of current situation and AMP 4 situation

The AMP4 STW upgrades are expected to cure the chronically poor dissolved oxygen conditions in the Lower Tideway. However the fish risk model in Appendix F to the 20110 Needs Case report shows the situation for salmon actually deteriorating from the current baseline, Threshold 2 risk factor 0.52 to the AMP4 situation, ie with the STW improvements completed to a risk factor of 0.63. This can only be because of the assumed increase in sewer dry weather flows, which I have shown will reduce, and the assumed increase in rainfall due to climate change which the Met Office now say for heavy summer rainfall that changes "*will not be discernible for many decades".*

Thus the plots of dissolved oxygen failures against the four dissolved oxygen standards **over predict failures** as they over predict sewer dry weather flow and climate change storms. Thus they cannot be taken as showing that post the current works the tideway dissolved oxygen standards would not be met.

Further, the important condition should be the sustainability of the fish species, as shown in the TFRMs.

It does appear that the TFRM for the post AMP4 condition would result in sustainable fish species without the need for the Thames tunnel.

Without robust analysis for the future one has to assume that the AMP4 conditions prevail.

16 Final conclusions

On the basis of the evidence and assumptions above, it is concluded that

1. The objective of the UWWTD is to protect the environment from the adverse effects of waste water discharges. Since it is recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species. The objective is to limit ecological damage by ensuring that fish species are sustainable.
2. The TTSS carried out trials on a representative suite of fish to establish their response to dissolved oxygen conditions. Salmon were the most sensitive. From these trials a table of dissolved oxygen standards was established.
3. The two big fish kills in 2004 & 2011 were primarily due to Mogden STW overflows.
4. Mogden STW has now been upgraded. Spill frequency has dropped from about 110 spills a year to about 20 spills a year, the limit proposed by the EC. Fish kills as a result of its overflows should not occur in future.
5. Beckton and Crossness STW are currently being upgraded to remove the chronic low dissolved oxygen conditions in the middle/lower Tideway and these are due for completion in 2014.

6. The sustainable mortality of various species depends on the factors such as length of life and a sustainable mortality. For salmon it was found to be 30%.
7. Further major investment could only be warranted by the need to provide sustainable conditions for the most sensitive fish species that will be present for sufficiently long to warrant the expenditure.
8. Migration and spawning conditions for salmon in the Thames catchment are not favourable but are being improved.
9. Salmon numbers have reduced to an average of less than 10 a year, 2013 3. They are considered by the EA as not sustainable in the Tideway in the short, and medium term and the Dr Friedland model shows that salmon would not be sustainable in the long term, primarily because of adverse temperature and marine conditions.
10. Salmon are the most sensitive fish species so if they are no longer sustainable then they need to be replaced by a similar species or the D.O.Table reconsidered. The additional fish species mentioned are all more tolerant of low dissolved oxygen (DO) than salmon and/or not sufficiently established. Thus the D.O. table needs reconsidering.
11. A meeting on 31st May 2012 discussed fish but the notes contain points that were not heard at the meeting and the notes were subsequently challenged.
12. In earlier years over 300 salmon migrated through the Tideway, so adverse dissolved oxygen conditions would have had limited effect on migration.
13. The 2011 analyses by TW of CSO and water quality conditions in 2021 were based on increasing dry weather flows in the sewers, and thus show deteriorating Tideway D.O. conditions. The 25 year Thames Water (TW) Water Resources Management Plans show reducing water delivered and reducing leakage, hence sewer dry weather flows will be reducing. Hence the conditions predicted in the models for future years are worse than would actually occur. Consequently the models need re-running with the latest information.
14. Storm runoff will be affected by climate change. The Met Office has said that during winter increases in heavy rain may start to be discernible in the 2020s whilst any changes in summer are not expected to be discernible for many decades. Also middle rainfall events will get smaller. TW has assumed that water temperature increase will be 0.4C more than the air temperature increase. No justification has been provided for this odd assumption which would adversely affect dissolved oxygen conditions. Any re-run of the models should include the latest climate change information.
15. Dr Turnpenny has developed a Tideway Fish Risk Model. This multiplies the proportion of stock in each river zone by month by the probability of standard breach to arrive at a risk factor. This is then multiplied by the mortality to assess the population effect. This is a powerful tool.
16. The Tideway Fish Risk Models risks for salmon were described as “precautionary” in the challenged roundtable meeting notes, hardly a strong basis for supporting a £4.2bn project.
17. TFRM output descriptions state FARL “*not sustainable incidences zero*.” Tideway Fisheries Review 2010 “*Tideway fish populations should already be sustainable*.”

18. The post tunnel TFRM are based on increasing sewer flows in 2021 and are thus not robust.
19. The AMP4 TFRM assumes that all salmon are present in the Tideway for 7 months of the year. In reality they are assumed to take about two weeks to migrate through the Tideway over a 3 to 4 month period. Thus only a small proportion would be affected by any one spill. Thus, at the time of any one spill, there will be those who have not yet entered the Tideway and those that have already arrived in freshwater prior to the spill.
20. The AMP4 post current works dissolved oxygen plot for Threshold 2 shows 1.15 dissolved oxygen failures a year on average. It would, on average, take about three weeks for a failure plume to exit the Tideway, thus failure conditions could last for the equivalent of less than a month a year on average. Salmon migrate over a three to four month period in the summer. Combining these factors, then the population level effect would be less than the 30% impact which is the limit of sustainable conditions for salmon.
21. Thus the AMP4 conditions, prior to construction of the tunnel, would indicate that, in the unlikely case of there being sufficient salmon, the salmon would be sustainable.
22. Thus, post the current works, fish in the Tideway would be sustainable and, subject to the future conditions not worsening, no further works would be required to meet ecology sustainability.

Prof Chris Binnie
MA, DIC, HonDEng, FREng, FICE, FCIWEM
31st December 2013

TT aspects of fish benefit 30 12 13

Annex A

Table 6.7 The presence (denoted as '1') or absence ('0') of fish lifestages in different months of the year in the Upper ('U') or Lower ('L') Tideway (see Figures A9.1-9.7, Appendix 9).

Species / Lifestage			Month											
			1	2	3	4	5	6	7	8	9	10	11	12
Flounder	Eggs	U	0	0	0	0	0	0	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	0	0	0	0	0	0	0
	Juv	U	0	0	0	0	1	1	1	1	1	1	1	0
	Juv	L	0	0	0	0	1	1	1	1	1	1	1	0
	Adult	U	0	0	0	0	1	1	1	1	1	1	0	0
	Adult	L	1	1	1	1	1	1	1	1	1	1	1	1
Bass	Eggs	U	0	0	0	0	0	1	1	0	0	0	0	0
	Eggs	L	0	0	0	0	0	1	1	0	0	0	0	1
	Juv	U	0	0	0	0	0	0	0	1	1	1	1	0
	Juv	L	0	0	0	0	0	0	0	1	1	1	1	1
	Adult	U	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	L	1	1	1	1	1	1	1	1	1	1	1	1
Common Goby	Eggs	U	0	0	0	0	0	0	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	0	0	0	0	0	0	0
	Juv	U	0	0	0	0	0	1	1	1	1	1	1	0
	Juv	L	0	0	0	0	0	1	1	1	1	1	1	1
	Adult	U	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	L	1	1	0	0	0	0	0	0	0	0	0	1
Smelt	Eggs	U	0	0	1	1	1	1	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	0	0	0	0	0	0	0
	Juv	U	0	0	0	0	0	0	1	1	1	1	1	0
	Juv	L	0	0	0	0	0	0	1	1	1	1	1	1
	Adult	U	0	0	1	1	0	0	0	0	0	0	0	0
	Adult	L	1	1	1	1	1	1	1	1	1	1	1	1
Sand-smelt	Eggs	U	0	0	0	0	0	0	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	1	1	0	0	0	0	0
	Juv	U	0	0	0	0	0	1	1	1	1	1	1	0
	Juv	L	0	0	0	0	0	1	1	1	1	1	1	1
	Adult	U	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	L	1	1	1	1	1	1	1	1	1	1	1	0
Salmon	Eggs	U	0	0	0	0	0	0	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	0	0	0	0	0	0	0
	Juv	U	0	0	0	1	1	1	0	0	0	0	0	0
	Juv	L	0	0	0	1	1	1	0	0	0	0	0	0
	Adult	U	0	0	0	0	0	1	1	1	1	1	1	1
	Adult	L	0	0	0	0	0	1	1	1	1	1	1	1
Dace	Eggs	U	0	0	1	1	1	0	0	0	0	0	0	0
	Eggs	L	0	0	0	0	0	0	0	0	0	0	0	0
	Juv	U	0	0	0	0	1	1	1	1	1	1	1	1
	Juv	L	0	0	0	0	1	1	1	1	1	1	1	1
	Adult	U	1	1	1	1	1	1	1	1	1	1	1	1
	Adult	L	1	1	1	1	1	1	1	1	1	1	1	1

Annex B Plots of modelled number of dissolved oxygen failures along the Tideway

When rotated, the horizontal axis is the distance up/down stream of London Bridge.

The vertical axis is the number of failures, red prior to works, mauve post STW and Lee tunnel.

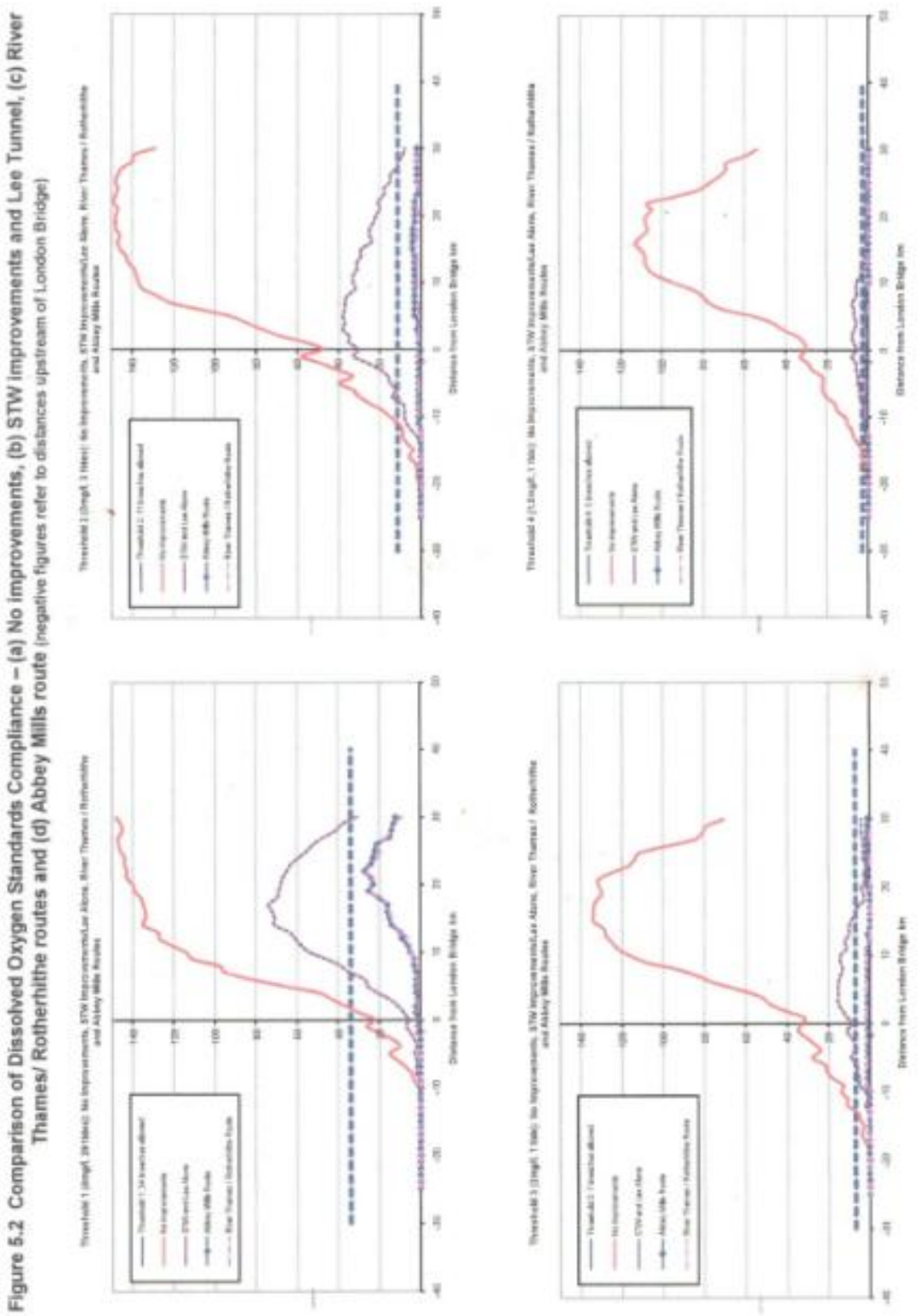


Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)