Assessment of Salmon Stocks and Fisheries in England and Wales

Cefas

Centre for Environment Fisheries & Aquaculture Science

Environment Agency

Cyfoeth Naturiol Cymru
Natural Resources Wales

ASSESSMENT OF SALMON STOCKS AND FISHERIES IN ENGLAND AND WALES

Standing report on methods, approaches, and wider stock conservation and management considerations in 2021

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This background report has been compiled jointly by staff from the Centre for Environment, Fisheries and Aquaculture Science (Cefas) Salmon and Freshwater Team at Lowestoft and fisheries personnel from the Environment Agency and Natural Resources Wales. The monitoring and assessment of salmon stocks is funded by Defra and Welsh Government. All the participating organisations would like to extend their thanks and recognition to the various operational fisheries personnel who collect and compile the data used in the annual assessment of salmon stocks (now published as a separate report). Thanks are also due to the National River Flow Archive at the UK Centre for Ecology and Hydrology for providing river flow data, the Game and Wildlife Conservation Trust for data relating to the River Frome, the General Secretary of the International Council for the Exploration of the Sea (ICES) for permission to cite the reports of the ICES Working Group on North Atlantic Salmon and the North Atlantic Salmon Conservation Organisation (NASCO) for permission to include their summary of regulatory measures for the high seas fisheries.

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FOREWORD

Annual reports on the status of salmon stocks and fisheries in England and Wales have been produced since 1997. Initially, the reports were prepared jointly by the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and the Environment Agency (EA). However, Natural Resources Wales (Cyfoeth Naturiol Cymru) (NRW) assumed responsibility for salmon management and regulation in Wales in 2013 and all three organisations have contributed to the annual assessment reports since 2014. It is anticipated that similar arrangements will continue to apply for future assessments.

Until the 2013 assessment, each annual report was designed to stand alone to avoid the need to refer to previous reports for background information. However, this resulted in much of the descriptive information being very similar to that in reports for previous years. From 2014, therefore, and in the interest of streamlining procedures, it was decided to include the more generic background information in this standing report and to produce a separate shorter annual assessment containing the latest tables and figures. Both documents are available on the GOV.UK website.

A key purpose of the annual assessment is to provide information on the status of salmon stocks and fisheries in England and Wales to the International Council for the Exploration of the Sea (ICES), which is used, in turn, to provide advice to the North Atlantic Salmon Conservation Organisation (NASCO). An account of the way in which ICES uses the national data presented in the annual assessment is provided in Annex 5.

The objectives of NASCO are to contribute to 'the conservation, restoration, enhancement and rational management of salmon stocks'. In particular, NASCO is responsible for negotiating the quotas for the marine salmon fisheries operated in Greenlandic and Faroese waters. Annexes 4 and 5 give further information on NASCO and ICES, respectively.

The most recent list of questions to ICES from NASCO is provided in the annual assessment report. Key requests relating to annual events include a need to provide:

- an overview of salmon catches and landings, including unreported catches, by country and catch-and-release, and production of farmed and ranched salmon;
- a description of the key events of the fisheries and the status of the stocks for the latest assessment year;
- age-specific stock Conservation Limits for all stocks; and
- a compilation of releases of tagged fish.

NASCO seeks information on the fisheries relating to *catches, gear, effort, composition, and origin of the catch (including escapees and sea-ranched fish), and rates of exploitation.* These headings have, therefore, been used in the appropriate sections of this report and are also reflected in the structure of the annual assessment.

As this report aims to provide relevant background in relation to the specific information required by ICES to address the request for advice from NASCO, it does not describe all the activities in England and Wales to maintain, improve, and develop salmon fisheries. More detailed descriptions of such management actions are provided in the following reports prepared for NASCO since 2007:

- NASCO Implementation Plan for Salmon Management in the UK (England & Wales) 2019 to 2024. Available at: https://nasco.int/wp-content/uploads/2020/12/IP1913rev2_Implementation-Plan-for-the-period-2019-2024_UK-England-and-Wales.pdf.
- Annual Progress Reports. Available at: https://nasco.int/wp-content/uploads/2021/04/CNL2129_Annual-Progress-Report_UK-England-and-Wales.pdf.
- Focus Area Report on Management of Salmon Fisheries, 2007. Available at: https://nasco.int/wp-content/uploads/2020/02/FisheriesFAR_EnglandWales.pdf.
- Focus Area Report on Protection, Restoration and Enhancement of Salmon Habitat, 2008. Available at: https://nasco.int/wp-content/uploads/2020/02/HabitatFAR_EnglandWales.pdf.
- Focus Area Report on Aquaculture, Introductions and Transfers, and Transgenics, 2009. Available at: https://nasco.int/wp-content/uploads/2020/02/AquacultureFAR_EnglandWales.pdf.

In August 2008, the Environment Agency published its sea trout and salmon fisheries strategy ('Better Sea Trout and Salmon Fisheries – Our Strategy for 2008-2021') with a goal of "more sea trout and more salmon in more rivers bringing more benefit" (Environment Agency, 2008). The strategy builds on the original 1996 Salmon Strategy, but puts emphasis on improving the environment, as experience has shown that the most significant gains for these fisheries have come from the big and broad environmental programmes. The European Union's Water Framework Directive (WFD) as retained under UK law and the programme of measures under the River Basin Management Plans are integral to delivering this. There is also a greater focus on partnership, reflecting the growth of other bodies such as the various River and Fisheries Trusts, who can deliver using wider sources of funding. In addition, the strategy recognises the considerable economic and social benefits that come from sea trout and salmon fisheries.

The annual assessment report aims to collate and present data from the most recent year as early as possible in the following year to meet the time schedule of ICES and NASCO. These data are initially published as provisional but are updated and confirmed when complete catch data are obtained and records validated, and thereafter published in the assessment report in the following year. However, the Environment Agency and NRW also publish a separate Salmonid and Freshwater Fisheries Statistics report each year that contains the final confirmed data. The latest report is available at: www.gov.uk/government/publications/salmonid-and-freshwater-fisheries-statistics-2020.

Cefas, the Environment Agency and NRW would welcome comments or suggestions for improvements to this report and the shorter annual assessment report and associated tables and figures. Contact details are provided on the back cover of this report.

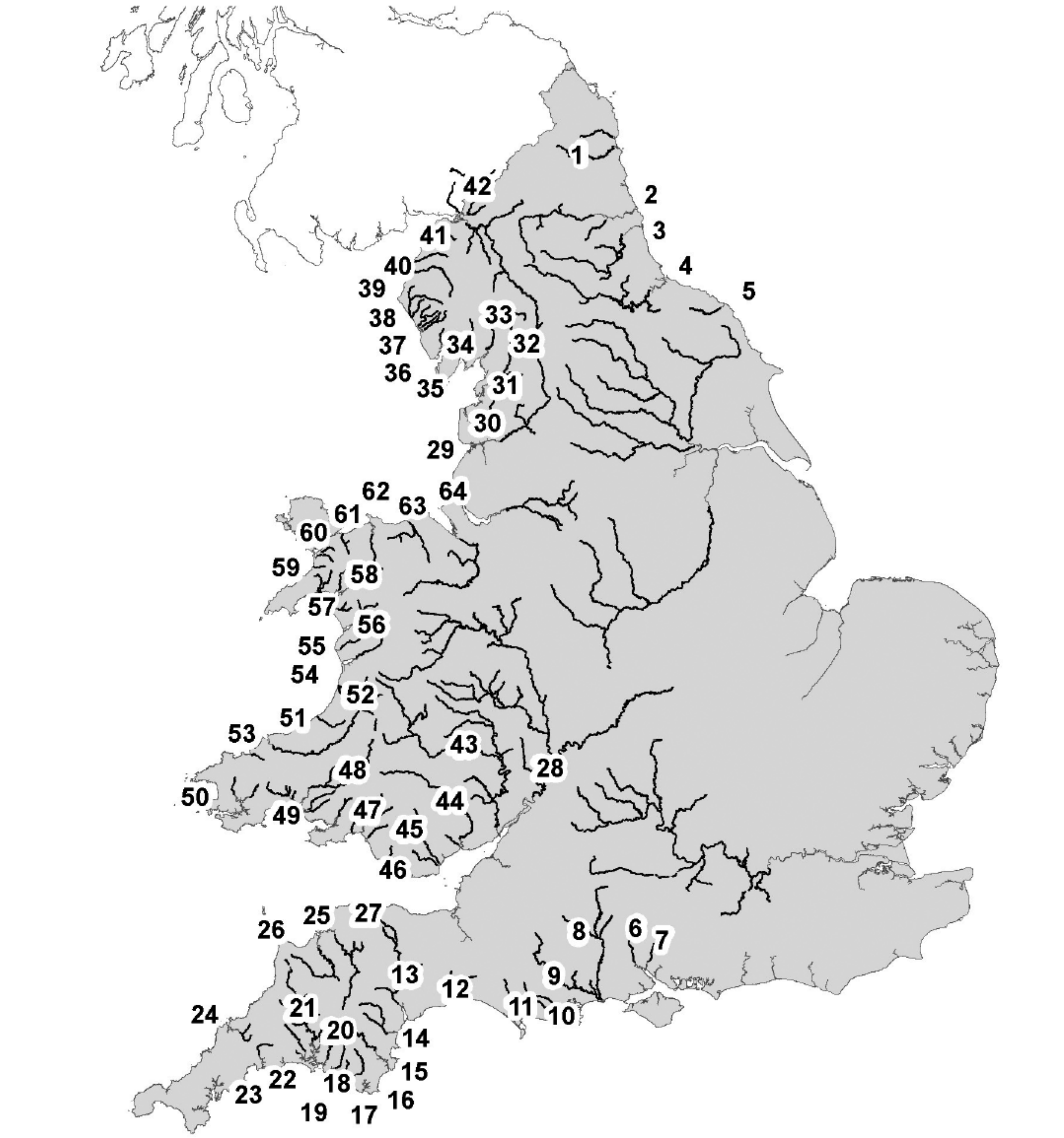
ASSESSMENT OF SALMON FISHERIES IN ENGLAND AND WALES

1. DESCRIPTION OF STOCKS AND FISHERIES

There are 49 rivers in England and 31 rivers in Wales that regularly support salmon (Figure 1), although some of the stocks are very small and support minimal catches. Of these, 64 rivers have been designated 'principal salmon rivers' on the basis of the prospect of annual rod catches of at least 50 fish and the existence of Salmon Action Plans (SAPs) reviewing the status of the stocks and fisheries, identifying the main factors limiting performance and drawing up a costed list of remedial options. Conservation Limits (CLs) and Management Targets (MTs) (see Annex 7 for details) have, to date, been set for these principal salmon rivers and are used to give annual advice on stock status and to assess the need for management and conservation measures. In the future, other rivers may also be designated principal salmon rivers, and be subject to the same assessment requirements, for example, following recovery from low stock levels (e.g., the Yorkshire Ouse).

Organisational structures have changed over time, however, salmon data are still compiled and presented separately in the annual assessment for Wales and seven regions of England (although many of the tables do not include data for the Anglian and Thames regions). The rivers containing salmon that fall into each geographical region are shown in the table below. There are no salmon rivers in the Anglian region, but this region is included in some tables as it has a coastal fishery, which prior to 2019 exploited very small numbers of salmon (see Section 2.5).

Region	River	Region	River	Region	River
North East	Aln	South West (cont.)	Fowey	Wales (cont.)	Afan
	Coquet		Camel		Neath
	Tyne		Torridge		Tawe
	Wear		Taw		Loughor
	Tees		Lyn		Gwendraeth Fawr & Fach
	Yorkshire Esk	Midlands	Trent		Tywi
	Ouse		Severn		Taf
Anglian		North West	Mersey		E & W Cleddau
Thames	Thames		Ribble		Nevern
Southern	Itchen		Wyre		Teifi
	Test		Lune		Aeron
South West	Hants Avon		Kent		Ystwyth
	Stour		Leven		Rheidol
	Piddle		Crake		Dyfi
	Frome		Duddon		Dysynni
	Axe		Esk (Cumbria)		Mawddach & Wnion
	Exe		Irt		Artro
	Teign		Ehen		Dwyryd
	Dart		Calder		Glaslyn
	Avon (Devon)		Derwent		Dwyfach & Dwyfawr
	Erme		Ellen		Llyfni
	Yealm		Eden		Gwyrfai
	Plym		Esk (Border)		Seiont
	Tavy	Wales	Wye		Ogwen
	Tamar		Usk		Conwy
	Lynher		Taff		Clwyd
	Looe		Ogmore		Dee



English river systems

1 Coquet*
2 Tyne*
3 Wear*
4 Tees*
5 Esk (Yorkshire)*
6 Test*
7 Itchen*$
8 Avon (Hants)*$
9 Stour (Dorset)*
10 Piddle*
11 Frome*
12 Axe*
13 Exe*
14 Teign*$
15 Dart*$
16 Avon (Devon)*
17 Erme*$
18 Yealm*$
19 Plym*
20 Tavy*$
21 Tamar*
22 Lynher*
23 Fowey*
24 Camel*$
25 Taw*$
26 Torridge*
27 Lyn*
28 Severn*
29 Ribble*
30 Wyre*
31 Lune*
32 Kent*
33 Leven*
34 Crake*
35 Duddon*
36 Esk (Cumbria)*
37 Irt*
38 Ehen*$
39 Calder*
40 Derwent*$
41 Eden*$
42 Esk (Border)*

Welsh river systems

43 Wye*$
44 Usk*$
45 Taff*
46 Ogmore*
47 Tawe*
48 Tywi*
49 Taf*
50 E & W Cleddau*
51 Nevern*
52 Teifi*$
53 Rheidol*
54 Dyfi*
55 Dysynni*
56 Mawddach*$ & Wnion*
57 Dwyryd*
58 Glaslyn*
59 Dwyfach & Dwyfawr*
60 Seiont*
61 Ogwen*
62 Conwy*
63 Clwyd*
64 Dee*$

Figure 1. Map of England and Wales showing the main salmon rivers and denoting those that are Principal Salmon Rivers (*) and those designated as Special Areas of Conservation ($) in which salmon must be maintained or restored to favourable conservation status.

Fisheries in all rivers are subject to the controls described below. Increasingly, actions to improve salmon stocks in England and Wales are being delivered through the WFD as retained under UK law. These actions build on the earlier SAPs that were prepared for all the principal salmon rivers and are delivered at catchment level and underpinned by the broader River Basin Management Plans (Section 11.1).

Eighteen rivers have been designated Special Areas of Conservation (SACs), under the EU's Habitats Directive (92/43/EEC) as retained under UK law, with salmon as a named qualifying species. This places an additional requirement on managers to maintain the habitats in these rivers in a favourable condition for salmon. Further details about this and other European Directives and measures, or UK equivalents, affecting salmon management are provided in Annex 6. Equivalent provisions still apply now that the UK is an independent coastal state.

A large number of specialised salmon fishing methods have been used in England and Wales. These can be grouped into five generic categories: gill nets (which entangle fish), sweep nets (which encircle and trap fish), hand-held nets, fixed engines (a term used to describe various fixed fishing gears), and rods. Brief descriptions of all the various netting methods (including fixed engines) that have been employed are provided in Annex 3.

Rod fishing for salmon is permitted on all rivers supporting salmon stocks, and a range of controls to protect these salmon stocks have been implemented including season, method, and catch-and-release (C&R) measures. For net or fixed engine fisheries, the majority have been closed to protect salmon stocks in England since 2019 and in Wales since 2020. Where they remain, they principally target sea trout and any salmon caught are required to be released.

Details of the various regulatory measures and other factors that limit fishing effort, and how these have changed over time, are provided in Section 2.

Lave netsman (photo courtesy of Environment Agency)

2. FISHERY REGULATION MEASURES

2.1 *Decision Structure*

A Decision Structure for determining controls on salmon fisheries in England and Wales has been developed in line with NASCO guidance to assist in applying fisheries regulations in a logical and consistent manner. This tool focuses on an assessment of the probability of a given river's salmon stock achieving the Management Objective (MO) in five years' time (the MO requires that a river stock meet or exceed its Conservation Limit (CL) in at least four years out of five – i.e., at least 80% of the time). It indicates the level of change in exploitation rate required to improve rivers failing to meet their CL and helps to highlight the need for other management actions, where these may be appropriate. The Decision Structure is applied annually as part of a regular review process when the stock assessment for the fisheries in England and Wales is published. It is also used when existing regulations (Net Limitation Orders and byelaws) are reviewed. A schematic representation of the Decision Structure is provided in Annex 7. A review is underway to re-examine the current methodology for assessing salmon stocks, along with the associated compliance scheme and Decision Structure; this will consider the need for possible improvements. The aim is to complete this within the next year with the likelihood that improvements will be introduced in stages as developments allow.

While the primary aim of management is to ensure the conservation or restoration of stocks, socio-economic factors may be taken into account when new management measures are considered. This may influence the nature and balance of controls affecting different stakeholder groups and the rate of stock recovery that is planned (Annex 7). Further details are available in the NASCO Implementation Plan for Salmon Management in UK (England & Wales) 2019 to 2024: https://nasco.int/wp-content/uploads/2020/12/IP1913rev2_Implementation-Plan-for-the-period-2019-2024_UK-England-and-Wales.pdf.

2.2 *Licensing, NLOs and Byelaws*

Salmon fisheries in England and Wales are primarily regulated by effort controls, which specify the nature of the gear that may be operated, along with where, when, and how it may be used. Anyone fishing for salmon with nets, traps or rods must have a licence, and numbers of net/trap licences issued are usually limited by Net Limitation Orders (NLOs) that apply to individual fisheries (e.g., within each estuary). A full listing of the NLOs applying to salmon net fisheries in England and Wales is provided in the annual assessment report. A small number of trap fisheries are privately owned and are not subject to NLOs; these fisheries are referred to as 'historical installations' and their use must be authorised by the Environment Agency (provisions that came into force with the Marine and Coastal Access Act, 2009); this authorisation may have conditions (e.g., catch limits) attached. There is no limit on the number of rod licences that can be issued.

Regulations have typically been applied on a multi-annual basis, usually operating for five to ten years, although with intermediate reviews where these are considered appropriate. This regulatory process has been designed to ensure some stability and continuity in the fisheries, while at the same time allowing new management objectives (e.g., restoring the stock above its Conservation Limit) to be applied over an appropriate time frame. The possibility of moving to a system whereby the annual assessment will be linked to an annual management response is one of the issues being explored further as part of the ongoing review of current procedures. The heritage status of some net and fixed engine fisheries can also be taken into account when determining appropriate regulatory controls. For example, consideration may be given to retaining a residual fishery and/or permitting a low level of catch. Further details of the approaches used for assessing the heritage value of fisheries are provided in a separate report, available at: www.gov.uk/government/publications/method-for-assessing-the-heritage-value-of-net-fisheries.

Byelaws may be introduced to make reductions in fishing effort in rod and net fisheries (e.g., length of seasons, fishing gear restrictions, or where and when fishing may take place). Where there is a justified and serious conservation concern, byelaws can be used to close fisheries. However, emergency byelaws can only be introduced where the cause for concern was previously unforeseen, that the measure being introduced addresses the concern, and that the byelaw is required as a matter of urgency. In response to ongoing concerns about the depleted status of stocks across England and Wales, new national byelaws have recently been introduced in both countries to further restrict the levels of exploitation by nets and rods (see Section 2.3).

Reductions in licence numbers imposed under NLOs will not necessarily have an immediate effect on the number of licences issued, because existing licensees who are dependent upon fishing for their livelihood may retain the right to receive a licence. Thus, phase outs have applied in some fisheries, whereby licence reductions have been achieved over time as licensees leave the fishery (see Section 2.5). In some circumstances, payments can be, and have been, made to fishers to cease fishing temporarily or permanently, facilitating more rapid reductions in fishing effort. The Marine and Coastal Access Act, 2009 removed the automatic right to a licence for future NLOs but provided the power to pay compensation to affected fishers.

Many rod fisheries are subject to local regulatory measures where specific protection is required to conserve stocks. A full listing of the byelaws applying to salmon rod fisheries in England and Wales is provided in the annual assessment report. This includes details of season lengths, method restrictions, mandatory C&R, and bag limits.

2.3 *New national byelaws*

Proposals to reduce fishing mortality to more sustainable levels to help protect and restore salmon stocks in both England and Wales have recently been implemented. In both cases, the measures have been developed based on the projected status of stocks for 2022, as assessed in 2017.

The Salmon and Sea Trout Protection byelaws for England were approved in December 2018 and applied from the 2019 season. These comprise:

- The closure of all net fisheries for 'at risk' and 'probably at risk' rivers in 2019, including all remaining drift net fisheries.
- Mandatory C&R by anglers on rivers that were classed as 'at risk' in the 2017 assessment and on rivers that are listed as 'recovering rivers' (Table 1).
- Voluntary C&R targets in excess of 90% on rivers classed as 'probably at risk'. A review of compliance with the voluntary C&R targets in 2021 revealed that 7 out of 29 (24%) of the rivers designated as 'probably at risk' in the 2017 assessment did not comply with high levels of voluntary C&R (>90%) after 16 June. The status of 5 of these river stocks has declined since 2017, with the latest assessment classing them as 'at risk'. As a result, consideration will be given on whether to persist with the voluntary measures or implement mandatory C&R byelaws to improve the protection of stocks.
- Renewal of the 1998 Spring Salmon Byelaws. These protect the larger, early running salmon, and do not introduce any new restrictions (see Section 2.6).

- Mandatory C&R fishing and method controls on the cross-border rivers Wye and Dee ("Border Rivers (England) byelaws") to complement Welsh measures. On the River Severn, emergency byelaws were introduced in 2019 requiring compulsory C&R by both rod and net fisheries. In 2021, a byelaw requiring mandatory C&R fishing and method controls replaced these emergency measures on the River Severn.

The 'All Wales' and 'Cross-Border (Wye and Dee)' fishery byelaws were implemented from 1 January 2020, following extensive public consultation beginning in 2017, including a Local Inquiry. These comprise:

- Mandatory C&R fishing of all salmon at all times for rod fisheries in all rivers in Wales.
- The introduction of partial method prohibitions on bait (worm, prawn and shrimp), use of treble hooks and barbed hooks.
- The implementation of mandatory C&R fishing and method controls on two of the three cross-border rivers – Dee and Wye in Wales. (N.B. River Severn emergency byelaws were introduced in 2019 and 2020 requiring compulsory C&R by both rod and net fisheries).
- Mandatory C&R of salmon at all times in all net fisheries, with arrangements for the last very small fishery under negotiation.
- Revised start and finish dates for net fishing seasons.

Both the English and Welsh measures apply for a period of ten years, subject to a mid-term review.

Table 1. Rivers in England designated as 'recovering rivers', which have been subject to mandatory C&R of salmon since 2019.

Name of River	County	Name of River	County
Allen	Cornwall	Medway	Sussex and Kent
Aln	Northumberland	Mersey	
Annas	Cumbria	Mite	Cumbria
Avill	Somerset	Otter	Devon
Bela	Cumbria	Par	Cornwall
Belford Burn	Northumberland	Parrett	Dorset/Somerset
Blackeney Brook or Backpool Brook	Gloucestershire	Porth	Cornwall
Blyth	Northumberland	Seaton	Cornwall
Bristol Avon		Sid	Devon
Brit	Dorset	Skelton Beck	North Yorkshire
Derwent (Tyne)	Tyne and Wear/County Durham	Skinningrove Beck	North Yorkshire
Don	Tyne and Wear	Stour	Kent
Doniford	Somerset	Team	Tyne and Wear
Ellen	Cumbria	Thames	
Ems	West Sussex	Trent	
Fal	Cornwall	Valency	Cornwall
Gilpin	Cumbria	Wansbeck	Northumberland
Harbourne	Devon	Waren Burn	Northumberland
Heddon	Devon	Washford	Somerset
Keer	Lancashire	Weaver	Cheshire
Lerryn	Cornwall	Winster	Cumbria
Looe	Cornwall	Yorkshire Ouse	Yorkshire
Meon	Hampshire		

Note: blank cells in the 'County' column indicate the river flows through multiple counties.

2.4 *Catch limits*

While, historically, there have been some catch limits for salmon net fisheries (with regulation focusing on effort controls), these have been superseded by the new salmon byelaws introduced in England and Wales, detailed in Section 2.3 above.

For rod fisheries, the England and Wales salmon byelaws have brought in new conservation measures to protect salmon populations, see Section 2.3. In addition, a number of local byelaws are in place including setting bag limits to limit the numbers of fish taken by individual anglers. Details of the rod bag limits currently in force are provided in the annual assessment report. It is unclear to what extent the imposition of bag limits may impact on the effort expended by anglers in river fisheries, but a preliminary investigation indicated no apparent difference in C&R rates on rivers with and without bag limits. Non-statutory restrictions have also been introduced in some areas by fishery owners and angling associations, but there is no national record of these.

2.5 *Phase-outs, closures, and buy-off arrangements*

Since 1996, there has been a policy in England and Wales to close coastal net fisheries that exploit predominantly mixed stocks where our capacity to manage individual stocks is compromised. Where this applies, an NLO of zero has been introduced and the number of licences issued has declined as existing licensees retire. Similar phase-outs have also been applied in some other fisheries where there were concerns about stock status. Following the introduction of the Salmon and Sea Trout Protection byelaws in England, all major salmon net fisheries around the English coast have been closed and mandatory C&R is required on rod fisheries exploiting river-stocks of salmon classed as 'at risk'. Mandatory C&R of salmon was also introduced on all net and rod fisheries in Wales because of the poor 'risk status' of all individual river stocks; arrangements for the last very small net fishery are under negotiation.

The largest phase-out scheme has operated in the north east coast net fishery. The phase-out began in 1993, immediately prior to which 142 drift net licences had been issued, with higher numbers previously. In 2003, the remaining 69 licensees using drift nets along the coast of Northumberland and Yorkshire were offered compensation, on a voluntary basis, to permanently relinquish their licences. This resulted in the number of drift net licences being reduced to 16 in 2003 (an immediate reduction of 77%). The number of drift net licences has subsequently been further reduced. The north east coast fishery NLO was reviewed again in 2012, and a decision made to maintain the phase-out of the drift net fishery, extend the phase-out to the coastal T & J nets, and for the drift net fishery to be closed by 2022 when the NLO expires. Under the new national byelaws (Section 2.3), the drift net fishery was closed in 2019 and mandatory C&R of any salmon caught by the remaining coastal T & J nets is required. The T & J nets will remain subject to a phase-out and fishing seasons have also been reduced in some districts to reduce the bycatch of salmon (i.e., fishing will be restricted to those months when sea trout predominate in the catch).

The Anglian net fishery is also subject to reduction based on the policy of phasing out coastal fisheries predominantly exploiting mixed stocks, although, in this case, the stocks targeted are primarily sea trout and the nets catch few salmon; typically, fewer than 5 salmon are reported each year. Under the new national byelaws introduced in England, it is now mandatory to release any salmon caught by the remaining nets.

The policy to phase out coastal salmon fisheries predominantly exploiting mixed stocks has had a major effect on catches. The largest change has occurred in the north east coast fishery, but there have also been reductions and closures of a number of other smaller fisheries. Although there have been large annual fluctuations, the overall effect of these various measures has been to reduce the catches in mixed stock coastal fisheries from an annual average of about 41,000 fish for the period 1988–1992 to a little under 32,000 for the period 1998–2002 and under 12,000 fish in the period 2003–2018. No retained salmon catches were declared by net fisheries in England in 2019 and all net caught salmon since 2020 have been released throughout England and Wales.

In addition to phase-outs, a number of other effort reductions have been implemented over recent years, in particular to restrict the available fishing time in some fisheries and through agreements to release fish. For example, netters fishing on the Avon and Stour (Christchurch Harbour) and on the Piddle and Frome (Poole Harbour) have previously been compensated to release all salmon caught. The Avon and Stour fishery was closed in 2012, but the release provision for all salmon continued to apply to the single seine net that is allowed to operate in Poole Harbour. Typically, such measures have been facilitated through compensation payments (buy-offs). Details of all the arrangements to reduce netting effort in the most recent year, and a summary of earlier measures, are provided in the annual assessment report.

2.6 *National spring salmon byelaws*

In response to a widespread decline in stocks of early-running multi-sea-winter (MSW) salmon in the 1980s and 1990s, it was determined that exploitation of this stock component needed to be reduced. Consequently, the national spring salmon measures were introduced in 1999. Under these measures, netters have been banned from killing, and in most cases fishing for, salmon before 1 June. However, there have been derogations that allowed fishing in some areas where netting is predominantly for sea trout, on the basis that any salmon caught were returned alive. For rod fisheries, the national measures banned the killing of salmon caught by anglers prior to 16 June and restricted the methods that they can use before this date to artificial flies or lures. Mandatory C&R was imposed for rod fisheries as an alternative to the closure of fisheries in the early part of the fishing season, aiming to allow continued fishing with minimal loss of stock. The total package of national spring salmon measures was reviewed, consulted upon, and renewed for a further 10 years in December 2008. In England and Wales, these measures have now been extended under the new national byelaws (Section 2.3).

The introduction of the national measures has had a substantial impact on catches. For net fisheries, the number of fish caught before 1 June has fallen from a 5-year average (1994–1998) of almost 3,000 fish (6.7% of the total catch) to under 70 (1.5% of the total catch) since 1999, all of which had to be released. In 2021, the number of salmon caught and released before 1 June was 11, representing 1.5% of the total catch. However, the percentage of salmon caught and released before 1 June since 2019 cannot be directly compared to the values presented in the preceding years. This reflects the introduction of new national byelaws in England and Wales, which restricted migratory salmonid net fisheries to harvest sea trout only and required mandatory C&R of any salmon captured within the fishing season. In addition, caution needs to be exercised when comparing the percentage of salmon bycatch since 2019. Net catches have declined to relatively low levels and small differences in these values result in large percentage differences among years. Annual fishing effort by nets, now targeting sea trout, has declined to historically low levels and proportionally more effort is spent fishing before 1 June compared to earlier periods in the time series.

The national measures have contributed to an increase in C&R rates in rod fisheries (Sections 2.7 and 4.4) and have also affected catches. On average, catches before 1 June, including fish released, comprised 11% of the total declared rod catch in the five years prior to the measures (1994–1998), while this has fallen to a mean of about 7% since 1999.

An analysis of the numbers of salmon released by weight category (<3.6 kg (8 lbs), 3.6–6.4 kg (14 lbs), and >6.4 kg) and season, for the years since 1998, is included in the latest annual assessment report. This indicates that since the introduction of the national measures to protect spring salmon, anglers have been voluntarily releasing an increased proportion of all fish caught after June, and large salmon in particular.

2.7 *Catch-and-release (C&R)*

The practice of C&R in rod fisheries has increased progressively over the last 30 years. When C&R was first recorded in 1993, 10% of the declared catch was reported to have been released. Levels have risen to at least 80% since 2016. In 2021, the C&R rate was 95%, which is the highest percentage ever recorded. While the spring salmon measures contributed to this increase (Section 2.6), the increase in C&R has largely resulted from voluntary implementation by anglers, aided by active promotion and the provision of best practice guidance. As a result of these efforts, a number of clubs have introduced bag limits (Section 2.4) and method restrictions. Levels of C&R have been further enhanced on some rivers through negotiated agreements. On the Rivers Test and Itchen (formerly Southern Region) and the Frome and Hampshire Avon (formerly South West Region), the salmon fisheries have reached voluntary agreements for all fish to be released and, in some cases, to make C&R compulsory in their Fishery Association rules. A number of other informal C&R targets have been agreed with fishery associations on other rivers.

More recently, mandatory controls requiring 100% C&R have been introduced on some rivers under local and national byelaws (Section 2.3). Mandatory C&R of salmon has been required on all rivers in Wales since 2020. In England, mandatory C&R of salmon has applied from 2019 for rivers categorised as 'at risk' and for recovering rivers. For rivers categorised as 'probably at risk', voluntary C&R targets in excess of 90% are required. Rivers in England were subject to further review in 2021 to ensure that the requirements and targets are being achieved. Of the 38 rivers that reported a catch of salmon in 2021, 13 (34%) had 100% C&R rates after 16 June and all those classed as 'at risk' in the 2017 assessment complied with the mandatory C&R requirement. In contrast, 7 rivers designated as 'probably at risk' in the 2017 assessment did not comply with the voluntary C&R target after 16 June in 2021. The status of 5 of these river stocks has declined since 2017, with the latest assessment classifying them as 'at risk'. Therefore, consideration will be given on whether to persist with the voluntary measures or implement mandatory C&R byelaws to improve the protection of stocks.

2.8 *Non-statutory restrictions*

As well as statutory measures, various voluntary measures are in place. These include agreements between angling and netting interests, which result in netters being compensated to release fish or not to fish. In addition, non-statutory restrictions are introduced by some fishery owners and angling associations on methods and fishing areas. However, there is no national record of these. For example, fishery owners on the Rivers Frome and Piddle have discouraged worming on their waters. Local arrangements also exist on the Hampshire Avon where angling for salmon ceases on days when water temperature (measured at 09:00 at Knapp Mill) exceeds 19°C. Similar arrangements have been in place on the Rivers Test and Itchen since 2013 to restrict angling during periods of high temperature.

2.9 *Carcass tagging scheme and ban on sale of rod caught fish*

A national byelaw came into effect in England and Wales in 2009 requiring all net-caught salmon and sea trout to be individually tagged with a carcass tag immediately after capture and for the details of all fish caught to be recorded in an annual logbook. A national byelaw banning the sale of rod-caught salmon and sea trout in England and Wales also came into effect in 2009, and the Marine and Coastal Access Act, 2009, extended existing legislation to enable 'handling salmon (and sea trout) in suspicious circumstances' to include 'selling'. These measures were designed to reduce the sale of illegally caught fish and to improve net catch estimates in compliance with international obligations to reduce the levels of illegal and unreported catch (Section 4.6). In tandem with the carcass tagging scheme, the ban on the sale of rod caught fish was designed to close a loophole whereby illegally caught fish could be offered for sale, and to discourage a small minority of anglers from killing a significant number of salmon (and sea trout) for sale.

Carcass tag (photo courtesy of Steve Williams, Environment Agency)

An initial review of the byelaw provisions relating to both carcass tagging and the ban on sale of rod caught fish concluded that the measures had worked well and that there was no need to change the byelaws (Environment Agency, 2010). Surveys have also indicated a high level of awareness among fishmongers and the wider catering industry, and that the measures were generally supported among the catering trade and by fishers. Further, anecdotal reports indicate that these measures have significantly raised awareness among those who buy fish, in particular, about the risks they face if they are found to be in possession of 'questionable' fish. Such reports also suggest that the new measures have greatly reduced the incidence of anglers taking and selling large numbers of salmon and sea trout; this is supported by evidence of fewer 'back door' sales of fish. Consultation with Environment Agency enforcement officers has indicated ongoing satisfaction with the measures which are regarded as being positive and working well. Surveillance, inspection (e.g., of catering premises) and information gathering activities support this view.

It is impossible to quantify the precise impact of these measures on catches. However, carcass tagging is expected to have resulted in a modest increase in reported catch, while the ban on sale of fish has facilitated the steady increase in C&R rates in rod fisheries. Both measures should also contribute to a simultaneous reduction in the unreported and illegal catch estimate (see Section 4.6).

3. FISHING EFFORT

The licences and byelaw controls described in Section 2 provide overall limits on the ‘allowable’ fishing effort in England and Wales and are used to regulate both fishing effort and levels of exploitation on salmon and sea trout. These have been subject to substantial change over recent years. Although catch limits are increasingly being used, these currently have relatively little effect on the overall fishing effort.

The amount that both netters and anglers actually fish (the ‘utilised’ effort) also varies due to weather conditions, perceptions about the numbers of fish available, and other factors, such as the increased costs of net licences, fuel and fishing gear. Changes in rod licence costs and the imposition of mandatory C&R in some fisheries may also have affected the take-up of licences and effort. Changes in the allowable and utilised effort are discussed in more detail below.

3.1 *Allowable effort in net fisheries*

The regulatory measures applied to net fisheries provide an overall limit on the ‘allowable’ fishing effort. There has been a decline in the numbers of licences issued for all types of nets and traps dating back to the 1970s. This marked decline in effort reflects both the measures taken to reduce levels of exploitation (especially in mixed stock fisheries) and the declining commercial viability of some fisheries. While the reduction in the number of licences provides an indication of the extent of recent effort reduction, the actual reduction in allowable effort has often been greater than this because of additional restrictions, principally on the amount of time available for fishing. Nevertheless, there may also be potential in some fisheries for fishers to make more use of the available time when conditions are favourable.

3.2 *Allowable effort in rod fisheries*

The regulatory controls applying to rod fisheries were summarised in Section 2. The national spring salmon measures, the ban on the sale of rod-caught fish, and C&R requirements are all thought to have influenced angling effort in recent years. Angling effort is likely to be further affected by the C&R requirements under the new national byelaws in England and Wales (Section 2.3). Bag limits also restrict catch levels on some rivers.

3.3 *Utilised effort in net fisheries*

Since the late 1990s, netters have been required to report effort data along with their catches. In most fisheries this has previously been reported as the number of tides fished, although in the north east coast fishery and for the fixed engines in the former Midlands and North West Regions effort has traditionally been reported as the number of days fished. Since 2011, revised logbook reporting arrangements have meant that effort data have been available as days fished for all fisheries. Reporting rates for net fisheries have been at, or close to, 100% for many years and latterly this has been reinforced by the requirement for carcass tagging.

These data provide an estimate of the total utilised effort in salmon net fisheries, and data for the most recent year are available in the latest annual assessment report. For those fisheries that target sea trout and which are allowed to fish before 1 June (but which cannot land salmon before or after this date), the allowable and utilised effort data include this extended fishing period.

There is typically considerable variation between the levels of utilised effort in individual fisheries. It is virtually impossible for most fisheries to utilise 100% of the allowable effort (except for some fixed engines) due to factors such as weather conditions, tide heights, and availability of fishing stations. In the north east coast fishery, for example, it has been suggested that no more than about 75% of the allowable effort could be used in the summer months under typical weather conditions (Anon., 1997). In some years prior to 2019, however, when conditions have been favourable (and catches relatively high), it has been possible for the drift nets in this fishery to utilise a higher proportion of the available days.

The overall changes in allowable and utilised effort (expressed in days), and the percentage of available days utilised by netters, over the time series is provided in the annual assessment report. The percentage of fishing days utilised has shown a general decline over much of the period, although there has been a marked upturn in some recent years. This is thought, in large part, to reflect the improved catch in these particular years and suggests that the take-up of available fishing opportunities is strongly influenced by catch rates, although the availability of suitable weather conditions also affects fishing opportunities.

3.4 *Utilised effort in rod fisheries*

The numbers of salmon and migratory (sea) trout angling licences purchased each year (annual and short-term) are provided in the annual assessment report for the period since 1994. No comparable data are available for earlier years because of changes in licensing arrangements. The number of short-term (one day and eight day) rod licences issued has shown a gradual decline over the period. The number of annual licences has changed more markedly, decreasing from ~27,000 in 1994 to ~15,000 in 2001 (down 44%), mainly due to the decline in salmon stocks and the introduction of restrictions on angling, especially those to protect early-run MSW fish (compulsory C&R before 16 June). Licence sales were particularly low in 2001 due to the restrictions on access to many rivers as a result of an outbreak of the 'foot and mouth' livestock disease. Sales of annual licences then increased, reflecting efforts to promote angling and to reduce levels of licence evasion through targeted enforcement, but have fluctuated subsequently. There was a marked upturn in the annual licences issued in 2017 due to the introduction of a new free licence for juveniles (under 18s). Both the outbreak of coronavirus (COVID-19) and a requirement for increased C&R fishing may have been linked to the reductions in licence uptake and angling effort in 2020. In 2021, 2,227 junior annual licences were issued compared with 19,076 adult annual licences. Junior licences accounted for 9% of all licence sales in 2021, including short-term licences.

Catch returns from licensed anglers indicate where fishing took place, and these data have previously been summarised on a regional basis. While the regional structure of the Environment Agency ceased to apply in 2014, data have continued to be reported in the same way to provide continuity of the time series. Time series of the total rod days fished in each former region are provided in the annual assessment report.

As indicated in Section 2.6, the national measures for rod fisheries introduced in 1999 banned the killing of salmon by anglers prior to 16 June and restricted the methods they can use before this date to artificial flies or lures. Mandatory C&R was also imposed before this date. The apparent decrease in average annual rod fishing effort between 1994 and 1998 (the 5 years prior to the national measures) and subsequently, is thought, in part at least, to reflect this change. Surveys suggested around 20% of the overall angler effort took place prior to 16 June, although there was substantial variation between regions. Expressed as a percentage of all the days fished early in the season in England and Wales, the highest fishing effort before 16 June consistently occurred in Wales and may reflect early season fishing targeted at sea trout rather than salmon.

Fishing effort data (days fished) submitted via the licence returns do not distinguish between times spent fishing for salmon and sea trout separately. However, this information is important for estimating angling exploitation rates, which are used on rivers without traps or counters in the assessment of compliance with Conservation Limits (see Annex 7).

Surveys conducted in 1992 and 2006 indicated that around a quarter (28% and 26%, respectively) of angler effort nationally was then directed at sea trout only (Table 2). Effort directed at sea trout appears to have been a little more consistent across regions in 1992 (range 24 to 34%), compared with 2006 (18 to 36%). In both years, the highest sea trout effort was reported for the former South West Region (35%, on average, for the two surveys); there are no clear differences among the other regions, where average effort directed at sea trout is around 25%.

Table 2. Percentage of rod effort (night and day combined) targeted at sea trout, based on questionnaires sent to anglers in respect of the 1992 and 2006 seasons.

Previous EA Region / NRW	**1992 survey**	**2006 survey**
North East	29	18
Southern	29	27
South West	34	36
Midlands		
North West	29	18
Wales	24	35
Total	**28**	**26**

4. DECLARED CATCHES

4.1 *Catch reporting arrangements*

Catches of salmon (and sea trout) by nets and fixed engines are derived from data reported in the mandatory catch returns (logbooks) submitted by licensed netters. There is typically full compliance with the submission of catch returns by netters (i.e., a 100% return rate), although there are some uncertainties in the reliability of the reported catches. The principal concern, supported by evidence where observed catches have been compared with those reported, is of under-reporting of catch. However, the possibility of over-reporting has occasionally been proposed, for example, prior to a possible buy-out agreement. Undeclared and illegal catches are discussed further in Section 4.6. To help address concerns about the reliability of catch return data, and in response to international obligations to reduce the levels of illegal and unreported catch, a carcass tagging scheme was introduced in England and Wales in 2009 (Section 2.9). These measures are thought to have improved the reliability of declared catch data for net fisheries since each net-caught fish must be tagged and each tag must be accounted for. Since implementation, the carcass tagging and logbook scheme have been subject to minor changes to help improve operation but are considered to have been a success in both reducing illegal catches and improving the reliability of catch data.

Information on catches of salmon and sea trout by anglers also relies on catch returns. However, while the submission of a return is a legal requirement (including nil returns), in practice rod catch return rates never reach 100%. Levels of reporting were typically lower at the start of the available time series (1950s) and progressive efforts have been made to improve levels of reporting since this time. The issue of undeclared and illegal catches, and how catches are corrected to account for these, is discussed further in Section 4.6. In 2017, changes were made to the rod licensing system in England and Wales with the introduction of annual licences that run for a full year from the date of issue, rather than for a specific calendar year.

A national rod catch return system has operated in England and Wales since 1992 to maximise the quantity and quality of catch returns received; catch data are stored on a national rod licence database for England and Wales maintained by the Environment Agency (including on behalf of NRW). This, together with other changes in rod licence administration, has generally facilitated better catch reporting in line with NASCO recommendations to reduce the level of unreported catch. For example, licences have been issued electronically since 2005 to provide a more up-to-date and accurate database for issuing reminders. Since 2014, anglers have also been able to provide their catch return online and greater reliance has been placed on this method of data capture since 2015. One aim of these changes has been to help ensure more timely and accurate catch return data. In 2021, 86% of angler's catch returns were submitted online; this proportion has increased year-on-year since this was introduced (50% in 2016, 65% in 2017, 75% in 2018, 80% in 2019, and 83% in 2020).

However, in response to concerns of under-reporting by anglers associated with the introduction of an online reporting system, a temporary raising factor was applied to declared rod catches between 2015 and 2018, informed by owner reported information. Since then, further development of the online reporting system, associated data reporting tools, and quality assurance tests has provided assurance that any previous shortcomings in the online catch reporting system have been resolved. An improvement in angler communications and reminders through various media platforms has also raised the catch reporting rates to those levels historically observed. Consequently, this temporary raising factor has not been applied to the declared rod catch data from 2019 (see Section 4.6).

National catch reminders, covering as many anglers as possible, were first issued in January 1995 (for the 1994 season), although some regional licensing and reminder schemes had operated previously. The national reporting and reminder system was initially subject to a number of difficulties. In 2001, a system was introduced enabling more effective targeting of reminders (for example, reminders were sent out earlier – in November – closer to the end of the fishing season in most regions). The system was subsequently modified to include the issue of targeted second reminders to anglers who failed to send in a return. In 2018, two reminder letters were issued with 29,930 catch return reminder letters sent (20,700 letters on 12 December and 9,230 letters on 16 January). In addition, 29,251 reminder emails, in three batches, were sent to anglers in cases where their email address were available (2 January 10,658 emails, 11 January 10,793 emails and 25 January 7,870 emails). These targeted reminders were supported by a communication and social media campaign. In 2021, 59,359 reminders to complete a catch return were sent to salmon and sea trout anglers across England and Wales, comprising of 22,129 letters (English and bilingual), 28,847 emails (English and bilingual), and 8,383 text messages.

For a small number of rivers, typically the River Wye in Wales and the Rivers Test and Itchen in the former Southern Region, fishery owner's rod catch returns have previously been reported as these were considered more complete than anglers' returns. However, in an effort to standardise and to encourage improved reporting rates, only the declared catch data have been included in the annual assessment report since 2012. Owner's catch return data are, nonetheless, considered to be the most reliable measure of total rod catch for the River Wye, and have therefore been routinely used to derive egg deposition estimates for use in the assessment of compliance with river-specific Conservation Limits (Section 8.1). Furthermore, owner's catch return data have been important in providing a basis for adjusting the declared rod catch data between 2015 and 2018 due to the reporting issues outlined above (see also Section 4.6).

4.2 *Catches for the latest assessment year*

The annual assessment of stocks and fisheries is carried out early in each year so that data can be collated and analysed in time for the annual meeting of the ICES Working Group on North Atlantic Salmon (WGNAS), which normally meets in late March / early April, and supports the ICES Advice which is required ahead of the annual NASCO meeting in early June. The salmon catch data available at this time are always deemed provisional. The data for nets and fixed engines are usually based on complete returns from netters and only require final validation. These data are thus typically subject to little, if any, subsequent change. Rod catch data, on the other hand, are based upon those returns received until an agreed cut-off date, usually early-February. While these data are largely complete, they are usually subject to some revision for late returns and final checking. The data provided in the annual assessment report include catches by both nets and fixed engines and rods for the latest year, together with available time series, and provide both regional and national totals.

Given that the data for the latest year presented in the annual assessment are provisional and likely to change slightly once all the catch returns are processed and the data validated, updated final figures for that year are routinely included in the next annual assessment report. Final confirmed data for the latest year are also reported in the Environment Agency and NRW annual compilation of catch data, which is typically published later in the year (the latest report is available at: https://www.gov.uk/government/publications/salmonid-and-freshwater-fisheries-statistics-2020). In 2020, rod catches were likely to have been constrained to some extent by COVID-19 restrictions throughout England and Wales, which imposed some limitations on angling opportunities and access to rod fisheries – particularly in the early part of the season.

Compass net fisherman on the River Cleddau (photo courtesy of the Environment Agency)

4.3 *Catches in coastal, estuary and river fisheries*

NASCO requests that catch data (fish caught and retained only) are grouped by coastal, estuary, and river fisheries. Relevant data for England and Wales for all years since 1993 are presented in the annual assessment report. The catch for the coastal zone has historically reflected the catch in the north east drift and fixed engine fishery, but also included drift nets on the Cumbrian coast (formerly North West Region) until 2003, and a number of nets and fixed engines fished around the Welsh and East Anglian coasts and in the Bristol Channel (Severn Estuary). In more recent years, only two coastal fisheries remained in operation, and one of these, Anglian, took very few salmon. All coastal fisheries were, however, closed in 2019 following the introduction of new national salmon byelaws in England (Section 2.3). The river fisheries comprise catches in freshwater and represent the total rod catch (fish retained) plus the very small catches in two ancient fixed engines, the River Conwy basket trap (last fished in 2002) and River Eden coops (not fished in some recent years). The remaining estuary fisheries closed in 2020 in line with the national byelaws in Wales.

A range of factors influence the relative proportions of fish taken in different areas, but the principal influences on these changes have been the national byelaws protecting early-running MSW salmon introduced in 1999, the increasing prominence of C&R, the phase-out of net fisheries generally, the partial buy out of the north east drift nets from 2003, and new national salmon byelaws. Catches (declared fish caught and retained) in each of the categories have, therefore, been subject to downward pressures over recent years, in the case of the coastal and estuary categories due to the substantial reductions in fishing effort (Sections 2 and 3), and, in the case of river (rod) fisheries, due to the increasing use of C&R (Section 4.4).

4.4 *Catch-and-release (C&R)*

There has been increasing use of C&R by salmon and sea trout anglers in England and Wales in recent years. This is in part a result of voluntary measures, but also reflects the legal requirement brought in to protect early-running MSW salmon, initially in 1999. It was also reinforced by the introduction of mandatory C&R on some rivers, and the introduction of the new national byelaws (Section 2.3). Details of the numbers of fish subject to C&R for each of the former regions in England and for Wales are provided in the annual assessment report; these data extend back to 1993 when information on C&R was first recorded. There has been a continued increase in the C&R rate over the period. C&R data for each major salmon river in England and Wales are published in the separate annual catch statistics reports produced by the Environment Agency and NRW.

The use of C&R is intended to increase the number of fish surviving to spawn and thus help rivers to meet their CLs and achieve long-term sustainability of the stocks. Such improvement is expected to benefit stocks and thus catches. However, the extent to which C&R directly affects catches is unclear. It is not known how many of the fish caught and released by anglers in any year may be recaptured one or more times. Further, there are uncertainties about the nature of the relationship between stock size and catch.

Results from an investigation on the River Dee (2007-2013) have provided some information on the 'second' recapture rates for rod-released salmon. In this tagging study, the rates of second capture for rod-released salmon were highly variable between years (0-18%), but averaged close to 7%, around a third of the initial capture rate of 21%.

To illustrate the possible effects of multiple C&R of individual fish on declared catches, in a scenario where:

(i) fish experienced an initial rod capture rate of 15% (in line with the general average exploitation rate for rivers in England and Wales);

(ii) the C&R rate was 100%;

(iii) the rod capture rate for released fish was half the initial or subsequent capture rate; and

(iv) no fish were caught more than three times;

then, for every 1,000 fish entering the rod fishery, 150 would be caught at first capture, ~11 at second capture and ~1 fish at third capture. Thus, the total catch of ~162 fish would be 'inflated' by recaptures of released fish by only around 8%. This is a relatively small amount and so may be of little concern, for example, as a source of error in estimating spawning escapement from rod catches.

This concern would be lessened for rivers with average exploitation rates less than 15% (typically, around a half of counted rivers) or where C&R rates were less than 100% (most rivers). Of more concern would be rivers where underlying exploitation rates and C&R rates were high; and/or where capture rates for released fish were greater than half the initial capture rate. For example, repeating the above scenario with an initial rod capture rate of 30% and 100% C&R would result in a total catch of around 350 fish inflated by ~16%.

4.5 *Long-term catch trends*

The annual declared net and fixed engine catch for England and Wales over the available time series, since 1956, is available in the annual assessment report. This distinguishes the catch taken in the north east coast fishery – which increased rapidly in the late 1960s with the introduction of synthetic nets and has comprised well over 50% of the total net catch in most subsequent years – from the catches elsewhere. Although this fishery is being phased out and catches have been much reduced, catches in other regions have fallen more quickly. The catches in the other net fisheries have been declining since the mid-1980s, reflecting reductions in both fishing effort (Section 2) and stock sizes. The catch taken in the north east coast fishery comprised around 90% of the total declared net and fixed engine catch for England and Wales between 2010 and 2018. In England, following the introduction of the Salmon and Sea Trout Protection Byelaws, no retained catches of salmon were declared by nets and fixed engines in 2019 and only a minimal catch of salmon was reported for Wales. Since 2020, all declared net caught salmon have been released throughout England and Wales.

The annual declared rod catch of salmon over the same time period is also provided in the annual assessment report. From 1993, this distinguishes fish that have been caught and released from those caught and retained. The former now comprise a relatively large proportion of the catch (at least 80% over the last five years); it is unclear to what extent fish may be caught and recorded more than once (see Section 4.4 above). Reporting rates are also known to have improved substantially since 1986 and more recently efforts to improve catch returns have embraced new mechanisms to remind anglers, as noted in Section 4.1.

4.6 *Undeclared and illegal catches*

The national catch data required by ICES for assessment purposes must be adjusted to allow for undeclared and illegal catches. The following sections outline the approaches used. The most recent estimate of undeclared and illegal catch for England and Wales is included in the latest annual assessment report.

Undeclared catch: All migratory salmonid rod and net licence holders in England, Wales, and the Border Esk are legally required to submit a catch return, even if a nil return, to the Environment Agency and NRW. This includes details of their catch of salmon and sea trout (numbers and weights), fishing dates, and information on fishing effort (e.g., the number of days fished in the case of anglers). Catch returns are received from 100% of net and fixed engine licence holders and typically ~70+% of full season migratory salmonid rod licence holders.

As part of the assessment of salmon stocks for ICES, countries are required to include an estimate of undeclared catch. The calculation of the under-reported rod catch in England and Wales comes from an estimate of undeclared catch using the method derived by Small (1991). This recognised that anglers who catch a fish are much more likely to make a catch return than those who do not. Under the current licensing system, the proportion of catch under-reporting across all rivers (i.e., a single national figure) was estimated to be around 10%. This reflects the fact that the ~70% of anglers who make a catch return are believed to account for 90% of the total catch. Historically, prior to the implementation of the current national rod licence reporting and catch reminder process, under-reporting was a much larger problem. This was found to vary within each reporting Region, and much higher correction factors were used (Environment Agency, 2003a).

Concerns were raised in 2015 that rod catches reported on some rivers via rod licence returns were unusually low compared to locally reported figures. This coincided with the introduction of a new online reporting system for licence returns. Pending investigation into the operation of that system, additional rod catch raising factors (utilising time-series of local catch figures available on some rivers) were used to account for the observed differences (i.e., in addition to the 10% correction factor described above). In the years 2015 to 2018, these additional rod catch raising factors ranged from an average per river of around x1.20 to x1.40, inflating estimates of the available spawning stock on all river catchments in England and Wales.

NASCO guidance requires member states to take a precautionary approach to the management of salmon stocks and basing the calculation of an additional stock raising factor on a small number of river catchments is not considered appropriate in the longer term. So, these additional rod catch raising factors were only intended to be a short-term adjustment. Subsequent development of both the online reporting system and associated data reporting tools, alongside data quality assurance testing, has provided an assurance that any previous shortcomings in the online catch reporting system have been resolved. An improvement in angler communication and reminders through various media channels stressing the importance and value in making a rod catch return has also raised the catch return rate (i.e., the proportion of licenced anglers submitting a catch return) to those levels observed historically.

The emphasis remains with anglers to fulfil the legal requirement to submit full and accurate catch returns. The information obtained from catch returns is integral to stock assessment procedures for salmon and sea trout in England and Wales that are used to inform management measures that seek to adequately protect stocks, which in turn ensure sustainable fisheries for future generations.

Consequently, additional rod catch raising factors based upon riparian owner catch data have not been applied since 2018 and the previous 10% rod catch correction factor will be applied as a national default. Individual river stock assessments will continue to use locally derived data if these are available and considered to represent an accurate assessment of the true rod catch. It should be noted that the majority of tables of catch data in the annual assessment report continue to report rod catches as declared. Adjusted catches (corrected for under-reporting based on Small, 1991) are only reported in Table 19 of the annual assessment report and are also used for the annual river-specific compliance assessments (Section 8.1) and the national assessments of stock status (Section 8.4).

For the net fishery, a figure of 8% was used for a number of years prior to 2009 to adjust for the level of under-reporting, based on the outcome of surveillance operations. The level may have been substantially higher in the past in certain fisheries, possibly as much as 50%. However, following the introduction of logbooks and a carcass tagging scheme in 2009 (Section 2.8), under-reporting in net fisheries is now considered to be minimal. An assumed figure of 2% of the declared catch has therefore been applied for correction purposes since this time (Cefas and Environment Agency, 2010).

Illegal catch: The illegal catch, by its very nature is difficult to quantify. A questionnaire survey of Environment Agency enforcement staff in 1998 indicated that an average value of around 12% of the declared catch was appropriate. The introduction of the carcass tagging scheme and ban on the sale of rod caught fish is expected to have made it substantially more difficult to dispose of illegally caught fish (Section 2.8). An assumed value of 6% of the declared catch has therefore been applied for correction purposes since 2009 (Cefas and Environment Agency, 2010).

Net seized from the River Afan, South West Wales (photo courtesy of Natural Resources Wales)

Actions: In order to maintain the low level of under-reporting in the rod fishery, the Environment Agency issues reminders to anglers that they should record and report their catch. Enforcement action has previously been used when there has been significant contravention of the law requiring reporting of catch. Targeted enforcement activity also aims to suppress illegal catch. A detailed report on illegal and under-reported catches was submitted to a special session of the 2007 NASCO meeting. Full details are available at: https://nasco.int/wp-content/uploads/2020/02/CNL0726.pdf.

4.7 *Other sources of non-catch fishing mortality*

Non-catch fishing mortality includes all sources of mortality generated directly or indirectly by fishing which are not included in the recorded catch. It includes the illegal and unreported catches discussed above in addition to losses of fish that are removed from fishing gear by predators, dead fish that fall out of a net and fish that escape or are released but subsequently die before spawning. The extent of the likely losses will vary between fisheries because of the type of gear used and its method of operation. In addition, the impact of predators, particularly seals, varies between areas.

In most net fisheries in England and Wales, the netters remain with their gear and remove any fish caught quite quickly; thus, relatively few fish will drop out and losses to predators can usually be limited. Sweep and hand-held nets cause very little damage to the fish and therefore losses of fish that escape are likely to be minimal. However, small losses may occur from enmeshing (gill) nets, and predation losses may be significant in the north east coast and Anglian net fisheries, which are close to large grey seal colonies.

No data are available on the mortality of salmon incurred during normal angling activities (e.g., due to lost or foul-hooked fish that subsequently die) that are not recorded in the retained catch. Whilst the use of C&R (Section 4.4) is likely to result in some fish dying through exhaustion or damage, studies have demonstrated that if fish are appropriately handled, mortality following capture is low and a large proportion of fish survive to spawn (Webb, 1998a,b; Whoriskey *et al.*, 2000). Radio-tracking studies carried out by the Environment Agency on the River Eden, Cumbria, found that more than 85% of released spring salmon can reasonably be expected to survive to spawn (Environment Agency, 2003b). In order to increase the survival of rod caught fish, the use of tailers was made illegal in England and Wales under the Marine and Coastal Access Act, 2009. Although in relatively infrequent use prior to this, tailers were considered to have an adverse effect on salmon survival following C&R. Further measures to improve the survival of fish subject to C&R, including method prohibitions on certain baits (worm, prawn and shrimp), the use of treble hooks and the use of barbed hooks (Section 2.3) have been introduced in Wales. It is planned to adopt some similar provisions on rivers in England through locally negotiated agreements.

Projected climate change scenarios for England and Wales (Hulme *et al.*, 2002; Murphy *et al.*, 2009; Lowe *et al.*, 2019) in the coming decades are of concern since the hotter, drier summers forecast are expected to result in salmon being under greater stress. On some rivers (e.g., Hampshire Avon, Test, and Itchen), changes in C&R practices are already applied when certain temperature thresholds are reached; additional policies or agreements may be required on other rivers to address this growing concern.

4.8 *Age composition of catches (nets and rods)*

The annual salmon stock assessments conducted by ICES focus on two separate stock components: those fish that mature after one winter at sea (i.e., one-sea-winter fish / 1SW or grilse) and those that mature after two or more winters at sea (i.e., multi-sea-winter / MSW fish). It is therefore important to be able to assess the relative contributions of these sea-age groups to net and rod catches.

Nets

Prior to 2001, it was not possible to estimate the proportions of 1SW and MSW salmon in the catch of all net fisheries, because netters were generally not required to report the sizes of individual fish caught, and few scale samples were collected. However, the introduction of standardised procedures for reporting the size of fish caught in most fisheries in England and Wales in 2001 has allowed the sea age composition of the catch to be inferred. For fish caught in the north east fishery, there has been a long-standing methodology for reporting catch by weight category.

Catches in most net fisheries are now reported as small (≤3.6 kg = 8 lb) or large (>3.6 kg) salmon, and this can be used as a rough indication of sea-age, the smaller fish typically being 1SW salmon (grilse) and the large fish MSW salmon. Inevitably, however, such a simple weight split will ignore potential differences between years, different stocks or over the duration of the season and will result in some fish being wrongly classified. A summary of the weight split data for net and fixed engine fisheries, based on former Environment Agency regions, is included in the annual assessment report. The estimated proportions of large (MSW) salmon in regional net catches over the available time series is also provided.

Rods

Monthly age-weight keys have been available for salmon caught in the River Dee and Tamar traps since the 1990s, and the latest (rolling 10-year) keys for these rivers have been used to estimate the age composition of catches for selected principal salmon rivers in the latest assessment year. These estimates are provided in the annual assessment report and were derived from (provisional) declared catches, as available at the time, for fish where weight data were also provided.

Summaries of the estimated proportion of MSW fish caught in different rivers and estimated numbers of 1SW and MSW salmon in regional rod catches, over available time series, are also provided in the annual assessment report.

4.9 *Origin of fish caught (salmon from other countries / farmed & ranched fish)*

As discussed in Section 4.10, many of the salmon historically caught in the English north east coast fishery were returning to rivers in Scotland. There is also likely to be some capture of Scottish origin fish in North West England, in particular in fisheries operating in the Solway. However, small numbers of fish of English origin will be taken in fisheries operating in south-east and south-west Scotland. Such mixing of stocks in fisheries has been demonstrated by previous tagging programmes and more recent genetic studies but is typically considered to be of limited extent for most current fisheries.

There are very few other records of tagged salmon released in, or originating from, rivers in other countries being taken in English and Welsh fisheries, and no such tag recoveries have been reported in recent years.

There is no salmon ranching in England and Wales. However, fish farm escapees from other countries can sometimes occur (Milner & Evans, 2003). A sampling programme was initiated by Cefas and the Environment Agency in 2003 to identify any salmon suspected of being of farmed origin in the England and Wales catch and to determine the extent to which such fish may be contributing to spawning stocks. This programme operated for four years, but no farmed fish were identified and the programme has been discontinued. Net catches are now much reduced and there is currently no formal mechanism for monitoring fish farm origin fish or any requirement for fish farm escapees to be recorded in catches. However, returning adult salmon are monitored on a small number of index rivers, and previous experience indicates that anglers and netters would be quick to identify and report such fish should they appear in catches. In 2020, anglers reported nine captures of escaped farmed salmon (verified by scale reading) from west Scotland on five rivers in North West England (Lune, Ehen, Derwent, Eden and Border Esk). Anglers also made unverified anecdotal reports of about 50 additional captures of escaped farmed salmon. No such reports were made in 2021.

NASCO convened a special theme session on minimising the impacts of salmon farming on wild Atlantic salmon. The proceedings of the session have been published and are available at: https://nasco.int/wp-content/uploads/2022/02/NASCO-2021-TBSS-web-hyperlinks.pdf.

In the past, non-native pink salmon have occasionally been reported in the UK. However, in 2017 relatively large numbers of these fish were recorded in the UK and elsewhere around the North Atlantic (ICES, 2018). In the UK, reports of pink salmon entering rivers were widespread, with evidence of spawning activity in some catchments in Scotland. These non-native salmon are believed to originate from what are now established populations of pink salmon in northern Russia and Norway. Pink salmon have a strict two-year life-cycle, so tend to establish distinct odd- and even-year populations. The introduction of pink salmon in the Russian Federation has resulted primarily in the establishment of odd-year populations, and this explains why strays primarily seem to be reported here in odd years (e.g., earlier reports of pink salmon in the UK have been in 2007, 2011 and 2015). Fish from the original introductions are known to have spread and established self-sustaining populations in a number of rivers in northern Norway, and there was widespread evidence of spawning activity in other Norwegian rivers in 2017. It remains unclear whether the large number of 'stray' fish reported in 2017 represents a step change in the rate of spread of this species, or simply reflects a strong year-class of fish as a result of particularly favourable conditions (i.e., a one-off). Pink salmon did not materialise in any great numbers in 2019, with only four confirmed reports across England and Wales. No reported captures of pink salmon were made in 2020. In 2021, there were 26 reported captures of pink salmon in England but none in Wales. All pink salmon were captured in North East England in 2021, except for one recorded at the Gunnislake fish trap on the River Tamar, which is the furthest southerly capture within England and Wales since 2007.

4.10 *Assessment of national catch trend*

Each year, the ICES Working Group on North Atlantic Salmon (WGNAS) assesses the status of the salmon stocks in the North East Atlantic as a basis for advising NASCO (e.g., ICES, 2021). Further details on this assessment are provided in Section 8.4 and Annex 5. This assessment endeavours to provide our best interpretation of what the available catch and effort data tell us about changes in the status of total national stocks of salmon over the past four to five decades.

The starting point for this assessment is the best available time series of nominal national catch data (i.e., fish retained), taking account of unreported and illegal catches. For England and Wales, nominal catches have been derived from the catch returns submitted by netters and anglers and split into 1SW and MSW categories using two different methods. For the 1990s onwards, monthly age-weight keys derived from salmon caught in the River Dee and Tamar traps have been used to estimate the age of all rod-caught fish where a weight and date of capture have been provided, as described in Section 4.8. This has then been scaled up to the total catch (rods and nets combined) on a pro-rata basis. For earlier years (1971-1991), the age composition of the total catch has been estimated using the mean weight of the fish caught and the mean weight of 1SW and MSW salmon recovered in tagging programmes. Estimates of unreported and illegal catches have been made on the basis of consultation with fisheries personnel and according to the approach described in Section 4.6.

As the contribution of farmed and ranched salmon to the national England and Wales catch is negligible (see Section 4.9), the occurrence of such fish is ignored in the assessments of the status of national stocks.

A large proportion of the salmon previously taken in the north east coast fishery were destined for Scottish rivers, and these have historically been deducted from the catch for England and Wales and added to the returning stock estimate for Scotland in the ICES assessment. This proportion is estimated to have declined from 95% of the North East net catch in the early part of the time-series to 75% in the 1990s, around 65% in the 2000s and closer to 50% from 2012 to

2018. This reflects both the steady improvement in the status of the stocks in North East England and the substantial buy-out of drift nets in 2003; the phasing out of these nets having started in 1992 (Section 2). The latter resulted in a major overall reduction in the fishery, with the remaining netters now fishing for sea trout mainly close inshore using T or J nets. Tagging studies have shown that these inshore nets exploit a much higher proportion of local salmon (Anon., 1991). A more recent genetic investigation based on samples collected throughout the fishery in 2011 (Gilbey *et al.,* 2016 a & b) confirmed that a smaller proportion of Scottish salmon were captured in the inshore nets and in the more southerly parts of the fishery, and provided values broadly consistent with those based on earlier studies. With the closure of the north east coast drift net fishery and a requirement for mandatory C&R of salmon in the inshore nets from 2019 (Section 2.3), it has not been necessary to make the above adjustment since this time.

The best estimate of the total catches of 1SW and MSW salmon in England and Wales, for the period since 1971, is available in the annual assessment report. The data indicate that catches of salmon in England and Wales (fish caught and killed only) have declined by over 90% since the early 1970s. It is also apparent that there was a marked decline in catch around 1990, which is consistent with the general perception of a decrease in the marine survival for many stocks around the North Atlantic at about this time.

5. CATCH PER UNIT EFFORT (CPUE)

Catch levels are influenced by factors such as stock abundance, the catchability of the fish, and the variation in the time anglers and netters spend fishing. Catch per unit of fishing effort (CPUE) is, therefore, used as well as the declared catch to help evaluate the relative status of stocks. CPUE can also provide an index of angler satisfaction (people would like to spend less time, on average, to catch each fish), and indicates changes in the profitability of net fishing, the income from the catch being set against the costs of time spent netting. For net fisheries in England and Wales, CPUE data (based on the former Environment Agency regional structure) have been collated using the number of tides fished (or for the north east coast fishery the number of days fished) as a measure of the amount of fishing undertaken by each licence holder. Rod CPUE data (catch per licence day fished) are now reported for all major salmon rivers in England and Wales in the annual catch statistics reports.

It should be noted that CPUE values only reflect the availability of salmon during the fishing season and may bear less relation to spawning escapement of fish migrating into rivers outside the fishing seasons. For both net and rod fisheries, the relationship between CPUE and salmon abundance can be influenced by confounding factors (e.g., river flows and altered angling practices). It should also be remembered that, when operated, net and rod fisheries are undertaken sequentially (the net fisheries exploit the returning fish first), and over different time periods (fishing seasons). Rod fisheries are active over a longer period and typically extend into the early autumn after net fisheries have ceased to fish. Thus, changes in patterns of run-timing may also impact on CPUE values in the different fisheries. Run-timing is known to vary for fish of different sea-ages and there have been marked changes in the age composition of returning stocks in recent years (Section 7.3).

5.1 *CPUE in net fisheries*

Time series of CPUE data, starting in 1997, for regionally aggregated net and fixed engine fisheries are provided in the annual assessment report. To ensure comparability and provide a consistent time series, annual mean CPUEs are only provided for fisheries that have fished in the same way over this period. Fisheries are excluded that have been subject to measures to reduce fishing effort, or other regulatory controls (e.g., a cap on the allowable catch). The number of fisheries represented in this time series is thus subject to change year on year and has reduced over time. No estimates of CPUE for nets and fixed engines since 2020 have been available because no fishing effort for salmon has occurred over this period throughout England and Wales. Salmon fishing has been restricted to C&R in England and Wales since 2020 as part of national salmon byelaws and/or licence conditions.

5.2 *CPUE in rod fisheries*

Evidence from selected rivers where we have estimates of returning stock size, as well as CPUE, suggests rod CPUE values provide a reasonable indicator of stock abundance.

Summaries of rod CPUE (expressed as number of salmon caught per 100 days fished), aggregated according to the former regional divisions, are also provided in the annual assessment report. The data for the most recent year are based on incomplete returns and should be regarded as provisional. These CPUE time series include returns from a wide variety of anglers (e.g., locals who fish regularly, holiday anglers and those who fish primarily for sea trout) and river types. This will result in the CPUE for salmon varying between regions, but still provides scope for comparisons through time within a region. It should be noted that reductions in effort due to the national measures to protect spring salmon may have affected CPUE from 1999 onwards.

6. EXPLOITATION RATES

6.1 *Homewater exploitation*

The relationships between salmon run and catch are mediated by fishing effort and catchability (the proportion of the stock taken per unit of fishing effort), which in turn are shown to vary within and between rivers. One prime cause of this variation is likely to be river flow, which acts by influencing the behaviour and availability of the fish to both nets and rods, and also angler activity (Section 9.2). Changes in run timing may also be a factor (Section 7.3).

Relatively few rivers have independent measures of run size (e.g., from counters and traps) to compare against catch. However, such data are available for some rivers in England and Wales and have been used with the total catch (retained and released combined) adjusted for under-reporting, to estimate exploitation rates. Both the counts and exploitation rate data are provided in the annual assessment report. The rod exploitation rate estimates often show varying trends, but the ‘true’ exploitation rates (i.e., fish retained) show a marked decline over the available time series, an effect largely attributable to C&R, which, over the past 20-30 years, has increased from 10% to over 90%. For many net fisheries, exploitation rates have declined due to reduced levels of fishing.

Data from seven rivers (Test, Itchen, Frome, Tamar, Fowey, Dee and Lune; Milner *et al*., 2001) have shown that, while exploitation rates tend to differ between rivers, there is also considerable variation between years within individual rivers. A tagging and recapture programme on the River Dee has also shown that early season entrants to the river (predominantly MSW salmon) are generally subject to higher exploitation than those entering later.

Since changes to regulatory measures occur frequently in salmon fisheries, with the explicit aim of changing exploitation rates, these need to be taken into account when interpreting historical catches in terms of indicating stock abundance.

6.2 *Assessment of national trend in exploitation*

As indicated in Section 4.10, ICES makes an annual assessment of the status of stocks in the North East Atlantic over the past five decades, based on their best interpretation of what the available catch and effort data suggest about changes in the status of national stocks (see Section 8.4 and Annex 5).

The national assessment generated by WGNAS first estimates the numbers of salmon returning to freshwater in each country, and then back-calculates the numbers of fish that must have been alive in the sea on January 1 in their first sea-winter to generate these returns. This is known as the pre-fishery abundance (PFA). The numbers of returning fish are estimated using the nominal catch data for each country (i.e., fish retained), raised to take account of unreported catches and exploitation rates for 1SW and MSW fish. The process of deriving a national catch trend was described in Section 4.10. These data are then adjusted by national exploitation rates to estimate numbers of returning fish. Each country therefore needs a time-series (beginning in 1971) of exploitation rates for 1SW and MSW salmon.

Time-series of exploitation rates for a number of monitored fisheries in England and Wales, referenced in Section 6.1 above, are provided in the annual assessment report. National exploitation rates have been estimated by deriving time-series of 'standard fishing units' employed in the salmon fisheries from 1971 to date. For the period 1971 to 1997, these were calculated from the numbers of net, fixed engine and rod licences issued weighted by their relative catching power, which was estimated from historic CPUE data. For the period 1998 to the present, they are calculated from the numbers of days fished by different net categories (and rod licence numbers) weighted in the same way. The annual exploitation rates are then estimated by referencing the number of 'standard fishing units' employed over the two periods relative to average age-specific exploitation estimates derived for the 1997 and 1998 seasons.

The overall trends in national exploitation rates derived from the above process are also provided in the annual assessment report. These indicate that exploitation rates, expressed in terms of fish killed, have fallen from about 50% for 1SW fish and 35-40% for MSW fish at the start of the period to 0.6% and 0.3%, respectively, currently, due to the measures taken to control both legal and illegal fisheries. The decline in exploitation rates occurred particularly in the 1990s, then levelled out, followed by a relatively sharp decline since 2019 due to reductions in salmon abundance and the introduction of national salmon byelaws.

6.3 *Exploitation in fisheries outside England and Wales*

Salmon originating from rivers in England and Wales have been exploited in a number of fisheries other than those operating under the jurisdiction of the Environment Agency and NRW. These include the distant-water fisheries at Faroes and West Greenland, and other fisheries such as those that have operated off Ireland and in other parts of the UK. Tagging studies have provided information on the levels of exploitation for English and Welsh stocks in many of these fisheries and this is summarised briefly below.

West Greenland

This fishery exploits only salmon that would have returned to Europe and North America as MSW fish. The exploitation rates on the MSW component of English and Welsh stocks in the late 1980s/early 1990s were estimated to be about 10-20% when catches at West Greenland were in the range of 300 to 900 t (Russell and Potter, 1996). However, following significant quota reductions and other initiatives since the late 1980s, exploitation is believed to have fallen to very low levels. Since 1998, the catch at West Greenland has usually been restricted to that amount used for internal subsistence consumption and catches have remained relatively low over this time (9-58 t). In addition, the majority of fish currently taken in the fishery are of North American origin. Exploitation of English and Welsh stocks is thus currently estimated to be very low (<1%) and expected to remain so. The regulatory measures agreed by NASCO in respect of the West Greenland salmon fishery from 1984 to date are provided in Annex 4.

Faroes

The Faroes fishery exploits both grilse and MSW salmon of largely northern European origin (i.e., not from England and Wales, which is part of the southern European stock complex). No quota has been set for this fishery since 2001, and the fishery has not operated since this time. The Faroese authorities have indicated an intention to manage any salmon fishery in a precautionary manner on the basis of the advice from ICES regarding the status of the stocks and with a view to sustainability, taking into account relevant factors such as socio-economic needs. Few tags of English and Welsh origin were recovered in this fishery when it operated, and estimated exploitation rates on English and Welsh stocks at this time were very low (<2%) (Russell and Potter, 1996). The regulatory measures agreed by NASCO in respect of the Faroes salmon fishery from 1984 to date are provided in Annex 4.

Republic of Ireland

The Irish coastal drift net fishery, which exploited salmon stocks originating from England and Wales, closed in 2007 and hence exploitation of these stocks by this fishery has ceased. Smolt tagging studies carried out by Cefas and the Environment Agency demonstrated that salmon from all parts of England and Wales were exploited in the fishery, but that levels of exploitation varied between stocks from different regions and from year to year. Exploitation rates were higher in the period before 1997 but declined following the introduction of management measures in the Irish fishery in 1997 and subsequent additional restrictions on catches (e.g., TACs) from 2002. In the latter years of fishery operation (1997-2006), exploitation of salmon from North East England in the Irish fishery was estimated to be negligible (<1%), exploitation on stocks from North West England and north Wales was low (~2%), but levels were greater for stocks from west and south Wales and Southern England (8-12%). However, the estimates for South West England in 2003 to 2006, immediately prior to the closure of the fishery, indicated an exploitation rate of only about 2% for the River Tamar stock (south-west England).

At the time of closure of the Irish coastal fishery, it was calculated that up to 5,000 more 1SW salmon would return to English and Welsh home-waters each year, representing a 4% increase overall (based on levels at the time). Rivers in the south and west of England and Wales were expected to benefit the most.

Other homewater fisheries

Few tags of English and Welsh origin have been returned from homewater fisheries in Northern Ireland or Scotland. The exploitation rates of English and Welsh salmon in these fisheries have not been estimated but are thought to have been low. Many of these fisheries have also either closed or been subject to reduction.

Marine by-catch

The ICES WGNAS has investigated concerns about the potential by-catch of salmon post-smolts and adults in pelagic trawl fisheries operating in the Norwegian Sea. Areas of overlap between the distribution of post-smolts and certain pelagic fisheries have been identified, but assessment of the level of by-catch has been constrained by insufficient knowledge about the temporal and spatial distribution of post-smolts and catches in pelagic fisheries. The Working Group has recognised that data derived from surveys conducted on commercial vessels using pelagic trawls will provide the most reliable indicators of by-catch, and previous assessments based on these data have indicated a fairly low level of impact. In 2005, the Working Group estimated that the upper level of potential post-smolt by-catch (from a range of ~40,000 to 150,000 fish) was less than 5% of the estimated pre-fishery abundance (PFA) of salmon for the North East Atlantic stock complex (ICES, 2005).

More recently, the pelagic fisheries in Nordic Seas and in the areas around Iceland have changed, raising new concerns about possible increased levels of salmon by-catch. The mackerel stock has expanded north-westwards during spawning and in the summer feeding migration, extending as far west as south-east Greenlandic waters. Significant catches of mackerel are currently taken in Icelandic and Faroese waters, areas where almost no such catches were reported prior to 2008. Catches from Greenland were also reported for the first time in 2011 and increased subsequently.

The latest by-catch estimates reported to the ICES Working Group arising from recent Icelandic and Faroese screening programmes suggest relatively low levels of by-catch in pelagic catches (1 to 6 salmon per 1000 tonnes of mackerel and herring), consistent with earlier findings (ICES, 2014; 2018). Genetic analysis has indicated that fish taken as by-catch originate from a number of countries around the North East Atlantic, including the UK and Ireland (ICES, 2018). Markedly higher ratios of salmon to pelagic species (20 to 50 times more than those recorded in catch screening) have been reported in salmon research surveys using pelagic trawls in Nordic Seas. It remains unclear how representative these data might be of the actual by-catch in the commercial fishery given differences in the design and operation of the gears used. However, even taken at face value, the capture rates remain quite low relative to the estimates of total North East Atlantic PFA (<2%). It remains the case that assessment procedures based on direct screening of commercial catches are considered to provide the most reliable data for extrapolation purposes. Nonetheless, it is recognised that the catches in these pelagic fisheries have increased and substantial uncertainties remain as to the extent to which the migration routes of post-smolt and adult salmon might overlap in time and space with these pelagic fisheries.

The ICES Working Group previously concluded that there was insufficient information to allow any assessment of the effect of non-targeted fisheries on salmon abundance, and this still remains the case. The latest available data remain consistent with the view that salmon by-catches appear to have a relatively low impact on salmon PFA and returns to homewaters. Further investigations (ICES, 2017a) also found little evidence for salmon by-catch in the blue whiting fishery. However, ICES recognises that these estimates remain uncertain and considers it would be informative to increase efforts to obtain more reliable estimates of the by-catch of salmon. Investigations based on the use of eDNA have recently been initiated and may provide further insights (ICES, 2018).

ASSESSMENT OF THE STATUS OF STOCKS

7. STOCK MONITORING

The Environment Agency and NRW monitor both stocks and fishery performance in most rivers supporting salmon stocks in England and Wales. This includes operating counters, undertaking surveys of juvenile fish, and collecting fishery statistics. These data provide the basis for assessing the status of stocks and thereby determining the need for management actions. Further information on factors affecting stocks is collected to inform management decisions.

In addition to protecting the abundance of salmon stocks, managers need to maintain the diversity of stocks in terms of their biological characteristics. Measures of stock diversity potentially encompass a wide range of characteristics, but those of greatest significance for the management of stocks are the population structure within the river, the river age of the emigrating smolts, and the run-timing and sea-age composition of the returning adult stock. There have been marked changes and trends in these characteristics among stocks around the North Atlantic over recent decades (e.g., ICES 2009, 2010; Russell *et al.*, 2012: Otero *et al.*, 2014), and in some cases these appear to be linked with variations in marine survival and trends in abundance. Monitoring changes in these characteristics therefore provides the potential to understand more about the factors affecting stocks, the potential to predict future trends and how to manage to maintain stock diversity.

The stock monitoring programme for salmon in England and Wales comprises several distinct elements:

- 'Counted' and index rivers – Returning Stock Estimates (RSEs) for salmon (and in some cases sea trout) are produced from the operation of automated counters/traps on a number of rivers in England and Wales. Time-series of RSEs for salmon from these rivers are provided in the annual assessment report (see also Section 7.4 below). Among them, the rivers Dee, Tamar, Lune, and Tyne have been designated as index rivers – primarily because of the provision of biological information alongside RSEs. The former – including information on age, size, sex composition etc. – is collected from trapping or equivalent sampling programmes and provides insight into population structure and processes. Similar data are collected for the River Frome by the Game and Wildlife Conservation Trust (GWCT). Data derived from these investigations aim to provide a better understanding of stock and fishery dynamics and to facilitate and support processes, such as the setting of NLOs, Environmental Impact Assessments and the making of byelaws.
- Temporal monitoring of juvenile salmon (and trout) using electrofishing survey methods – this programme provides long-term time-series of data for the principal salmon rivers; similar long-term monitoring programmes also apply to other species (e.g., European eel). Sites in the temporal programme are electrofished annually or biennially for salmon. Information from temporal monitoring sites can be used to show trends over a larger area, such as in the Environment Agency's 'State of the Environment' report.
- Spatial monitoring of juvenile salmon (and trout) using electrofishing survey methods – this programme is used to identify changes in the distribution of fish, to detect differences between groups of sites (for example, between habitat types or sub-catchments), to determine the distribution of species, and to provide a basic level of

surveillance monitoring over the widest practical area. Sites in the spatial programme are sampled at six yearly intervals; the spatial monitoring programme also utilises data from temporal sites.

- WFD specific electrofishing surveys – these occur where coverage from other routine programmes does not provide all the data required for classification of sites. These sites are surveyed every six years.
- Local investigative electrofishing surveys – designed to meet specific local needs. Local teams determine the site density and survey frequency for such monitoring by referring to best practice guidelines.
- Provision of catch statistics – already described in previous sections, rod and net catch statistics inform adult stock assessment on all principal rivers - including performance against Conservation Limits.

7.1 *Surveys of salmon fry and parr*

The juvenile salmon monitoring programme aims to: (1) identify trends in the juvenile population, (2) provide an overview of the status of the population in a catchment, and (3) identify those parts of the system that are under performing. Juvenile salmon surveys typically take place between June and September using electrofishing equipment. Data derived from the surveys are routinely added to a data storage repository – e.g., the National Fish Population Database (NFPD) in England or KiEco in Wales.

In England, the spatial monitoring programme requires that up to 12 sites per sub-catchment are sampled semi-quantitatively (semi-quantitative surveys provide an approximation of juvenile abundance at each site) every 6 years, while the temporal programme comprises two sites per sub-catchment sampled semi-quantitatively every two years. This gives an approximate coverage of one spatial site per 5.3 km and one temporal site per 42.4 km of river length. In total, there are 1264 spatial sites and 252 temporal sites in England that are salmon-specific.

The design of spatial and temporal electrofishing survey programmes undertaken by NRW in Wales has a similar origin, purpose and coverage to those described for England.

Juvenile salmonid monitoring in South West Wales (photo courtesy of Paul Hyatt, Natural Resources Wales)

One output from the juvenile monitoring investigations is an assessment based on a classification scheme that produces a juvenile salmon density score for each site, using average values for the early 1990s as a baseline (Mainstone *et al.*, 1994). The scheme enables the proportion of sites falling into different salmon abundance classes (A to F) to be determined and provides a measure of the health of the juvenile salmon populations for each river. Sites are typically grouped into those that are at or above average (Classes A to C), below average (Class D) and well below average or fishless (Classes E or F). This aggregated assessment for the most recent six-year period is provided in the annual assessment report.

Juvenile survey data are generally based on relatively small samples of the total population and must always be interpreted with care. Fish populations also vary considerably with time and location, and good time-series are required to detect meaningful trends. The Environment Agency developed a "River Fish Habitat Inventory" (RFHI: Wyatt, 2005) that combines statistical modeling techniques with a Geographical Information System (GIS) for producing a quantitative inventory of the juvenile salmonid habitat and populations present within a catchment. The RFHI methodology has also influenced the development of a Fisheries Classification Scheme 2 (FCS2), which the Environment Agency has developed, in accordance with requirements set out in the WFD as retained under UK law, to help prioritise actions to improve salmon stocks (and other fish species). This classification is applied in both England and Wales.

7.2 *Smolt age and run timing*

Many salmon stocks in England and Wales appear to have experienced a decline in mean smolt age over the past 30 years or more, largely based on the ageing of scales taken from returning adult fish. These changes are consistent with declines in smolt age in many other stocks around the North Atlantic (ICES 2009, 2010; Russell *et al.*, 2012). The decline in mean smolt age may have been the consequence of an increase in growth rate, as faster growing parr migrate to sea earlier. This, in turn, may relate to an increase in temperatures associated with climate change, although other explanations are possible (e.g., density-dependent processes and/or increased freshwater production). However, while smolt age has apparently decreased over the longer term, more recent patterns in the mean smolt ages of salmon returning to the Rivers Tyne, Tamar, Dee, and Lune suggest these are now increasing, from around 2003/2004 onward.

In addition to changes in smolt age composition, it is apparent that smolt run timing is also changing, with a trend for fish to migrate to sea earlier over recent decades (Russell *et al.*, 2012; Otero *et al.*, 2014). The timing of smolt emigration has been linked to river temperature patterns but has raised concerns about the subsequent survival of smolts when they reach the sea due to a possible increased thermal discrepancy between river water and the sea at the time of migration. Such a mechanism has been proposed for the River Bush in Northern Ireland, where the marine survival patterns in 1SW salmon have been strongly influenced by the run timing of the preceding smolt year, such that later emigrating cohorts demonstrated increased survival (Kennedy and Crozier, 2010).

7.3 *Sea-age and run timing*

Run timing in adult Atlantic salmon is highly variable. Different sea-age classes of salmon have different patterns of run timing and these vary on a geographic scale, but also between stocks in a region and within stocks over time. A change in the pattern of run timing could therefore result from a change in the balance between the various sea-age classes, a change in run timing within sea-age classes or both. A more detailed review of run timing and sea age is provided by ICES (2009, 2010). In England and Wales, 1SW salmon mainly enter rivers from June to

August, though some rivers have strong autumn runs, 2SW fish enter throughout the year, but sometimes with spring, summer or later peaks, while 3SW fish generally enter rivers early in the year, with few entering after about May. Fish spawning for a second time tend to adopt similar run timing to that of their first migration.

Changes in the sea-age composition and run timing of adult salmon have been reported for numerous populations throughout their geographic range, including populations in England and Wales (e.g., Anon, 1994; Aprahamian *et al.*, 2008). Current information on the assessment of the sea-age composition in net and rod catches in England and Wales is provided in the latest assessment report.

An analysis of long-term data sets for 12 salmon stocks in the UK (Anon, 1994) examined changes in the monthly pattern of catches and in the contribution of different sea-age classes. The spring component of the catches increased both numerically and as a proportion of total catch from 1910 to about 1930, remained generally stable until the early 1950s, but then showed a steady decline to the low levels evident in recent years. It was concluded that the dominant process in these shifts in timing of runs and catches was a change in sea-age composition. While there was some evidence of a shift in run timing within sea-age classes, this was evidently not the main mechanism of change.

For monitored rivers in England and Wales with time-series dating back to the 1970s, there is an apparent decrease in the proportion of 2SW (and older) salmon returning in the early part of the time series, with 1SW salmon predominating. More recently, however, this trend has reversed and there has been a marked increase in the proportion of 2SW and older salmon in the past 11 years, and a corresponding decline in the proportion (and abundance) of 1SW fish. Similar changes in sea-age composition have been evident in other European stocks (ICES, 2021).

7.4 *Upstream counts of adult salmon*

Traps or electronic fish counters are operated on a number of river catchments to provide estimates of the upstream run of adult salmon and sea trout. Where it is possible to separate the species, the counts are adjusted to provide estimates of the numbers of returning salmon. Values for some counters have previously been adjusted retrospectively to accommodate new corrections or efficiency estimates. Time series of counts and returning stock estimates of returning adult salmon entering freshwater, including provisional estimates for the latest assessment year where available, are provided in the annual assessment report.

Forge Weir fish trap and counter on the River Lune (photo courtesy of the Environment Agency).

Work has continued to upgrade and improve the resilience of the salmon counter network. In 2021, a new counter was installed on the River Test and wider improvements have included upgrading computer systems, cameras, remote access capabilities, and operating procedures. Further work is planned over the next three years.

7.5 *Tagging investigations*

Tagging studies have often been employed to monitor stocks and to evaluate the outcome of different management initiatives. Various marks and tag types are used ranging from fin-clips, coded-wire microtags, and passive integrated transponder (PIT) tags, typically used in relatively large numbers on juveniles in population studies, to the use of radio and acoustic transmitters in behaviour studies.

Details of all the marked and tagged salmon released in England and Wales in the most recent calendar year are provided in the annual assessment report. These data are also collated and reported annually by ICES for all salmon-producing countries in the North Atlantic.

7.6 *Return rates to rivers*

There is extensive evidence from monitored rivers around the North Atlantic that the survival of salmon during the marine phase of their life-cycle has declined in recent decades, with a marked downturn around 1990. However, few data are available to evaluate long-term trends in the marine return rates of salmon stocks in England and Wales. Percentage return rates over an extended period are reported in the annual assessment report for the River Corrib (Republic of Ireland), River Bush (Northern Ireland), and River North Esk (Scotland). These data indicate that marine survival can be quite variable between stocks and between years but has generally decreased since 1987. Shorter time-series for the Rivers Dee (Wales), Tamar and Frome are also available in the annual assessment report and indicate similar low levels of marine survival in recent years.

7.7 *Genetic sampling*

There has been increasing focus in recent years on the use of genetic techniques to aid in the management of salmon stocks and fisheries. Work to establish the genetic identity of salmon stocks in the principal rivers in England and Wales has continued, with the initial aim of providing a basis for identifying salmon to specific rivers or regions of origin. This has enabled patterns of exploitation in mixed stock fisheries to be assessed and has helped to inform management decisions. In time, such investigations may be able to answer a range of additional questions relating to the size and structure of breeding populations and the contribution of stocked fish. The work has complemented wider investigations to genetically characterise salmon stocks around the North East Atlantic, such as the SALSEA MERGE and Atlantic Salmon Arc Project (ASAP) programmes, and has used the same techniques (microsatellites and Single Nucleotide Polymorphic (SNP) markers) as in these other studies. Further details on the SALSEA MERGE investigations can be found at: http://salmonatsea.com/wp-content/uploads/2020/10/SALSEA_An-International-Cooperative-Research-Programme-on-Salmon-at-Sea.pdf.

One example of the use of genetic sampling in informing management is provided by work carried out on fish caught in the north east coast fishery (Gilbey *et al.,* 2016 a & b). An analysis of salmon caught in 2011 was used to help inform deliberations about the NLO renewal for the fishery, as well as in assessing trends in national catches (Section 4.10). The proportions of fish caught in the fishery that originate from Scotland and England were assessed through a genetic stock identification programme. The genetic baseline used consisted of genetic samples from 3,787 fish from 147 sites covering 27 rivers in Scotland and North East England, screened by a panel of 349 SNP markers. A total of 1,000 fishery samples were screened at the SNP markers and the proportions of fish in the different fisheries estimated using genetic Mixed Stock Analysis (MSA) analytical techniques. Overall, 47% of the fish sampled throughout the fishery were determined to be of Scottish origin (53% English), but with the proportion of Scottish fish being higher for drift nets in the Northumbria area (65%) than in the Northumbria coastal nets (37%) or the nets fished in Yorkshire (42%). It was noted, however, that it was not possible to be sure how levels might vary between years. More recently, similar genetic analyses have also been used to inform management deliberations in relation to the net and fixed engine fishery in the Severn Estuary.

A study has also been completed on the population structure of salmon in the Rivers Dove and Churnet (Trent catchment) using microsatellite analysis. It suggested that the extensive introductions from stocked fish whose parents originated from elsewhere, had contributed to a lack of genetic structuring, probably exacerbated by a limited starting gene pool in the native salmon of these rivers (Environment Agency, 2014).

A further investigation has explored the genetic origin of salmon recolonising the River Mersey (Ikediashi *et al*., 2012). Following extensive restoration work on the river from the 1970s, salmon were first observed back in the Mersey in 1999. Subsequently, a fish trap was installed, and adults sampled. In this study, 138 adults and one juvenile salmon sampled over the period 2001–2011 were genotyped using 14 microsatellites. Assignment analysis was carried out using a pan-European microsatellite baseline to identify their most probable region of origin. This indicated that fish entering the Mersey originated from multiple sources, with the greatest proportion (45–60%, dependent on methodology) assigned to rivers in the geographical region just north of the Mersey, which includes North West England and the Solway Firth, suggesting fish were mainly straying in a southerly direction. Fish from other regions were also recorded. However, the number of fish originating from nearby rivers to the west of the Mersey was lower than expected.

8. ASSESSMENT OF STOCK STATUS

The status of individual river stocks in England and Wales is assessed annually against Conservation Limits (CLs) and Management Targets (MTs) in line with the requirements of ICES and NASCO.

A separate, national assessment of the status of the salmon resource in England and Wales is also undertaken annually, using the Pre-fishery Abundance (PFA) and National Conservation Limit Models (Potter *et al*., 2004), and reported to ICES to assist with the development of management advice for the distant water fisheries.

8.1 *Assessment procedure for river stocks*

In England and Wales, CLs have been developed indicating the minimum spawning stock levels below which stocks should not be allowed to fall. Details of the process for setting CLs and assessing compliance with these biological reference points are given in Annex 7. The CL for each river is set at a stock size (defined in terms of eggs deposited) below which further reductions in spawner numbers are likely to result in significant reductions in the number of juvenile fish produced in future generations. In reviewing management options and regulations, the Environment Agency and NRW also use an over-arching Management Objective (MO) that a river's stock should be meeting or exceeding its CL in at least four years out of five (i.e., at least 80% of the time). A MT is set for each river, representing a spawning stock level for managers to aim at in order to be assured of meeting this objective. Details of all the CLs and MTs for the 64 principal salmon rivers in England and Wales are provided in the annual assessment report.

The CLs for individual rivers typically remain fixed from year to year. However, these can be revised in light of new data or where changes occur to the catchment. For example, the CL for the River Wye in Wales was revised a few years ago as a result of efforts to open up previously inaccessible parts of the catchment to adult salmon. A new fish pass was installed on the River Monnow, a Wye tributary, in autumn 2008 and a further impassable barrier was removed on the Monnow in 2011. Together, these improvements have opened almost 175 km of newly accessible habitat. A counter located in the fish pass has been used to monitor the natural recovery (no supplementary stocking has taken place or is planned) in the tributary. The accessible wetted area and CL for the Wye have both been revised; the CL was increased from 35.7 to 38.6 million eggs.

Annual compliance with the CL for each principal salmon river is assessed using egg deposition estimates. These are derived from returning stock estimates where such data are available, but for rivers without traps or counters, the usual procedure for estimating egg deposition involves derivation of run size from rod catch using estimates of exploitation (and an appropriate adjustment for under-reporting). Currently, these procedures do not take into account annual changes in fishing effort for most rivers. In years when effort was low – such as the 'low-flow' year of 2003 and the 'foot-and-mouth' disease year of 2001 – this approach has probably resulted in rod exploitation being over-estimated on a number of rivers and hence escapement and egg deposition being under-estimated. In wetter years, when conditions are more favourable for angling, and fishing effort increases, the opposite is likely to be true. Ideally, an improved procedure is needed to take account of annual changes in fishing effort, as well as partitioning effort between salmon and sea trout (no distinction is currently made between these species when reporting fishing effort - but see analysis in Section 3.4). Efforts to address this specific shortcoming and to explore other possible changes in the current assessment procedure are underway, as noted in Section 2.1. Many rivers, and particularly some of the smaller catchments on the west coast of Wales, support relatively small salmon stocks and are principally regarded as sea trout rivers. Current procedures may also fail to take adequate account of this.

8.2 *Compliance with Conservation Limits (CLs)*

NASCO requires a time series of CL compliance for all rivers. Egg deposition estimates are calculated annually for each of the 64 principal salmon rivers in England and Wales and a 10-year time series for each river, expressed as the percentage of the CL attained and including provisional data for the latest assessment year, is provided in the annual assessment report. A summary of these data, indicating the number of rivers with egg deposition estimates above their CL, between 50% and 100% of their CL, and below 50% of their CL for all years since 1993 is also presented. This table is adjusted annually to take account of the routine correction of the previous year's estimates, but also where some time series of egg deposition estimates have been revised in light of new information.

8.3 *Compliance with the Management Objective (MO)*

The MO for salmon stocks in England and Wales is that they should meet or exceed their CLs in at least four years out of five (i.e., at least 80% of the time). Compliance with this objective is calculated annually for all 64 principal river stocks in England and Wales for the latest assessment year and projected for five years ahead. These assessments for each salmon river are then incorporated into a national Decision Structure for guiding decisions on the need for fishery regulations. The compliance details for the latest assessment year and a time series of compliance assessments for the rivers in England and Wales are provided in the annual assessment report. Full details of the compliance assessment process and Decision Structure are provided in Annex 7.

8.4 *Assessment of pre-fishery abundance (PFA) for England and Wales for ICES*

Each year, the ICES WGNAS makes an assessment of the status of the salmon stocks in the North East Atlantic (NEAC) area as a basis for advising NASCO and providing catch advice for the distant water fisheries. A key part of this assessment is the estimation of the PFA of all NEAC stocks (full details of the assessment process are provided in Annex 5) using a run-reconstruction model. The PFA of salmon from countries in the NEAC area is defined as the number of fish alive in the sea on January 1 in their first sea-winter. This is split between maturing (potential 1SW) and non-maturing (potential MSW) fish. ICES uses estimates of PFA for the period 1971 to the present to investigate the effects of fisheries and other natural and anthropogenic (man-made) factors on stocks. ICES also uses these estimates to develop a forecast of PFA for coming seasons in order to advise on management actions for the distant water fisheries.

Whilst the model is acknowledged as containing a number of uncertainties, it endeavours to provide the best interpretation of what the available catch and effort data may tell us about changes in the status of the national stock of salmon over the past four to five decades. It is important to note that the overall national trends estimated by the model will mask conflicting changes in individual river stocks. Many river stocks in England and Wales have declined substantially in the past 30 to 40 years, but these will tend to be obscured by the very substantial improvements and recovery in others, such as the Tyne and Wear. The model sums all of these trends. Furthermore, the model is likely to provide a more reliable picture of the medium-term trends than of more short-term year-to-year fluctuations.

The latest WGNAS estimates of the PFA of salmon from England and Wales are provided in the annual assessment report. This has declined by over 46% from the early 1970s to the present time. Over much of the period, the decrease has tended to be somewhat greater for the non-maturing (i.e., potential MSW) component of the PFA than the maturing 1SW (i.e., potential grilse) component. However, there has been a marked reduction in the PFA of 1SW salmon over the last ten years, and the decline in PFA between the start and the end of the time series is now greater for 1SW fish (64%) than for MSW salmon (39%). The results also suggest that there was a marked decline in PFA around 1990, which is consistent with the general perception of a decrease in the marine survival for many stocks around the North Atlantic at about this time. It should be noted that the model cannot provide an estimate of PFA of potential MSW fish for the most recent year, because this requires information on the returns of these fish to homewaters, which will not occur until the following year.

The latest estimates of the numbers of salmon returning to rivers in England and Wales (prior to exploitation in homewater fisheries) and spawning are also available in the annual assessment report. The number of returning fish shows a similar downward trend to the PFA, although the decrease is less marked due to the reduction in net fishing exploitation in distant water fisheries. Thus, numbers of returning fish are estimated to have declined by 39% between the early 1970s and the present time. As with the PFA, the decline in returning MSW fish has tended to be greater than that of the 1SW (grilse) returns over much of the time period. However, owing to the increase in the proportion of MSW salmon in recent years, the percentage reduction in returning fish between the start and the end of the times series is now substantially greater for 1SW fish. The difference between the estimated numbers of returning fish and those surviving to spawn has reduced progressively over the time series and the total spawning escapement has remained reasonably consistent over the time period. This reflects the marked reduction in homewater net and rod fisheries, and the increasing use of C&R. The recent upturn in MSW returns means that MSW spawner numbers are now similar to those at the start of the time period. This will be expected to have a disproportionate effect on egg deposition, given the substantially higher fecundity of these larger fish.

STOCK CONSERVATION AND MANAGEMENT CONSIDERATIONS

Actions being delivered to protect and enhance salmon stocks in England and Wales are described in Annual Progress Reports (APR) produced for NASCO. These reports highlight actions on the management of salmon fisheries, the protection and restoration of habitats and actions relating to aquaculture, introductions, transfers, and transgenics (www.nasco.int).

9. OTHER FACTORS AFFECTING STOCKS, FISHERIES, AND CATCHES

9.1 *Condition of returning adult fish*

In recent years, concerns have been expressed not only about higher levels of salmon mortality at sea, but also about the size and condition of returning adult fish. For example, Todd *et al*. (2008) reported unusually small returning 1SW fish in some Scottish rivers and linked this to indirect effects of warming in areas where salmon are located at sea. The results were considered consistent with other analyses in providing evidence of major, recent climate-driven changes in North East Atlantic pelagic ecosystems, and the likely importance of bottom-up control mechanisms resulting in changes in the quality and/or quantity of available prey. While this study drew no connection with stock abundances, it also showed that under-weight individuals had disproportionately low reserves of stored lipids, which are crucial for successful spawning.

Information on the condition of returning adult fish in England and Wales is collected on a small number of monitored rivers. Data for recent years indicate a strong correlation in the condition of 1SW and 2SW salmon sampled in head-of-tide traps on the Rivers Tamar and Dee – suggesting common marine factors are influencing the growth of fish returning to these two west coast rivers. For the River Dee, where a longer time series (starting in 1991) is available, the mean condition of both sea age groups declined sharply in the late 1990s but has shown signs of stabilisation (1SW salmon) or recovery (2SW salmon) in recent years.

While variations in the size (weight) of returning salmon are taken account of in the procedures for estimating egg deposition and compliance with CLs on all rivers, decline in condition – which may have implications for survival of fish as well as fecundity – remains a concern.

9.2 *The effect of river flows on angler effort and catches*

For rod fisheries, river flow is a key factor affecting both availability of fish and angler effort. The ability of salmon to enter river systems from the sea and successfully migrate upstream to spawning areas is strongly influenced by the prevailing flow conditions. Extended dry periods can delay or prevent upstream movements resulting in smaller numbers of fish available to anglers. When such conditions occur in the summer, water temperatures can also become elevated with potential adverse effects for fish. In wetter periods, migration is likely to be facilitated, making fish more readily available, although angling activity is restricted during periods of high flow, with fishing conditions commonly considered to be optimum as a river falls away and clears after a spate. The annual assessment report comments on conditions that may have affected catches in that particular year.

The timing and pattern of rainfall events over a year can thus have a marked influence on the migratory behaviour and run timing of returning fish and on their availability to anglers within the fishing season. This, in turn, has a direct impact on angler effort, with this typically being focused on periods considered to provide the most suitable fishing conditions. Given that many climate change models for the UK project drier summers and wetter winters in the future, river flow conditions may play an increasingly important part in influencing salmon runs and catches.

A summary of the mean monthly flows for 12 rivers across England and Wales for the most recent year, assessed against long-term trends, is provided in the latest annual assessment report, together with a similar assessment of monthly rod catches for the majority of these rivers also expressed in relation to long-term trends.

9.3 *Extreme weather events*

Climate change is projected to affect all components of the global freshwater system, with temperature increases over the land expected to exceed those over the surface of the oceans (IPCC, 2007). Among the changes, rainfall levels are expected to increase with 'wet' areas typically becoming even wetter, but with increased variability such that the risk of both floods and droughts will increase. Increasing trends in river water temperatures are also forecast.

Concerns have been raised about the effects of extreme flows on salmon stocks in England and Wales. Extreme floods may affect both juveniles (e.g., through wash-out of redds and/or fry/parr) and returning adult fish (e.g., by altering their ability to migrate upstream and spawn successfully) (Gillson *et al*., 2020). Low flows can also affect adult migrations and spawning, and juveniles, for example, through loss of habitat and increased vulnerability to predation (Riley *et al*., 2009).

Elevated temperatures may also impact on salmon stocks in a variety of ways. For example, elevated summer temperatures may alter the migratory behaviour of fish or increase the risk of mortality following C&R angling (e.g., Wilkie *et al.,* 1996; Havn *et al*., 2015). Impacts on adult reproduction and subsequent juvenile survival can also occur at elevated winter water temperatures above 11-12°C (Taranger and Hansen, 1993; Solomon and Lightfoot, 2008; Pankhurst and King, 2010; Fenkes et al., 2016).

Extreme conditions are believed to have affected salmon recruitment across England and Wales in 2016, with unusually low levels of juvenile fish, particularly 0+ fry, observed in surveys (see Section 10.1 for further details).

9.4 *Water and habitat quality*

A wide range of natural and man-made factors have the potential to influence Atlantic salmon during the freshwater stages of their life-cycle, and these need to be investigated and monitored to help direct and prioritise management actions. Earlier reviews have identified that key pressures on salmon stocks in England and Wales include deficiencies in land management, degradation of in-river salmon habitat, and effects of diffuse pollution and siltation. These reviews further highlighted that concerted and integrated action is required at a broad scale to address these issues.

Although salmon have been returning strongly to some historically polluted rivers (e.g., the Tyne and Wear), there is concern about chronic environmental degradation in others, mainly in rural areas, caused by changing land-use practices, especially agriculture and forestry. Issues of particular concern are siltation resulting from soil erosion (Collins *et al*., 2013), diffuse pollution such as pesticides from sheep-dip chemicals (Moore and Waring, 1995, 2000), herbicides (Moore and Waring, 1998; Moore *et al.,* 2007), run-off from industrial processes (Lower and Moore, 2007) and effluents from fish farms (Waring *et al.*, 2012), and acidification and water abstraction. The relative importance of these effects varies around the country, but clusters of high pesticide levels have been found in Welsh upland streams, and acidification still occurs in the uplands of Wales and North West England.

Salmon runs in the chalk-streams of Southern and South West England have declined since the 1980s and, while reduced marine survival will have undoubtedly been an influential factor, increasing concerns have been expressed regarding the impact of climate change (Solomon and Lightfoot, 2009) and low flows in freshwater (Riley *et al.*, 2009). It is also increasingly evident that water quality issues in freshwater may have a significant impact on the survival of salmon when they enter the marine environment (Waring and Moore, 2004; McCormick *et al.*, 2009).

Factors affecting individual river stocks are identified and prioritised in plans for catchments supporting the 11 River Basin Management Plans for England and Wales. Priority for action is given to improving those water bodies that are not achieving ‘Good Ecological Status’ and/or fisheries that are below CLs and to those actions likely to generate the most gain (see Sections 11.1-11.2 for more information).

The Government’s 2017 Water Abstraction Plan sets out reforms to water abstraction management over the coming years to help protect the environment and improve access to water. The abstraction plan contributes to the delivery of the Government’s 25 Year Environment Plan long-term goal of ‘clean and plentiful water’. The abstraction plan consists of three main elements: (1) addressing unsustainable abstraction, (2) building a stronger catchment focus, and (3) modernising the abstraction service to support reform. The regulation of abstraction and impounding licensing is moving into the Environmental Permitting (England and Wales) Regulations 2016 in 2023. The move into the Environmental Permitting Regulations is part of the drive to modernise abstraction and impounding management and to streamline the overall environmental regulatory framework. The move allows for further rationalisation and unification of regulations to enable most environmental permissions to fit under one legal framework. The work to bring previously exempt abstractors (New Authorisations) into regulation including trickle irrigation, de-watering in quarries, Canal and Rivers Trust water transfers, and Inland Drainage Board abstractions will be complete by December 2022.

9.5 *Coronavirus (COVID-19) pandemic*

In 2020, salmon angling opportunities were likely to have been affected by the outbreak of COVID-19 and the resulting access and movement restrictions imposed to prevent its spread throughout England and Wales. A lockdown period was in place between the 23 March and the 12 May. Once lockdown restrictions on outdoor activities eased on the 13 May, angling was permitted within a 5-mile distance from one’s home. Restrictions were further lifted on the 23 June in England and the 6 July in Wales to allow unimpeded travel. Wales entered a further ‘firebreak’ lockdown between the 23 October and the 9 November, but this would have had a minimal effect on salmon angling because on most rivers the season ended on the 17 October, with only a few rivers or parts of rivers fishing until the 31 October.

An investigation into angling returns for 2020 indicated that COVID-19 restrictions were likely to have constrained fishing effort and hence rod catch in the early part of the season, but similar effects were not evident thereafter (fishing effort comparisons were restricted by established reporting formats that collect data ‘before 16 June’ as a proxy for the early season and ‘16

June onward' for the remainder of the season). Since early season effort and catch comprise a relatively small proportion of the total on most rivers, whole season effects were not pronounced (including exploitation rates estimated on the counted rivers) compared to the preceding 6 years (i.e., 2014–2019 – the start of this period being the first year in which fishing effort was recorded before the 16 June). It was therefore deemed necessary, as a special case, to adjust declared rod catches during the lockdown period between the 23 March and the 12 May in 2020 to account for the possible influence of the COVID-19 pandemic on angling. Further details about the procedure used to adjust the declared rod catches in 2020 are provided in Annex 8.

As no lockdown periods occurred during the 2021 fishing seasons, no adjustment was applied to declared rod catches in 2021 for COVID-19 effects.

10. EXISTING AND EMERGING THREATS TO SALMON POPULATIONS

10.1 *Climate change*

Changes in climate are global, and the increased natural mortality of salmon at sea in recent years may be linked to climate change (Chaput, 2012; ICES, 2017b). There is also growing interest in the role that global climate change might play in modifying the freshwater environment (Russell *et al.*, 2012; Otero *et al.,* 2014). The higher temperatures predicted as a result of climate change are expected to affect all components of the global freshwater system (IPCC, 2007). Scenarios for future climate change (Hulme *et al.*, 2002; Jenkins *et al.*, 2009), suggest that warming trends are likely to be far more severe in the coming decades than those experienced in the past – even under the best case 'low emissions' scenario. Changes in the British climate are projected to become more pronounced (Hulme et al., 2002) and the most likely scenarios are for higher temperatures, wetter winters, drier summers, and more extreme flood and drought events.

- Jonsson and Jonsson (2009) reviewed the potential effects of climate change on the different life-stages of Atlantic salmon, with particular reference to water temperature and flow. These effects include: increased growth rates of parr and reduced smolt age; earlier in-season smolt migrations with possible increased early post-smolt mortality due to greater increases in river temperatures compared with marine waters; earlier spawning migrations under suitable flow conditions, but delays and increased levels of straying under extreme flow conditions; and decreased post-smolt growth, survival, age at sexual maturity and recruitment, particularly in the southern parts of the distribution range. They also suggest a northward shift in the thermal niche of the species, with expansion in the north but decreased production and population extinction in the southern part of the distribution.
- Events in the winter of 2015/16 provide an example of the potential effects that climatic changes might have on salmon populations. Densities of juvenile salmon, particularly 0+ fry, were found to be very low in many rivers in England and Wales in the summer 2016 surveys and well below long-term averages. While there has been a modest decline in juvenile salmon densities since 2009, the scale of the downturn in 2016 was particularly notable and affected rivers throughout the country. The widespread nature of these observations suggested that factors operating at a broad scale were responsible for the declines in juvenile densities, albeit with some regional variation.

- An investigation of seven catchments in Wales following the events of winter 2015/16 (Bewes, Davey and Gregory, 2019), concluded that 2016 recorded the lowest salmon fry density of any year in the time-series (1992–2018). Densities in 2017 and 2018 were also low by historical standards, so 2016 was not an isolated poor year. This pattern was also true for salmon parr sampled in 2017 (i.e., fish largely of the same cohort), which also recorded the lowest density of the time-series. Furthermore, there were also significantly lower densities of trout fry in 2016 and trout parr in 2017 than most years.
- Bewes, Davey and Gregory (2019) identified a range of environmental variables that were found to have statistically significant associations with salmon and trout fry abundance – i.e., they appeared to affect survival between spawning and summer juvenile abundance as observed by electrofishing. However, the ecological mechanisms by which temperature and flow influence juvenile salmonid abundance are complex and spatially variable and, unsurprisingly, the models developed in the study were unable to identify any one variable critical to juvenile salmonid survival.
- Gregory *et al*. (2020) found that the extreme winter weather conditions in 2016 reduced the recruitment of juvenile salmon due to unusually warm temperatures during the spawning period and higher flood frequencies during pre-emergence and emergence. Warming patterns over recent decades suggest that such conditions may become a more frequent occurrence in the future – leaving (in some cases) already weakened stocks vulnerable to adverse episodic events and longer-term environmental change.
- The UK Met Office described the winter of 2015/16 as ‘remarkable’, with severe flooding in December from record rainfall totals, accompanied by exceptional warmth from a persistent flow of tropical maritime air. The winter was the second wettest on record in the UK (in a time series back to 1910) and Storm Desmond on 5 December set a new 24-hour rainfall record for the UK. This resulted in severe and extensive flooding across many northern and western parts of the country and affected many rivers, with rivers like the River Tyne registering the highest winter flows on record. These extreme high flow events coincided with the salmon spawning period and may have caused mortality due to the wash-out of eggs and alevins from redds and/or sediment deposition in the redds.
- The winter of 2015/16 was also the warmest on record and temperatures in December were reported to be the warmest for both the UK and the Central England Temperature (CET) series, which for the latter dates back to 1659. It is speculated that these elevated temperatures may have influenced early fry survival or reproductive success. Impacts on adult reproduction and subsequent juvenile survival can occur at winter water temperatures above 11–12°C (Taranger and Hansen, 1993; Solomon and Lightfoot, 2008; Pankhurst and King, 2010; Fenkes *et al*., 2016) and temperatures at or above this level were recorded in some rivers. The unusually warm conditions in the winter of 2015/16 may also therefore have been an important factor in the observed declines in juvenile salmon recruitment.
- In some rivers, the observed low fry numbers may also have been influenced by lower numbers of returning adults, particularly in rivers where 1SW fish normally comprise the main component of the run, since 1SW salmon numbers have declined in recent years.

- In summary, low densities of juvenile salmon in 2016 probably resulted from a combination of factors including unusually high winter flows and temperatures, with relatively low numbers of spawners in some catchments. It is probable that the relative importance of different factors affected different catchments and sub-catchments to varying degrees.

10.2 *Red Vent Syndrome*

The occurrence of salmon returning to rivers in England and Wales with swollen and/or bleeding vents has been noted since 2004. The condition, referred to as Red Vent Syndrome (RVS), has continued to be observed since this time.

Monitoring programmes on salmon 'index' rivers provide the most consistent measure of the incidence of RVS. Since 2007, this consistency has been improved through the introduction of a system whereby symptoms have been classified according to their apparent severity (with samplers referring to a set of standard photographs and descriptions to assist their judgement). Time series of RVS incidence in returning fish are available in the annual assessment report for the Rivers Tyne, Tamar, Dee, Lune and Caldew (a tributary of the River Eden), extending back to 2004 in the case of the Dee.

The trapping records indicate that RVS has generally been less prevalent in early and late running fish than mid-season fish. Early running fish comprise mainly MSW salmon whereas late running fish are predominantly 1SW fish. Monitoring on the Caldew has previously indicated a higher incidence of RVS in female than male fish; and provisional results from the Dee suggest no significant differences in the condition factors of affected and unaffected fish.

Preliminary investigations on both the Tyne and the Dee have indicated that salmon with affected vents often show signs of healing during the period of in-river residence. It appears from these initial findings that the time when a fish is examined for RVS relative to its period of in-river residence is likely to influence perceptions about the prevalence of the condition. Thus, the relatively low incidence of RVS in fish sampled on the Tyne and the Caldew may reflect the longer in-river residence of fish sampled at these sites compared to the other (lower river) sampling locations. This is further supported by evidence from the Tyne in 2011 when a sample of fish taken in the estuary and lower river showed a far higher incidence of RVS (~12%) compared to upper river broodstock samples (~4%), the latter being the usual sampling location.

The cause of RVS has been linked to the presence of a nematode worm, *Anisakis simplex* (Beck *et al.*, 2008). This is a common parasite of marine fish and is also found in migratory species. However, the larval nematodes are usually found spirally coiled on the mesenteries, internal organs, and less frequently in the somatic muscle of fish, and it is unusual for them to be located in the muscle and connective tissue surrounding the vent. The reason for the occurrence of the nematodes in the vents of migrating wild salmon, and whether this might be linked to possible environmental factors, is unclear. The potential significance of the swollen vents, or whether the severity of the vent damage could impair spawning, is also unclear. However, the healing of vents described above, and reports of the successful stripping of affected hatchery broodstock and the normal development of their offspring, suggests the effects of the condition - at least on spawning success - may be small.

A press release was issued in 2007 to advise anglers in England and Wales about RVS and to provide reassurance that there are no risks to human health if fish are processed and cooked properly. In 2021, the incidence of RVS on the Rivers Dee and Tamar was higher and lower than the previous year, respectively.

10.3 *Other disease issues*

The Environment Agency and NRW continue to monitor disease problems on all the major salmon rivers across England and Wales. Over the last decade, there have been increased reports of fungal (*Saprolegnia*) infections in salmon and sea trout in some rivers, with resulting mortalities above those considered usual from this disease.

In response to this, the Environment Agency established a collaborative project with Cardiff University to improve our understanding of *Saprolegnia* in the UK and help identify the drivers for infections that could explain recent observations. This work has included genetic comparisons of samples obtained over the last five years and collating environmental data to help identify the diversity and behaviour of this fungal pathogen in rivers and to develop improved methods to monitor and use novel approaches for disease surveillance.

Nationally, 2021 was a relatively quiet year for *Saprolegnia*, with numbers of reported infections comparable to those in 2019 and 2020. A small number of rivers reported short-term events involving elevated infection and associated mortalities, but these were short-lived and considered to be within natural levels for this disease and not a cause of serious concern. Reports of Saprolegnia infections have substantially reduced over the past five years.

Reports have been made of salmon returning to rivers in Scandinavia, the Russian Federation, the Republic of Ireland, and parts of the UK displaying signs of ventral haemorrhaging since 2019. This condition has been termed 'Red Skin Disease' (RSD) and efforts are ongoing to monitor its occurrence, confirm the exact characteristics of the skin lesions, and identify the cause. Since the symptoms were first reported internationally, the Environment Agency and NRW have monitored the situation in all the major salmon rivers across England and Wales. Guidance on the symptoms and current understanding of RSD has been issued to raise awareness of the condition, allay concerns, and encourage reporting among anglers and stakeholders. Significant cases of ventral lesions consistent with RSD were first observed in England and Wales in the summer of 2021. Monitoring was undertaken on salmon 'index' rivers to establish the prevalence and severity of cases, with the samples obtained for diagnostic examination providing valuable insights into disease characteristics. Despite these efforts, the cause of RSD remains unclear and further detailed diagnostic tests are ongoing. A severity field guide has been developed in collaboration with Marine Scotland Science and Inland Fisheries Ireland to better characterise RSD and standardise reporting of this condition across the UK and the Republic of Ireland by defining the symptoms and distinguishing it from other, common skin conditions experienced by salmon.

10.4 *Renewable energy schemes (in-river)*

Many of the hydropower (HEP) installations in England and Wales have focused on run of river schemes that are typically associated with in-river structures such as weirs or old mills and rely on making use of differences in the levels of water (head). Such structures may already be impacting upon the ability of salmon to migrate upstream and downstream. Where such structures are no longer required efforts are often made to remove them to improve connectivity within catchments, but where the structures must stay (e.g., where hydropower schemes have been installed), fish passes will need to be employed to allow fish passage to take place. The position of fish passes in relation to the location of a hydropower scheme is critically important to the effectiveness of the pass. Best practise is to co-locate the fish pass with the HEP discharge to avoid having opposing attractant flows which can misdirect fish away from the fish pass and cause delays to migration.

Where run of river schemes make use of existing mill leats, the distribution of flow between the leat, river, by-wash and fish pass is also important. Poorly designed schemes could result in either the inability of fish to migrate or delays to migration. These delays could also lead to enhanced predation or a reduced distribution of adult fish during the spawning period. Depleted reaches can also exacerbate underlying water quality issues because water temperatures in the shallower waters of depleted reaches (when exposed to direct sunlight) will rise more quicker compared to those of the deeper waters in the main stream channel. Elevated water temperatures can trigger algal blooms in eutrophic waters which can lead to oxygen depletion and other associated water quality problems that can be lethal to fish. Furthermore, salmon are very sensitive to ammonium levels in water, and the toxicity of ammonium to fish increases with temperature, so any upstream ammonium discharges (e.g., from Waste Water Treatment Works) can become more of an issue for fish in depleted reaches compared to fish in the main channel.

Most hydropower turbines need to incorporate screens at both their intake and outfall to safeguard fish moving both downstream and upstream. The aperture of these screens depends on the size of fish requiring protection and the potential impact on fish if they were to pass through the turbine. A best practice guide on "Screening for Intake and Outfalls" is available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291570/scho0205bioe-e-e.pdf.

The Environment Agency reduces the potential for impact from these various sources through regulation and by encouraging developers in England to follow its 'Guidance for run-of-river hydropower development', which is available on request from the Environment Agency. This guidance describes the measures that need to be adopted to ensure appropriate environmental protection. Similar provisions apply in Wales and guidance is available at: https://naturalresources.wales/permits-and-permissions/water-abstraction-and-impoundment/hydropower/applying-for-licences-for-hydropower-schemes/?lang=en.

10.5 *Renewable energy schemes (offshore)*

In looking to meet the targets for renewable energy production, efforts are increasing to promote and develop offshore renewables. Such developments also have the potential to affect fish stocks through factors such as increased underwater noise (e.g., from pile driving), sediment plumes, and electro-magnetic fields. The likelihood and degree of any impacts on Atlantic salmon will depend on the location and extent of offshore developments in relation to the migratory routes and behaviour of the fish, the technologies used, and the status of the particular stocks in an area. Information on the migration and behaviour of salmon at sea is limited. Nonetheless, it is important to ensure that potential environmental impacts are assessed and, if necessary, minimised through appropriate mitigation to ensure that new marine energy industries develop on a sustainable basis.

As part of the increasing focus on developing new sources of renewable energy, there has been growing interest in recent years in the potential development of tidal lagoons and barrages for power generation. Such structures would, in particular, be located in regions of large tidal range, such as the Severn Estuary and Solway Firth, and would aim to generate power on both the incoming tide as water entered the lagoon and through the release of impounded water at low tide periods.

Tidal lagoons may have a range of environmental effects. For fish, they have the potential to impact diadromous species (e.g., salmon, shad, sea trout and eels) as they seek to migrate between marine and freshwater habitats. Intertidal habitats are also very important for many commercially important marine fish species such as cod, mullet, bass and plaice that use these areas for spawning and juvenile development.

Substantial improvements have been made in turbine designs in recent years. However, whenever water passes through a turbine there is still a risk of damage to, and mortality of, any entrained fish. Impacts on different species are likely to vary as a consequence of factors such as the volume of water impounded, current speeds, turbine approach velocities, and the proximity of rivers, as well as features of the fish themselves, such as their swimming speed, morphology, behaviour, population size and life-cycle. Impacts may be more acute for species that are resident in a particular area given the large volumes of water involved and the potential risk of repeat turbine passage. However, impacts may also be acute for diadromous species where barrages restrict migration and prevent or delay fish from accessing the freshwater habitats necessary for them to complete their life-cycle. At present, the extent of possible impact is unclear; risks are not yet quantified and the ecology, distribution, population size and population dynamics of many fish species are relatively poorly understood.

Aside from turbine-related mortality and possible effects on migration, tidal lagoons may impact on fish stocks in other ways. For example, through temperature changes associated with increased solar radiation of the impounded water, noise, changes in sediment loads and dynamics during construction and operation, increased risk of predation, and the establishment of novel non-native species. Altered flows may also result in migratory fish and marine mammals being stranded within lagoons.

Tidal lagoons and barrages may also create new fish habitats (e.g., in and around the retaining walls) and provide benefits for some species and populations. Turbidity changes and increased daylight penetration could increase productivity of waters within lagoons. In addition, lagoons and barrages may provide new opportunities for angling, recreation and in creating commercial mariculture opportunities such as mussel farming.

11. SALMON CONSERVATION ACTIVITIES AND OPPORTUNITIES FOR SALMON MANAGEMENT

11.1 *Environmental improvements delivered through River Basin Management Plans*

Improving the environment is key to improving salmon stocks and hence catches. In parallel with exploitation control measures, concerted and integrated action is being taken to address the environmental problems limiting salmon production in many catchments in England and Wales.

The European Union's WFD as retained under UK law has established an integrated approach to the protection, improvement and sustainable use of rivers, lakes, estuaries, coastal waters, and ground-waters. Salmon management in England and Wales is becoming increasingly linked with this Directive and its six-year planning cycle. The Directive requires the drawing up of River Basin Management Plans (RBMP) and Programmes of Measures (PoM) with the aim of achieving Good Ecological Status or, for artificial or more modified waters, Good Ecological Potential.

England and Wales have been divided into 11 River Basin Districts (RBDs), including the cross-border Solway and Tweed RBD which is partly in Scotland. The RBDs have been 'characterised' by assessing the pressures and impacts on the water environment, such as overuse or pollution. A RBMP for each District was published in December 2009 setting out how these impacts will be reduced through its PoMs. More information about the Directive, its RBMPs, the catchment scale approach that is being taken and the programme of associated investigations can be found at: www.gov.uk/government/collections/river-basin-management-plans-2015.

As part of this process, assessment procedures have been developed to identify those rivers where fish populations are at less than good status and the reasons why. The main pressures affecting salmon have been identified as issues around channel morphology (including barriers to fish migration), sediment, and hydrology (including abstraction and flow modification). Monitoring programmes chart progress towards achievement of Good Ecological Status or Potential. The second-round plans were published in 2015.

In the latter stages of implementing the first-round plans, use of the Government's Catchment Restoration Fund through partnerships involving the Environment Agency, Natural England (NE), NRW, Wildlife Trusts, Rivers Trusts, and others delivered many river improvements that should benefit salmon.

Examples of environmental improvements are also reported in the annual progress report to NASCO detailing actions against the current Implementation Plan (IP); the latest such report is available at: https://nasco.int/wp-content/uploads/2020/12/IP1913rev2_Implementation-Plan-for-the-period-2019-2024_UK-England-and-Wales.pdf.

11.2 *Improving riparian shade to help combat climate change effects*

'Keeping Rivers Cool' is an ongoing climate change adaptation project focused on using riparian shade to keep rivers cool. The UKCP09 Climate Projections (Jenkins *et al.*, 2008, 2009) forecast a rise in average air temperature of 2-4°C by 2050. There is already evidence of warming from the Environment Agency water temperature archive and temperatures of more than 31°C have been recorded in small streams in Southern England (Broadmeadow *et al.*, 2011). Studies have shown that shaded river channels can be 1.5°C lower on average than open reaches or 2-3°C lower in maximum temperatures (Bowler *et al.*, 2012); larger stretches associated with woodland can be up to 5°C cooler.

The 'Keeping Rivers Cool' Project aims to benefit salmon and trout by reducing river temperatures throughout upland England and Wales. It works by inspiring action through demonstration projects. Mapping tools and guidance have also been developed to identify where riparian shade is lacking and where to target resources and the latter has been distributed to landowners and partners. A copy can be downloaded at: www.ecrr.org/Publications/tabid/2624/mod/11083/articleType/ArticleView/articleId/3370/Keeping-Rivers-Cool.aspx. Pilot projects have been set up on the Rivers Tyne, Hampshire Avon, Wye, and Ribble.

11.3 *Stocking and hatchery-origin fish*

Juvenile salmon (eggs, fry, parr, and smolts) have previously been stocked from hatcheries in a number of catchments by the Environment Agency, NRW, and private fishery interests, and some such stocking activities continue. Stocking purposes include mitigation, restoration, enhancement (private schemes only), investigation, and legal obligation. Full details of the numbers of fish stocked in these programmes, and the stage (eggs, fry, parr and smolts) of release, are included on a catchment-by-catchment basis in the annual 'Salmonid and Freshwater Fisheries Statistics' publications.

All keeping and introduction of fish in inland waters is subject to permitting by the Environment Agency in England and NRW in Wales. The Environment Agency has a national approach to stocking together with specific guidance on 'Schemes to stock rivers with salmon, sea trout and brown trout from locally sourced broodstock', which outlines the risks and difficulties of such programmes. In Wales, following a review of the scientific evidence and a public consultation exercise, NRW stopped stocking of Atlantic salmon and sea trout into all Welsh rivers after 2014.

There has been no formal requirement for juvenile fish stocked into rivers in England and Wales to be marked. Thus, if stocked juveniles return as adults, they cannot usually be distinguished from fish derived from natural spawning, although scale analysis may enable this. Marking and tagging programmes are undertaken in some areas to assess the impact of stocking programmes (Section 7.3), but few results are available from these initiatives.

An examination of mitigation stocking on the River Tyne (Milner *et al.*, 2004) reviewed the role that a stocking programme played in the recovery of the Tyne fishery. In the 1950s, salmon runs in the River Tyne were severely depleted due to estuarine pollution. However, the river now consistently produces the largest rod catch in England and Wales. Water quality improved between the 1960s and 1990s, following reduction in industrial activity and improvements to effluent treatment and disposal. This coincided with a salmon stocking programme, which started in 1979 as mitigation for lost production resulting from the construction of a new reservoir (Kielder Reservoir). An extensive review of the observed patterns of change in rod catches, juvenile abundance, estuarine water quality, and returns of stocked fish marked with coded wire microtags indicated that natural recovery was the dominant process. However, the contribution of stocked fish, which peaked in 1986, is believed to have accelerated and stabilised stock recovery in its early stages when water quality improvements were still inconsistent.

The River Thames provides another example of a restoration programme based on stocking. Attempts to restore salmon to the Thames showed initial promise in the 1980s and 1990s with up to 300 adults returning each year. However, after 2000 the programme saw declining returns, with typically less than 20 fish returning annually. The stocking programme has now ceased. The decline coincided with increased likelihood of unfavourable flow and water quality conditions in the tidal river. Earlier investigations indicated that a freshwater discharge in excess of 650 megalitres per day was needed at the tidal limit to enable salmon to pass through the Thames tideway (Alabaster and Gough, 1986). Summer flows have been below this level in a number of years and intermittent storm events have also resulted in significant discharges of raw sewage and rainwater from combined sewage overflows with resultant impacts on water quality. River temperatures in the summer months have also increased in recent years and may be affecting migration into freshwater. A genetic analysis indicated that many of the salmon entering the Thames in recent years originated from other rivers in Southern England, highlighting the potential for natural processes of re-colonisation to operate in rivers where salmon have become locally extirpated (Griffiths *et al.*, 2011).

Analysis of angler catch statistics from 62 rivers in England and Wales suggest stocking programmes have had little effect on total rod catch or catch per unit effort between 1995 and 2009 (Young, 2013). The relatively small scale of stocking and low survival of stocked fish is consistent with the finding that stocking programmes have little effect on adult abundance in England and Wales (Harris, 1994). It remains unclear to what degree the absence of detectable demographic effects result from the small scale of most programmes, the low survival of stocked fish, or stocked fish compensating for stocking induced declines in natural recruitment (e.g., Chilcote *et al.*, 2011). There is, however, increasing evidence that stocking can pose a threat to wild salmon populations.

Efforts to further develop a consensus on the issue of salmon stocking were advanced at a salmon stocking conference held in Glasgow in November 2013 hosted by the Atlantic Salmon Trust and Integrated Aquatic Resources Management Between Ireland, Northern Ireland, and Scotland (IBIS). This was attended by a large number of scientists, managers and stakeholders, and resulted in some short guidance documents, including a paper summarising the current scientific consensus on salmon stocking (as viewed by the majority of those attending). Details are available at: http://ibis-eu-know.weebly.com/nov-2013---salmon-stocking--glasgow.html.

NASCO also convened a special theme session on the issue of salmon stocking. The proceedings of the session have been published and are available at: https://nasco.int/wp-content/uploads/2020/02/2017ThemeBasedSession.pdf.

11.4 *The Salmon Five-Point Approach*

The Environment Agency's Salmon Five-Point Approach (5PA), which has been developed jointly by the Environment Agency, Defra, Cefas, NGOs and fisheries interests, was formerly launched in May 2016 and sets out high level commitments to restore England's salmon populations.

The 5PA aims to restore the abundance, diversity, and resilience of salmon stocks throughout England by maximising the production of healthy wild salmon smolts in freshwater and seeking to reduce salmon mortality at sea. This is being achieved through working in partnership across Government, its agencies, and partner organisations to introduce new initiatives and improve the delivery of existing measures to protect and maximise salmon stock performance.

This work is focused on five areas:

1. Improving marine survival;
2. Further reducing exploitation by nets and rods;
3. Removing barriers to migration and enhancing habitat;
4. Safeguarding sufficient flows; and
5. Maximising spawning success by improving water quality.

Since the start of the Approach, the Environment Agency and its partners have been working on a range of actions in each of these five areas. The Approach has raised the profile of salmon in England and has helped deliver a number of improvements, including closing all salmon net fisheries and increasing the level of angler C&R; ensuring salmon is a priority species within the Water Industry National Environment Programme and the Water Environment Improvement Fund, that salmon are recognised within water resource's environmental ambition, and it has helped galvanise and deliver catchment-based actions such as fish passage and habitat improvements.

The most notable area where progress has been harder to achieve is in tackling diffuse pollution and improving water quality. There is still a lot to do in freshwater to maximise smolt output as a key objective for our future salmon strategy. For an update on progress, see the latest NASCO Annual Progress Report for England and Wales (https://nasco.int/wp-content/uploads/2020/12/IP1913rev2_Implementation-Plan-for-the-period-2019-2024_UK-England-and-Wales.pdf).

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Annex 2. Glossary of terms and abbreviations used in this report

This glossary has been extracted from various sources, but chiefly the EU SALMODEL report (Crozier *et al.*, 2003) and Environment Agency reports.

Acoustic tag – An electronic transmitter which emits acoustic frequencies and is attached to (or inserted into) a fish to enable its position to be determined in fresh water or the sea.

Adult – Salmon after the middle of the first winter spent at sea, after which the main categorisation is by sea-age, measured in sea-winters (e.g., grilse, or 1SW; two sea winter, or 2SW).

Abstraction – Taking water, either permanently or temporarily, from a water source (river, stream, spring, pond, lake, or groundwater).

Anadromous fish – Fish, born in freshwater, that migrates to sea, to grow and mature, and then returns to freshwater as an adult to spawn (e.g., salmon and sea trout).

Buy out – Payment made to a net fisher to permanently relinquish his/her fishing licence.

Buy off – Payment made to a net fisher to cease fishing (for all or part of the fishing season) on a temporary basis. The fisher retains entitlement to a licence, and a licence is issued to him/her each season.

By-catch – The incidental capture of non-targeted fish.

Catchment – The area of land drained by a river (e.g., River Tyne catchment).

Conservation Limit (CL) – The minimum spawning stock levels below which stocks should not be allowed to fall. The CL for each river is set at a stock size (defined in terms of eggs deposited) below which further reductions in spawner numbers are likely to result in significant reductions in the number of juvenile fish produced in future generations.

Dissolved oxygen – The amount of oxygen dissolved in water; one of the features that is used to classify water quality.

Distant-water fisheries – Fisheries in areas outside the jurisdiction of the country of origin of the exploited stock. With respect to the NASCO convention, this specifically refers to the fisheries under the jurisdiction of the Faroe Islands and Greenland.

EU Directive – A European Union legal instruction, binding on Member States, but which must be implemented through national legislation within a prescribed time-scale.

Escapement – Fish that survive to spawn after exploitation of the stock.

Exploitation – Removal of fish from a stock by fishing.

Extant exploitation rate – Catch of fish from a particular stock divided by the number of fish from that stock estimated to be alive at the time of the fishery.

Favourable condition – A term used in relation to the EU's Habitats Directive (92/43/EEC) where a designated feature and its associated environment is in good ecological condition.

Favourable conservation status – A term used in relation to the EU Habitats Directive (92/43/EEC) where a habitat or species is in a state where its distribution, abundance, structure or function is sustained throughout the biogeographic region over the long term.

Focus Area Reports (FARs) – Reports prepared by each relevant jurisdiction within NASCO providing an in-depth assessment of measures being taken or planned to implement NASCO Agreements, Resolutions, and Guidelines in relation to Fishery Management, Protection, Restoration and Enhancement of Salmon Habitat, and Aquaculture and associated activities.

Fishery – The area where it is, or may be, lawful to fish and where the resource is exploitable.

Fixed engine (FE) – The term fixed engine is an ancient one used in the UK as a general descriptor of stationary fishing gears.

Fry – Young salmon that have hatched out in the current year, normally in May at the stage from independence of the yolk sac as the primary source of nutrition up to dispersal from spawning areas (redds).

Good ecological status – A key target under the EU's Water Framework Directive (WFD). Water bodies of 'good ecological status' should have the biological and chemical characteristics expected under sustainable conditions. Practicality and the cost to society have to be considered in achieving this and this principle is also inherent in the WFD as retained under UK law.

Good ecological potential – An alternative key target under the EU's Water Framework Directive (WFD). Water bodies that have been artificial or physically altered to fulfil important uses such as flood and coastal risk management are designated as Heavily Modified Waterbodies (HMWBs) under the WFD as retained under UK law. These water bodies are set the alternative target of Good Ecological Potential (GEP), which is the maximum ecological quality they could achieve given the constraints imposed upon them.

Grilse – An adult salmon that has spent only one winter feeding at sea (1SW salmon) before returning to freshwater to spawn; normally only applied to salmon in homewaters.

Homewater fisheries – Fisheries within the jurisdiction of the countries of origin of the exploited stocks (within 12 miles of the shore).

IBIS (Integrated Aquatic Resources Management between Ireland, Northern Ireland and Scotland) – A partnership between the Loughs Agency, Queen's University Belfast, and the University of Glasgow, supported by the EU's INTERREG IVA Programme.

Implementation Plan – Reports prepared by each relevant jurisdiction within NASCO describing proposed approaches for meeting the objectives of NASCO's Agreements, Resolutions, and Guidelines.

Management target (MT) – A spawning stock level for managers to aim at in order to meet the management objective. The 'management objective' used for each river in England and Wales is that the stock should be meeting or exceeding its CL in at least four years out of five (i.e., at least 80% of the time).

Microtag – A coded wire tag 1.1 mm long and 0.25 mm diameter, typically inserted into the nasal cartilage (snout) of juvenile salmonids and detectable in live fish, but only readable after removal from the fish. Commonly abbreviated to CWT (coded wire tag).

Mixed stock fishery (MSF) – A fishery that predominantly exploits mixed river stocks of salmon. The policy in England and Wales is to move to close coastal net fisheries that exploit predominantly mixed stocks where the capacity to manage individual stocks is compromised. Fisheries, including MSFs, operating within estuary limits are assumed to exploit predominantly fish that originated from waters upstream of the fishery; these fisheries are carefully managed to protect the weakest of the exploited stocks, guided by the decision structure and taking into account socio-economic factors and European Conservation status where applicable.

Multi-Sea-Winter (MSW) salmon – An adult salmon that has spent two or more winters at sea.

NLO – Net Limitation Order – Mechanism within the Salmon and Freshwater Fisheries Act, 1975 whereby the competent authority may apply to limit the number of nets or traps fishing a public fishery.

Nominal catch – The nominal catch of a fishery is defined as the round, fresh weight of fish that are caught and retained.

One-Sea-Winter (1SW) salmon – An adult salmon that has spent one winter at sea (see also grilse).

Parr – Juvenile salmon in the stage following fry until its migration as a smolt, salmon parr are typically <16 cm long and have parr-marks (dark vertical bars) on the sides of the body.

Post-smolt – Young salmon, at the stage from leaving the river (as smolts) until the middle of its first winter in the sea.

Precautionary approach – A concept enshrined in Principle 15 of the Rio Declaration of the UN Conference on Environment and Development, which states: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

Pre-fishery abundance (PFA) – The PFA of salmon from England and Wales is defined as the number of fish alive in the sea on January 1 in their first sea winter. This is split between maturing (potential 1SW) and non-maturing (potential MSW) fish.

Production – The assimilation of nutrients to produce growth in a population over a given period.

Radio tag – An electronic transmitter which emits radio frequencies and is attached to (or inserted into) a fish to enable its position to be determined in fresh water.

Ranching – The production of salmon through smolt releases with the intent of harvesting the total population that returns to fresh water (harvesting can include fish collected for broodstock).

Recruits – The abundance of fish measured at a particular point in the life cycle, e.g., at the juvenile stages, the smolt stage, prior to the first fishery (recruitment to the fishery), or as returning spawners.

Reference point – An estimated value derived from an agreed scientific procedure and/or model which corresponds to a state of the resource and/or of the fishery and can be used to assess stock status or inform management decisions.

River Basin District (RBD) – A river basin or several river basins, together with associated coastal waters. For each River Basin District, the Water Framework Directive requires a River Basin Management Plan to be published. These are plans that set out the environmental objectives for all the water bodies within the River Basin District and how they will be achieved. The plans are based upon a detailed analysis of the pressures on the water bodies and an assessment of their impacts. The plans must be reviewed and updated every six years

Run – The number of adult salmon ascending, or smolts descending, a river in a given year. The main smolt run takes place in spring, whereas adult salmon runs may occur in spring, summer, autumn or winter.

Special Areas of Conservation (SACs) – An area designated under the EU Habitats Directive (92/43/EEC) giving added protection to identified species and habitats. Where salmon is a "qualifying species", additional protection measures are required specifically for salmon.

Salmonid – A fish belonging to the family *Salmonidae*, which includes the Atlantic salmon (*Salmo salar*), brown trout / sea trout (*Salmo trutta*), charr (*Salvelinus alpinus*) and rainbow trout (*Oncorhynchus mykiss*).

Sea age – The number of winters that a salmon has remained at sea.

Sea trout – Anadromous form of the trout (*Salmo trutta*) from the post-smolt stage; the brown trout remains in fresh water throughout its life.

Sea Trout and Salmon Catchment Summary – A document produced by the Environment Agency in consultation with partners which sets out the actions, either current or planned, for sea trout and salmon work within River Basin Districts as part of the WFD planning process as retained under UK law. These summaries build on existing Salmon Actions Plans for principal salmon rivers but also cover sea trout and other rivers supporting salmon such as the Trent and Mersey which are recovering from historic industrial problems.

Site of Special Scientific Interest (SSSI) – An area of land notified under the Wildlife and Countryside Act 1981 by the appropriate nature conservation body as being of special interest by virtue of its flora and fauna, geological or physiogeographical features.

Smolt – The stage in the life cycle of a salmon when the parr undergo physiological changes, become silver in appearance and migrate to sea. Salmon smolts are typically 12–16 cm long and migrate to sea in spring.

Smolt age – The number of winters, after hatching, that a juvenile salmon remains in freshwater prior to emigration as a smolt (this does not, therefore, include the winter in which the egg was laid).

Spring salmon – Multi-sea-winter salmon which return to freshwater early in the year, usually before the end of May.

Special Area of Conservation (SAC) – Protected Areas established for the protection of habitats or species under the EU Habitats Directive (92/43/EEC) (Special Areas of Conservation).

Stock – A management unit comprising one or more salmon populations, which may be used to describe those salmon either originating from or occurring in a particular area. Thus, salmon from separate rivers are referred to as "river stocks". (N.B. Very large management units, such as the salmon exploited at West Greenland, which originate from many rivers, are often referred to as 'stock complexes').

Stocking – The intentional release of fish into an ecosystem.

Sustainable use – The use of a biological resource in a way and at a rate that does not lead to the long-term decline of its potential to meet the needs and aspirations of present and future generations. Sustainable use does not imply that abundance is constant.

Annex 3. Description of fishing methods (nets and fixed engines) used for taking salmon and migratory trout in England and Wales

A wide variety of nets and fixed engines have been used to take salmon and sea trout. The term fixed engine is an ancient one used as a general descriptor of stationary fishing gears. The following are generalised descriptions of the gear used in England and Wales (for further details see Russell *et al.*, 1995); in practice there is considerable regional variation in the precise mode of operation of specific gears and in the dimensions and mesh sizes of the nets. These characteristics have generally evolved to suit local conditions and are regulated by local byelaws. As a result of measures over recent years to reduce exploitation of stocks, many of the fishing gears listed here are now no longer in use.

GILLING NETS:

Drift net – A drift net consists of a sheet of netting which hangs from a floated head rope to a weighted foot rope and is designed to drift with the current or tide. Regional names include: hang, whammel, sling and tuck nets.

Coracle net – These nets are only used in parts of Wales. Short lengths of trammel net are suspended between two coracles (small boats), which then drift downstream with the net strung across the current.

Trammel net – Trammel nets are similar to drift nets but are modified by the addition of sheets of larger mesh netting on one or both sides of the net. Such nets are referred to as being ‘armoured’. A fish striking a trammel net pushes the small mesh net through one of the large meshes in the adjoining net and is caught in the resultant pocket. Sometimes known locally as tuck nets (Severn Estuary).

Sling net – The sling net is a type of drift net previously used exclusively on the River Clwyd in North Wales. It differs from other drift nets only in so far as the nets are permitted to carry weights (not exceeding 4 kg) at either end, designed to retard the drift.

Coastal net – A loose term used to describe the nets used in the fishery off the East Anglian coast. In practice, various methods of fishing have been employed, including drift nets and beach seine nets (which may take fish by gilling).

SWEEP/ENCIRCLING NETS:

Seine net – A seine net (also known as a draft or draw net) consists of a wall of netting with a weighted foot rope and floated head rope. One end is held on the shore while the rest is paid out from a boat to enclose an area of water between two points on the shore. The net is then retrieved, and any fish enclosed drawn up onto the shore. Seine nets normally operate within estuaries, although some have also been fished off coastal beaches.

Wade net – A wade net consists of a short (~30 m) single sheet of netting which is attached to a pole at each end, and is pulled along the foreshore parallel to the beach by two men, one wading and the other on the beach. Nets are ‘beached’ at regular intervals, or when a fish strikes, in much the same way as a seine net.

FIXED ENGINES:

Basket trap – This is a type of fixed engine which has only been used on the River Conwy in North Wales. It consists of a metal basket set between two boulders, which is designed to catch salmon and sea trout which fall back when attempting to ascend a small waterfall.

Compass net – These nets are operated from a boat held stationary against the current. A net is hung between two long poles lashed together in a V-shape and held over the side of the boat so that the net streams out underneath the boat. When a fish strikes the net, the poles are pivoted upwards with the aid of counter-balancing weights.

Crib (or Coop) – These ancient, fixed engines consist of stone buttresses set across a river, the gaps between the buttresses being filled by box-like traps made of either wood or metal with in-scale entrances. The River Eden cribs were understood to have been first built by monks in 1133 A.D.; the River Derwent cribs are of more recent construction.

Putchers (and Putts) – Putchers are wickerwork or metal conical baskets which, when erected on stages, form putcher ranks (containing up to 800 putchers). This type of fixed engine is peculiar to the Bristol Channel and is dependent upon the high turbidity and large tidal range which occurs in this area. Each putcher has a mouth from 1 to 1.5 m wide, tapering to a narrow point which will prevent fish of moderate size from passing through. A netting leader is often used to guide fish into the putchers. Putts are of similar design to putchers, only larger.

T-net – T-nets are fixed engines operated close to the shore, usually in specific berths. They comprise a 'leader', usually about 200 m in length, stretching out from the beach to a 'headpiece', which contains two traps with funnel entrances. Some fish may become enmeshed or entangled in the leader of the net, but the majority are taken, free-swimming, in the traps.

'T or J'-net – 'T or J'-nets consist of plain sheets of netting on a floated head rope which hang vertically in the water by means of a weighted foot rope and are set from the shore in the shape of a 'T', inverted 'J' or 'P'. These nets are usually operated as fixed engines, held stationary by means of weights, anchors or stakes, but can also be drifted with weights used to retard the rate of movement. Fish can only be caught in a 'T or J' net by becoming enmeshed or entangled in the walls of the net.

HAND-HELD NETS:

Haaf or heave net – These one-man-operated nets are operated exclusively in the North West Region. The gear consists of a rectangular net hung from a horizontal wooden beam up to 5.5 m wide. A central pole permits the netters to stand in the tideway holding the net facing the current with the netting streaming behind him. The net is lifted when a fish strikes the net. It is usual for several netters to work together line-abreast, moving along the line as the tide rises/falls.

Lave (or dip) net – Lave nets are hand-held, one-man-operated nets consisting of a large Y-shaped wooden frame supporting a net, similar in design to an angler's landing net, but measuring up to 2 m across. The netsman actively stalks fish in estuary pools or shallows at low tide. This gear is only used in the Severn Estuary and parts of the North West Region.

Annex 4. North Atlantic Salmon Conservation Organisation (NASCO)

The North Atlantic Salmon Conservation Organisation (NASCO) was established in 1984 following calls for international co-operation on the management of salmon stocks. It is an international body with the objective of contributing through consultation and co-operation to the conservation and rational management of salmon stocks taking account of the best available scientific evidence. The Contracting Parties to the NASCO Convention are currently: Canada, Denmark (in respect of the Faroe Islands and Greenland), European Union, United Kingdom, Norway, the Russian Federation, and the USA. Iceland was previously also a Contracting Party, although has currently relinquished this position. Since leaving the EU, the UK has become an independent contracting party to NASCO. Much of the business of the organisation is conducted by three regional Commissions: (1) the North American Commission, (2) the North East Atlantic Commission, and (3) the West Greenland Commission. One of the main functions of these Commissions is to propose regulatory measures for fisheries of one Party to the NASCO Convention, which exploit salmon originating in the rivers of other Parties. The main fisheries of relevance for the management of European stocks are those operated off the west coast of Greenland and within Faroese waters; tables summarising the regulatory measures agreed by NASCO for these fisheries are provided below. To support this process, NASCO obtains scientific advice on the status of salmon stocks and fisheries and their management from ICES (see Annex 5). The list of questions posed by NASCO to ICES for consideration in the latest assessment year is provided in the annual assessment report.

In 1998, NASCO and its Parties agreed to apply a Precautionary Approach to the conservation, management, and exploitation of salmon in order to protect the resource and preserve the environments in which it lives. To this end, NASCO has adopted a number of Resolutions, Guidelines, and Agreements which address the Organisation's principal areas of concern for the management of salmon stocks. In 2004, NASCO initiated a review of its activities, and as part of this 'Next Steps' process, determined that it should develop a simpler and more transparent approach for reporting on progress on the implementation of its agreements. NASCO therefore agreed that each relevant jurisdiction should develop an Implementation Plan for the period 2006-2011 to describe its proposed approach for meeting the objectives of NASCO's agreements and to report on developments through Annual Progress Reports. Following this, jurisdictions were also requested to prepare Focus Area Reports (FARs) to provide a more in-depth assessment of measures they are taking or planning to take to implement NASCO Agreements, Resolutions, and Guidelines in relation to Fishery Management (completed in 2008), Protection, Restoration and Enhancement of Salmon Habitat (completed in 2009), and Aquaculture and associated activities (completed in 2010). In 2012, NASCO agreed that jurisdictions should develop a second round of Implementation Plans for the period 2013-18; these are available on the NASCO website at: https://nasco.int/conservation/second-reporting-cycle/. In 2018, NASCO approved a third round of Implementation Plans, for the period 2019-24, and these documents are currently under development.

Summary of Regulatory Measures agreed by NASCO for the West Greenland Salmon Fishery

Year	Allowable catch (tonnes)	Comments/other details in the measures
1984	870	
1985	-	Greenlandic authorities unilaterally established quota of 852t.
1986	850	Catch limit adjusted for season commencing after 1 August.
1987	850	Catch limit adjusted for season commencing after 1 August.
1988-1990	2,520	Annual catch in any year not to exceed annual average (840t) by more than 10%. Catch limit adjusted for season commencing after 1 August.
1991	-	Greenlandic authorities unilaterally established quota of 840t.
1992	-	No TAC imposed by Greenlandic authorities but if the catch in first 14 days of the season had been higher compared to the previous year a TAC would have been imposed.
1993	213	An agreement detailing a mechanism for establishing annual quota in each of the years 1993 to 1997 was adopted by the Commission.
1994	159	
1995	77	
1996	-	Greenlandic authorities unilaterally established a quota of 174t.
1997	57	An addendum to the 1993 Agreement was agreed by the Commission.
1998	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t.
1999	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t.
2000	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t. A Resolution Regarding the Fishing of Salmon at West Greenland was agreed by the Commission.
2001	28 – 200	Under an *ad hoc* management programme the allowable catch will be determined on the basis of CPUE data obtained during the fishery.
2002	20 - 55	Under an *ad hoc* management programme the allowable catch will be determined on the basis of CPUE data obtained during the fishery.
2003-2008	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t.
2009 – 2011	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t.
2012 -2014	Internal consumption fishery only	Amount for internal consumption in Greenland has been estimated in the past to be 20t.
2015 - 2017	Internal consumption fishery only	Greenland unilaterally committed to limit the total annual catch for all components of the fishery to 45t in 2015, 2016 and 2017. Any overharvest in one year will result in an equal reduction in the catch limit the following year.
2018 - 2020	Internal consumption fishery only	Total annual catch for all components of the fishery to be limited to 30t in 2018, 2019 and 2020. Any overharvest in one year will result in an equal reduction in the catch limit the following year, and there will be no carry forward of any under-harvest into a subsequent year.
2021	Internal consumption fishery only	Total annual catch for all components of the fishery restricted to 27t. Any under-harvest will not be carried forward into a future year.

Summary of Regulatory Measures/Decisions agreed by NASCO for the Faroese Salmon Fishery

Year	Allowable catch (tonnes)	Comments/other details in the measures/decisions
1984-85	625	
1986	-	
1987–89	1,790	Catch in any year not to exceed annual average (597t) by more than 5%.
1990–91	1,100	Catch in any year not to exceed annual average (550t) by more than 15%.
1992	550	
1993	550	
1994	550	
1995	550	
1996	470	No more than 390 tonnes of the quota to be allocated if fishing licences issued.
1997	425	No more than 360 tonnes of the quota to be allocated if fishing licences issued.
1998	380	No more than 330 tonnes of the quota to be allocated if fishing licences issued.
1999	330	No more than 290 tonnes of the quota to be allocated if fishing licences issued.
2000	300	No more than 260 tonnes of the quota to be allocated if fishing licences issued.
2001–03	No quota set	It is the intention of the Faroese authorities to manage the fishery in a precautionary manner with a view to sustainability, and to make management decisions with due consideration to the advice from ICES concerning status of stocks contributing to the fishery.
2004–06	No quota set	It is the intention of the Faroese authorities to manage the fishery on the basis of the advice from ICES concerning status of stocks contributing to the fishery in a precautionary manner with a view to sustainability and taking into account relevant factors such as socio-economic needs and other fisheries on mixed stocks.
2007	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2008	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2009	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2010	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2011	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2012	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2013–15	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2015/16 – 2017/18	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.

Year	Allowable catch (tonnes)	Comments/other details in the measures/decisions
2018/19 – 2020/21	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
2021/22 – 2023/24	No quota set	It is the intention of the Faroese authorities to manage any salmon fishery on the basis of the advice from ICES regarding the stocks contributing to the Faroese salmon fishery in a precautionary manner and with a view to sustainability, taking into account relevant factors such as socio-economic needs.
Note: The quotas for the Faroe Islands detailed above for the period 1984-2000 were agreed as part of effort limitation programmes (limiting the number of licences, season length and maximum number of boat fishing days) together with measures to minimise the capture of fish less than 60 cm in length. The measure for 1984/85 did not set limits on the number of licences or the number of boat fishing days.		

Annex 5. International Council for the Exploration of the Sea (ICES)

The International Council for the Exploration of the Sea (ICES) provides biological information and advice on a wide range of fish stocks in order to help fisheries managers maintain viable fisheries within sustainable ecosystems. Information is compiled and assessments are conducted by Working Groups, which are comprised of national experts on the specific fish stocks. The Working Group reports are passed to the Advisory Committee (ACOM) for peer review and to provide the formal advice to managers. The advice may take many forms, but in general it involves assessments of stock dynamics, evaluation of the status of the stocks, projections of various stock parameters into the future, and management options. For Atlantic salmon, ICES provides advice relating to a list of questions posed by NASCO each year; the questions for consideration in the latest assessment year are provided in the latest annual assessment report. The assessment of salmon stocks and their fisheries presents particular problems to the ICES scientists both because of the highly migratory nature of the fish and because they comprise a large number of distinct river stocks which must, to some extent at least, be managed separately.

Description of the ICES assessment methodology for England and Wales

The model that ICES uses to estimate the PFA for North East Atlantic Commission (NEAC) countries endeavours to provide our best interpretation of what the available catch and effort data tell us about changes in the status of total national stocks of salmon over the past four to five decades.

The model first estimates the returns of salmon to freshwater, and then back-calculates the numbers of fish that must have been alive in the sea to generate these returns. The numbers of fish returning to homewaters are typically estimated using the catch data for each country, which are raised to take account of non-reported catches and exploitation rates for 1SW and MSW fish. To estimate the PFA (the numbers of fish alive prior to exploitation in high seas fisheries), these values are then further raised to take account of catches in the distant water fisheries and natural mortality between January 1 in the first sea winter (the date of which PFA is estimated) and their return to homewaters. Ranges of values are used for some of the input data in order to obtain a measure of the uncertainty in the PFA estimates. In order to run the NEAC PFA model, each country requires time-series (beginning in 1971) of catch in numbers, non-reporting rates and exploitation rates for 1SW and MSW salmon.

For England and Wales, nominal catches have been derived from the catch returns submitted by netters and anglers and split into 1SW and MSW categories using two different methods. Over the period 1992 to the present, monthly age-weight keys derived from salmon caught in the River Dee trap have been used to estimate the age of all rod-caught fish where a weight and date of capture have been provided. This has then been scaled up to the total catch (rods and nets combined) on a pro-rata basis. In earlier years (1971-1991), the age composition of the total catch has been estimated using the mean weight of the fish caught and the mean weight of 1SW and MSW salmon recovered in tagging programmes. Estimates of unreported and illegal catches have been made on the basis of consultation with regional fisheries personnel and according to the approach described in Section 4.6.

As the contribution of farmed and ranched salmon to the national England and Wales catch is negligible, the occurrence of such fish is ignored in the assessments of the status of national stocks. However, a large proportion of the fish taken in the north east coast fishery were destined for Scottish rivers, and these were historically deducted from the returning stock estimate for England and Wales and added to the data for Scotland in the ICES assessment. This proportion is estimated to have declined from 95% of the north east net catch in the early part of the time-series to 75% in the 1990s around 65% in the 2000s and closer to 50% from 2012 to 2018. This reflects both the steady improvement in the status of the stocks in North East England and the accelerated phase-out of the fishery in 2003. The latter resulted in a major overall reduction in the fishery, with the majority of the remaining netters now fishing close inshore using T or J nets. In 2019, the north east coast salmon fishery was closed, and therefore no catches have been reallocated to UK (Scotland) since this period. Previous tagging studies have shown that these inshore nets exploit a much higher proportion of local fish (Anon., 1991); a recent genetic study has confirmed this, and provided updated estimates of the relative proportions of Scottish and English origin fish in the fishery (see Section 7.7 for further details).

Exploitation rates for a number of monitored fisheries in England and Wales are derived annually. National exploitation rates have then been estimated by deriving time-series of 'standard fishing units' employed in the salmon fisheries for the period 1971 to the present. For the period 1971 to 1997, these are calculated from the numbers of licenses issued weighted by their relative catching power, which is estimated from historic CPUE data; and for the period 1998 to the present, they are calculated from the numbers of days fished by different net categories weighted in the same way. The annual exploitation rates are then estimated by referencing the number of 'standard fishing units' employed over the two periods relative to average age-specific exploitation estimates derived for the 1997 and 1998 seasons. Finally, ICES has agreed to apply a natural mortality rate of 3% per month in back-calculating the PFA of salmon in the sea, on the basis of studies undertaken on a range of stocks (ICES, 2002 and 2003).

Annex 6. European Directives and other measures, or UK equivalents, affecting salmon management

Habitats Directive

The main aim of the European Union's Habitats Directive (92/43/EEC), on the Conservation of Natural Habitats and of Wild Fauna and Flora is to promote the maintenance of biodiversity. It stipulates the measures that must be taken to maintain or restore natural habitats and wild species to favourable conservation status, introducing robust protection for those habitats and species of European importance. To comply with this Directive, a number of rivers in England and Wales have been designated Special Areas of Conservation (SACs) because they support important populations of vulnerable qualifying species. Equivalent provisions still apply now the UK is an independent coastal state outside of the EU.

The following rivers in England and Wales are SACs and have salmon as a "qualifying species", which confers additional protection measures specifically for salmon in these rivers and associated online lakes:

Southern Region:	Itchen.
South West Region:	Hampshire Avon*, Camel, Dartmoor Headwaters (Dart, Teign, Erme, Taw, Yealm, and Tavy including its tributary the Walkham).
Wales:	Wye*, Usk*, Teifi*, Dee* (and Bala Lake), Gwyrfai* (and Llyn Cwellyn) and Eden (West Gwynedd - part of the Mawddach catchment).
North West Region:	Derwent* (and Bassenthwaite Lake), Eden* and Ehen.

For eight of these rivers (marked *), Atlantic salmon are recognised as a primary species for SAC designation purposes.

Water Framework Directive (WFD)

The European Union's Water Framework Directive (Directive 2000/60/EC) came into force on the 22 December 2000 and became part of UK law in December 2003 and was retained under UK law following the UK's exit from the EU in December 2020. Section 11.1 provides further information and web links for further information.

Data Collection Framework / EU Multi annual Plan (MAP)

The Data Collection Framework (DCF) is an EU programme established under EU Regulation 199/2008 (updated EU Regulation 2017/1004) for the collection, management and use of data to provide a sound basis for scientific assessments of fish stocks. The framework has been retained under UK law following the UK's exit from the EU and establishes rules on the collection and management of biological, technical, environmental and socio-economic data for the fisheries sector, and the use of these data for scientific analyses (EU Implementing Decision 2016/1251). The framework was originally developed for marine fisheries, but commercial and recreational fisheries for salmon (and eel) have been included in the legislation since 2007.

The framework provides EU co-funding to support data collection, on the basis that these data are collected to specified, rigorous standards of method and quality to meet the needs of national and international bodies such as ICES in the provision of scientific advice relating to fish stocks and fisheries. In England and Wales, the DCF previously contributed funding towards the collection of catch statistics, juvenile salmon surveys, and the counted and 'Index River' monitoring programmes, which provide estimates of marine survival and exploitation rates. The framework also provided partial funding to support UK scientists to prepare stock assessments and to attend annual assessment working groups at ICES, which in turn provide advice to NASCO on the assessment and management of Atlantic salmon throughout the North Atlantic.

United Kingdom Post-2010 Biodiversity Framework

The 'UK Post-2010 Biodiversity Framework' was published in July 2012 and succeeded the UK Biodiversity Action Plan (UK BAP). Salmon was added to the list of priority species under the UK BAP in 2007. This gave added emphasis to efforts to conserve and improve salmon populations and this still applies. Listing brings with it a need for programmes to be developed and delivered by partnerships of statutory, voluntary, academic and business organisations and for status and trends to be recorded and reported. The latest version of the England Biodiversity Strategy to 2020 can be found https://www.gov.uk/government/publications/biodiversity-2020-a-strategy-for-england-s-wildlife-and-ecosystem-services. More information about biodiversity in Wales can be found at https://www.biodiversitywales.org.uk.

United Kingdom 25 Year Environment Plan

Launched in January 2018, the 'UK 25 Year Environment Plan' sets out government action to improve the environment within a generation. The plan makes a commitment to become the first generation to leave the environment in a better state than it inherited. Its goals are to deliver clean air and water; thriving plants and wildlife; reduce the risks of harm from environmental hazards; ensure more sustainable and efficient use of natural resources; enhance the beauty, heritage and engagement with the natural environment; mitigate and adapt to climate change; minimise waste; manage exposure to chemicals; and enhance biosecurity over the next 25 years. Salmon have been included in the plan as an iconic species worthy of conservation. More information about the plan is available at: www.gov.uk/government/publications/25-year-environment-plan.

Annex 7. Salmon management procedures/ developments in England and Wales

Conservation Limits (CLs) and Management Targets (MTs)

Setting Conservation Limits

The use of Conservation Limits (CLs) in England and Wales has developed in line with the requirement of ICES and NASCO to set criteria against which to give advice on stock status and the need to manage and conserve individual river stocks. CLs indicate the minimum desirable spawning stock levels below which stocks should not be allowed to fall. The CL is set at a stock size below which further reductions in spawner numbers are likely to result in significant reductions in the number of juvenile fish produced in the next generation.

Two relationships are required to derive the CLs:

(i) **a stock-recruitment curve** – defining, for the freshwater phase of the life cycle, the relationship between the number of eggs produced by spawning adults (stock) and the number of smolts resulting from those eggs (recruits).

(ii) **a replacement line** – converting the smolts emigrating from fresh water to surviving adults (or their egg equivalents) as they enter marine homewaters. This relationship requires an estimate of the survival rate at sea.

The model used to derive a stock-recruitment curve for each river assumes that juvenile production is at a 'pristine' level for that river type (i.e., it is not affected by adverse water quality, degraded physical habitat, etc.).

Similarly, in deriving the replacement line, marine survival rates for most river stocks were assumed to be equivalent to the rates estimated on UK monitored rivers (such as the North Esk) in the 1960s and 1970s. Default survival values recommended for this purpose were 25% for 1SW salmon and 15% for MSW fish (Environment Agency, 1998). However, that period is thought to have been one of high sea survival, and new default values of 11% for 1SW salmon and 5% for MSW fish, which are more representative of sea survival over the last 20-30 years, were introduced by the Environment Agency in April 2003 (Environment Agency, 2003a).

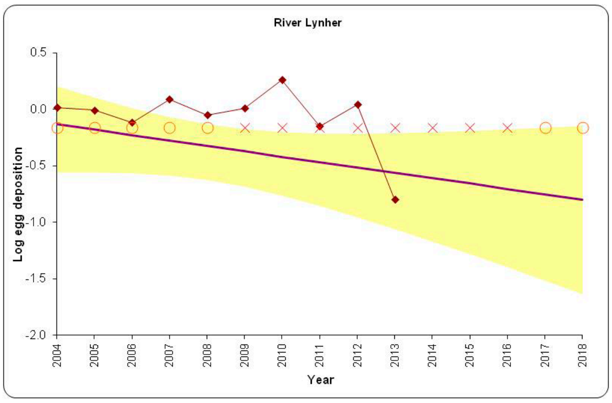
These rates have now been applied in calculating CLs for all the 64 principal salmon rivers. Since 2003, the CLs for all principal salmon rivers for which egg deposition estimates are assessed annually have incorporated the lower marine survival estimates. The net effect of these changes was to reduce the CLs: the scale varied from river to river, but resulted in a 26% reduction, on average, in England and Wales from values used prior to 2003.

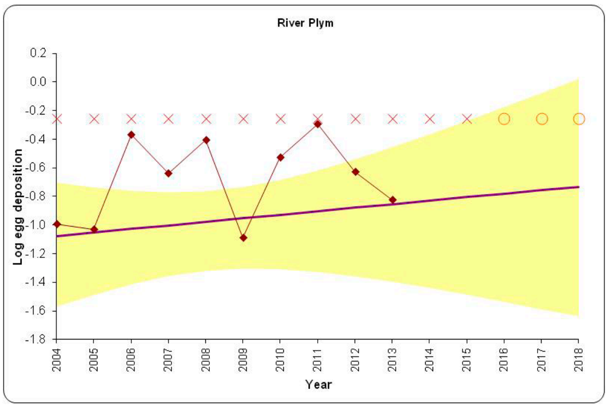
Introducing marine survival rates which are intended to be closer to those currently experienced by UK salmon stocks will reduce the effect of high mortality at sea as a cause of failing CLs. This will help managers focus on other issues over which they have more control (e.g., poor environmental quality in-river, over-exploitation by net and rod fisheries, etc.) when compliance failure occurs. The reduction in CLs means, however, that lower levels of spawning escapement are accepted before the stock is considered to be threatened. The Environment Agency also uses the 'Management Objective' for each river (e.g., in reviewing management actions and regulations) that the stock should be meeting or exceeding its CL in at least four years out of five (i.e., at least 80% of the time). This MO is built into statistical procedures for assessing compliance with CLs (below).

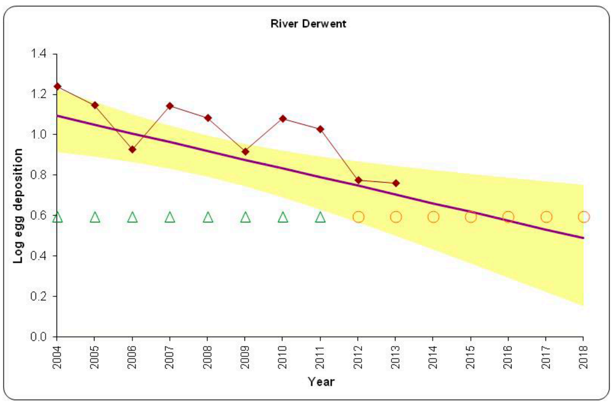
Compliance assessment

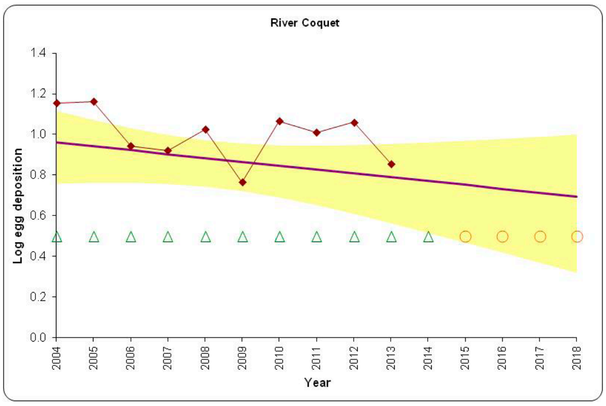
The performance of salmon stocks in England and Wales is assessed using a compliance scheme designed to give an early warning that a river has fallen below its CL. An approach introduced in 2004 provides a way of summarising the performance of a river's salmon stock over the last 10 years (including the current year), in relation to its CL. Bayesian regression analyses are applied to egg deposition estimates from the last 10 years, on the assumption that there might be an underlying linear trend over the period. The method fits a 20-percentile regression line to the data and calculates the probability that this regression line is above the CL, and thus that the CL will be exceeded four years out of five (the MO). If there is a low probability (<5%) that the 20-percentile regression line is above the CL, the river fails to comply (i.e., is regarded 'at risk'). If the probability is high (>95%), the river complies in that year (i.e., is 'not at risk'), whereas between these probability values we cannot be certain of the stock status (the river is assessed as either 'probably at risk' (5%< p <50%) or 'probably not at risk' (50%≤ p <95%). The results are in broad agreement with the compliance scheme used prior to 2004. The current scheme also allows the 20-percentile regression line to be extrapolated beyond the current year to project the likely future performance of the stock relative to its CL if one was to assume a continuing linear trend, and so assess the likely effect of recent management intervention and the need for additional measures.

The compliance plots for the Rivers Lynher, Plym, Derwent, and Coquet for the years 2004-2013 are shown below as examples. These include individual egg deposition estimates (red diamonds on the graphs) for these years, the 20-percentile regression lines and (shaded) 90% Bayesian Credible Intervals (BCIs), and the CL (represented by up to three symbols: X, O and Δ).









When the upper bound (95 percentile) of the regression line BCI is below the CL line, the river is judged to be failing its CL (i.e., there is a ≥95% probability of failure or the river is 'at risk'). For example, this is the case on the Lynher from 2009 to 2016 and the Plym from 2004 to 2015 and is indicated by the X symbol on the CL line. When the lower bound (5 percentile) of the regression line BCI is above the CL line the river is judged to be passing its CL (i.e., there is a ≤5% probability of failure and the river is 'not at risk'). This is the case on the Derwent from 2004 to 2011 and the Coquet from 2004 to 2014 and is indicated by the Δ symbol on the CL line. For all other years on these rivers, the shaded BCI of the regression line overlaps the CL line and so the status of the river is judged as 'uncertain' (i.e., the probability of failure is >5% but <95%, and the river is either 'probably at risk' or 'probably not at risk'). This is the case on the Lynher from 2004 to 2008 and in 2017 to 2018, on the Derwent from 2012, the Coquet from 2015 and on the Plym from 2016 and is indicated by the O symbol on the CL line.

Egg deposition estimates for a river may be consistently above the CL but status may still be uncertain. This is the case on the Coquet from 2015 and the Derwent from 2012 (O symbol on the CL line). In part, this reflects the marked year to year variation in egg deposition estimates on these rivers, which produces broad BCIs around the regression lines, but also arises because of the slope of the trend line and the increasing uncertainty associated with all regressions once extrapolated beyond the data set.

As well as providing an assessment of the status of a river in relation to its CL, the direction of the trend in the 10-year time-series of egg deposition estimates and its statistical significance may also serve as an important indicator of the need to take management action and of the degree of intervention required. Thus, a clear negative trend would give additional cause for concern.

The MT for each river is a spawning stock level for managers to aim at, to ensure that the objective of exceeding the CL is met at least four years out of five in the long run (i.e., at least 80% of the time). The value of the MT has been estimated using the standard deviation (SD) of egg deposition estimates for the last 10 years, where: MT = CL + 0.842*SD. The constant 0.842 is taken from probability tables for the standard normal distribution, such that the CL forms the 20-percentile of a distribution, the median (50-percentile) of which equates to the MT.

CLs and MTs form only one part of the assessment of the status of a stock, and management decisions are never based simply on a compliance result alone. Because stocks are naturally variable, the fact that a stock is currently exceeding its CL does not mean that there will be no need for any management action. Similarly, the fact that a stock may fall below its CL for a small proportion of the time may not mean there is a long-lasting problem. Thus, other indicators of stock performance are also taken into account, particularly the structure of the stock and any evidence concerning the status of particular stock components, such as tributary populations or age groups, based for example on patterns of run timing and the production of juveniles in the river sub-catchments. These data are provided by a programme of river catchment monitoring.

The assessment approach described above is incorporated into the national Decision Structure (see below) for guiding decisions on fishery regulations.

The Decision Structure for developing fishing controls in England and Wales

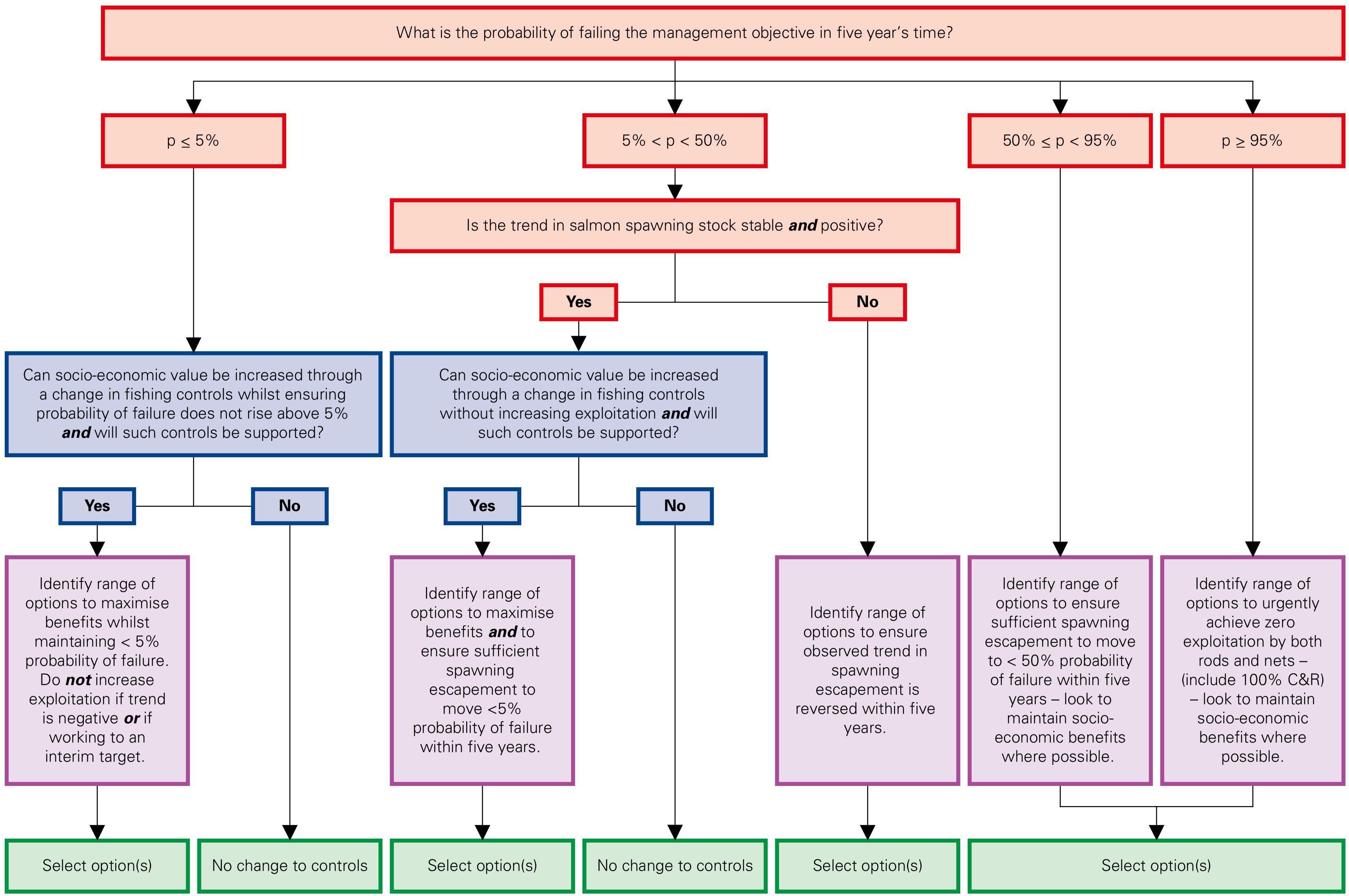
The compliance assessment approach described above for determining the performance of each salmon river is also incorporated into a 'Decision Structure' for guiding decisions on the need for fishery regulations. The Decision Structure is applied annually to each salmon river in April following the annual stock assessments. Fishery managers for each river are then advised of these assessments and the outcome of applying the Decision Structure. They then decide what, if any, changes in regulation are appropriate as guided by the Decision Structure outputs. Recovering rivers that do not yet have CLs set are deemed to be 'at risk' and, under new measures approved in December 2018, all such rivers in England will be subject to mandatory C&R from 2019. Similar provisions have applied in Wales from 2020.

In 1998, NASCO and its Parties agreed to apply a Precautionary Approach to the conservation, management, and exploitation of salmon in order to protect the resource and preserve the environments in which it lives. In keeping with this, the assessment and management of salmon in England and Wales seeks to avoid the possibility of stocks reaching unfavourable levels. The Precautionary Approach requires that more caution is exercised when scientific information is uncertain. Where there are threats of serious or irreversible damage to stocks, uncertainty in scientific information should not be used as a reason for postponing or failing to take management and conservation measures.

As noted in Section 2.1, the methodology for assessing salmon stocks, and the associated compliance scheme and Decision Structure, are currently under review to consider the need for possible improvements. The aim is to undertake this within the next two years with the likelihood that improvements will be introduced in stages as developments allow.

The Decision Structure is shown in the schematic flow chart below, together with explanatory notes for its use.

The Decision Structure – Developing fishing controls for salmon fisheries in England and Wales



Notes to accompany Decision Structure

1. Initial stage – stock assessment (red boxes)

This is the assessment of the probability that the salmon river will meet its CL in at least four years out of five (the management objective) in five years' time. The information to answer these questions comes from the annual assessment process outlined in Section 8, with the latest results available in the most recent annual assessment report.

2. Second stage – initial screening for potential options (blue boxes)

This stage screens options appropriate to those rivers that have a **<50% probability of failing the management objective** taking into consideration socio-economic concerns and stakeholder support. Management options that would not be supported by stakeholders can be ruled out. One of the possible options is to 'do nothing'.

For rivers where there is **>50% probability of failing the management objective**, all options must be carried through to the next (evaluation) stage.

3. Third stage – option evaluation (purple boxes)

The purpose of this stage is to set out and evaluate options to realise the required changes in exploitation.

For rivers where 50%≤ p <95% (where p = probability of failing the management objective) **and the trend is down** and with an annual catch of >20 salmon and C&R rate <90%, then voluntary catch and release (C&R) will be promoted for 1 year. If this fails to significantly improve C&R rates, mandatory C&R or closure of the fishery will be considered. Protected rivers such as SACs (Special Areas of Conservation) are given particular emphasis.

For rivers where the above criteria apply, except that the annual mean salmon catch is <20 salmon, voluntary measures will be promoted.

For rivers where p>95% (i.e., the management objective is clearly being failed) and with an annual catch of >20 salmon and a C&R rate <90%, then voluntary C&R will be promoted for 1 year. If this fails to significantly improve C&R, mandatory C&R or closure of the fishery will be considered.

For rivers where p ≤ 95% for 5 consecutive years (i.e., the management objective is clearly being met), the possibility of relaxing controls including on nets will be considered if stakeholders agree.

Rivers that are recovering from historical degradation that do not yet have CLs set are deemed to have a >95% probability that they are failing unless there is better information available. Fishers on such rivers are encouraged to practice 100% C&R at the same time as regulators and partner organisations work on the necessary environmental improvements. If the potential for these rivers is greater than an average rod catch of 20 salmon, then mandatory C&R is considered throughout the season as an interim measure. However, controlled development of fisheries may be permitted on these rivers in parallel with the recovery of stocks.

4. Final stage – selection and implementation (green boxes)

The final stage of the Decision Structure is the selection and implementation of the appropriate regulatory action.

Annex 8. The impacts of the coronavirus (COVID-19) pandemic on the 2020 stock assessment

Background

Angling opportunities for salmon in 2020 were potentially affected by the coronavirus (COVID-19) pandemic and the resulting access and movement restrictions imposed to prevent its spread throughout England and Wales.

A total of 64 principal salmon rivers in England and Wales are included in the stock assessment. Of these, only 11 rivers have fish counters and/or traps that provided a fishery-independent estimate of the numbers of returning adult salmon, known as a returning stock estimate (RSE), in 2020. For the remaining 53 rivers without fish counters and/or traps, the numbers of returning adult salmon are derived by raising declared rod catches by estimates of the proportion of the available salmon caught. This proportion (obtained from the 'counted' rivers) is known as the extant exploitation rate ($Exploitation$) and is calculated as:

$$Exploitation = Catches/RSE$$

Therefore, the numbers of adult salmon returning to rivers without fish counters and/or traps are estimated as:

$$RSE = Catches/Exploitation$$

Since declared rod catches ($Catches$) are used in the derivation of extant exploitation rates and are the primary data used in the derivation of RSEs for rivers without fish counters and/or traps, then any factors affecting catches could have consequences for the estimation of the numbers of adult salmon returning to most rivers. Once the numbers of adult salmon returning to rivers are estimated, these are subsequently used to generate egg deposition estimates. If the COVID-19 pandemic reduced angling activity, and as a consequence declared rod catches in 2020, then egg deposition estimates in rivers without fish counters and/or traps could be inaccurate and affect their stock status designations. Therefore, the aim of this investigation is to use the best available data to explore whether the COVID-19 pandemic affected the stock assessment in 2020.

Data

As described above, the stock assessment uses two main data sources:

1) Declared rod catches, which are the numbers of salmon caught and declared in rod licence returns; and

2) Returning stock estimates, which are the estimated numbers of adult salmon returning to a river in a given period.

Declared rod catches are reported for all 64 principal salmon rivers with an associated date of capture and can thereby be summed to any period of interest. In contrast, RSEs in 2020 were only reported annually on 11 rivers with fish counters and/or traps, except on the Rivers Dee and Tamar where monthly RSEs are available. Angling effort, which is the number of declared days spent angling for salmon and sea trout, is also available from licence returns and has been recorded for two periods – before and after 16 June – annually since 2014. These angling effort data could be informative in helping to explain any differences in declared rod catches during these periods between years.

To investigate the potential impacts of the COVID-19 pandemic on the 2020 stock assessment, monthly RSEs, angling effort, and declared rod catches were compared between 2020 and the preceding 6 years (2014-2019). These years were selected for comparison because angling effort data before and after 16 June were only available for this period.

Objective

The objective of this investigation was to assess whether the 2020 stock assessment should be adjusted to account for the possible impacts of the COVID-19 pandemic on angling activity, and, as a consequence, declared rod catch. This was done by evaluating the following:

1) Differences in monthly counts of returning adult salmon to the Rivers Dee and Tamar from March to May in 2020 compared to the same months in the preceding 6 years (2014-2019).

2) Differences in declared angling effort before and after 16 June in 2020 compared to the same periods in the preceding 6 years (2014-2019).

3) Differences in declared rod catches during the COVID-19 lockdown (23 March to the 12 May) and other periods of the year in 2020 compared to the same periods in the preceding 6 years (2014-2019).

Results

Monthly counts of adult salmon returning to the Rivers Dee and Tamar from March to May in 2020 and the preceding 6 years (2014-2019) are shown in Figure A1. For both rivers, the monthly counts in 2020 were within the range of monthly counts observed over the preceding 6 years.

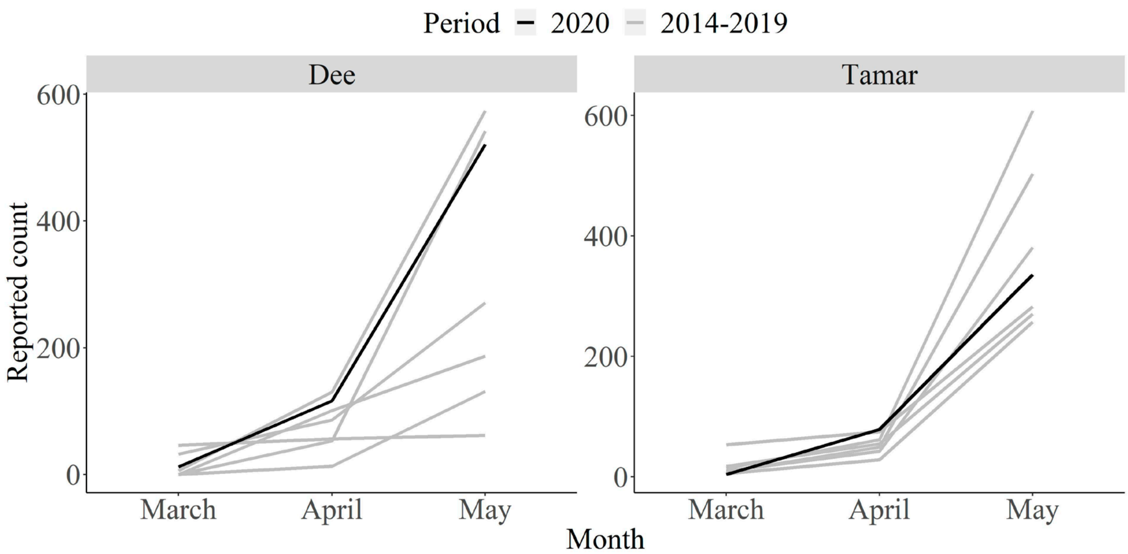


Figure A1. Monthly counts of adult salmon returning to the Rivers Dee and Tamar from March to May in 2020 and in the preceding 6 years (2014–2019).

Differences in declared angling effort before and after 16 June in 2020 and in the preceding 6 years (2014-2019) for all 64 principal salmon rivers are illustrated in Figure A2. A statistical model comparing angling effort in 2020 to the angling effort in each of the preceding 6 years showed that 2020 angling effort was significantly lower than all other years in the time series (Table A1). After 16 June, angling effort in 2020 was significantly lower than all years, except for 2018, and it was also similar to 2019.

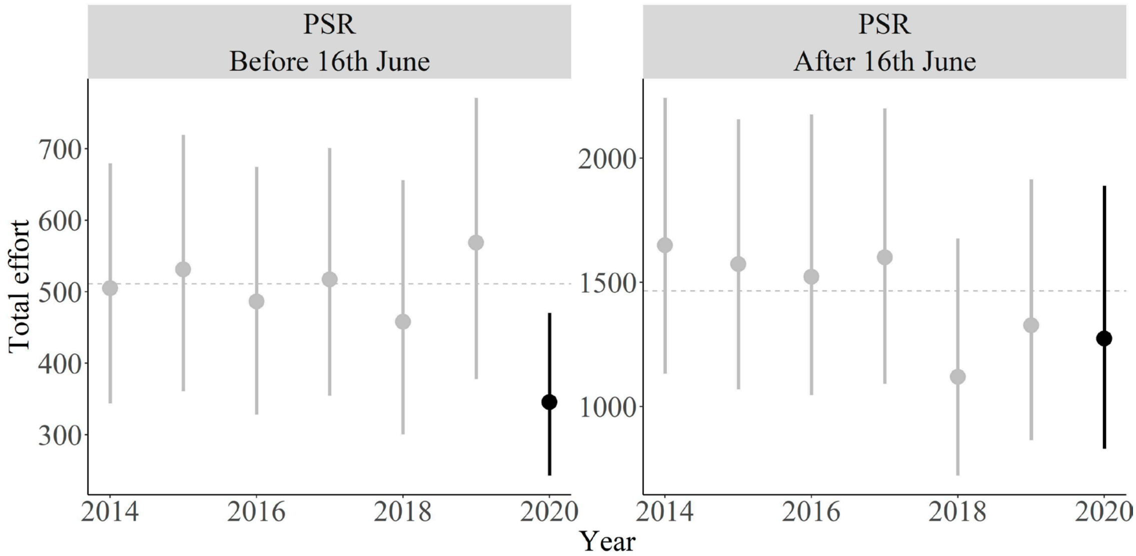


Figure A2. Mean and bootstrap 95% confidence intervals of declared angling effort before and after 16 June in 2020 compared to the preceding 6 years (2014-2019) for all 64 principal salmon rivers. The dashed horizontal line shows mean declared angling effort before and after 16 June in the preceding 6 years.

Table A1. Summary of the statistical model contrasting declared angling effort before 16 June in 2020 with declared angling effort before 16 June in each of the preceding 6 years (2014-2019).

Model	Coefficient	Estimate	Std. Error	df	t value	Pr(>|t|)	Significance
Year	(Intercept)	2.13	0.084	71	25.4	0.0e+00	***
Year	Year2014	0.18	0.030	384	6.0	0.0e+00	***
Year	Year2015	0.18	0.030	384	6.0	0.0e+00	***
Year	Year2016	0.13	0.030	384	4.4	1.3e-05	***
Year	Year2017	0.18	0.030	384	6.0	0.0e+00	***
Year	Year2018	0.11	0.030	384	3.7	2.8e-04	***
Year	Year2019	0.23	0.030	384	7.9	0.0e+00	***

Differences in declared rod catches during the COVID-19 lockdown and other periods of the year in 2020 and in the preceding 6 years (2014-2019) for all 64 principal salmon rivers are shown in Figure A3. A statistical model comparing declared rod catches during lockdown in 2020 to declared rod catches over the same period in each of the preceding 6 years showed that 2020 rod catch was significantly lower than all other years in the time series (Table A2). Declared rod catches during other periods of the year in 2020 were higher than in 2014, 2015, 2018, and 2019, and it was also similar to 2016.

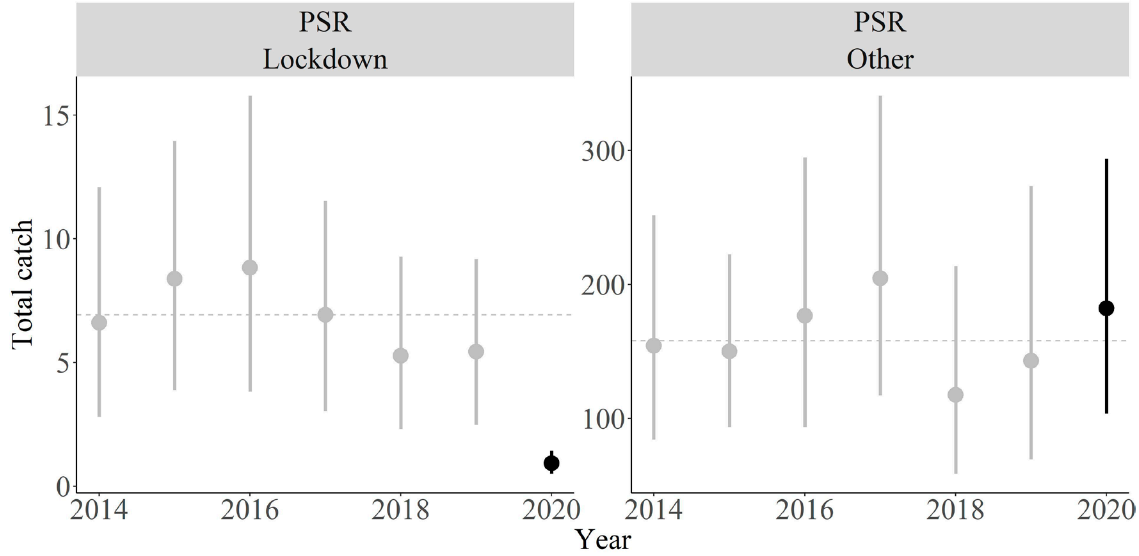


Figure A3. Mean and bootstrap 95% confidence intervals of declared rod catches during lockdown and other periods of the year in 2020 compared to the same periods in the preceding 6 years (2014-2019) for all 64 principal salmon rivers. The dashed horizontal lines show mean declared rod catches during lockdown and other periods of the year in the preceding 6 years.

Table A2. Summary of the statistical model contrasting declared rod catches during lockdown in 2020 with declared rod catches over the same period in each of the preceding 6 years (2014-2019).

Model	Coefficient	Estimate	Std. Error	df	t value	Pr(>|t|)	Significance
Year	(Intercept)	0.14	0.065	91	2.2	3.2e-02	*
Year	Year2014	0.28	0.040	370	6.9	0.0e+00	***
Year	Year2015	0.31	0.040	370	7.8	0.0e+00	***
Year	Year2016	0.30	0.040	371	7.5	0.0e+00	***
Year	Year2017	0.26	0.040	370	6.6	0.0e+00	***
Year	Year2018	0.23	0.040	370	5.7	0.0e+00	***
Year	Year2019	0.20	0.040	370	4.9	1.2e-06	***

Given the difference in declared rod catches during lockdown in 2020 compared to each of the preceding 6 years, a statistical model was developed to provide an objective and river-specific correction to the 2020 declared rod catches. This model compared declared rod catches during lockdown in 2020 and the mean declared rod catches over the same period in the preceding 6 years. It was confirmed that this model better described observed rod catch than a model omitting a difference between 2020 and the mean of the preceding 6 years (Table A3).

Table A3. Comparison of statistical models with (year) and without (null) a term contrasting declared rod catches in lockdown in 2020 with the mean of declared rod catches for the same period in the preceding 6 years (2014-2019).

Model	Model terms	elpd_diff	se_diff	elpd_loo	se_elpd_loo	p_loo	looic	se_looic
m1	year	0.000	0.000	-174.840	20.091	27.216	349.680	40.181
m0	none	-2.212	1.469	-177.052	20.604	19.192	354.103	41.207

Model terms include year (year) and the null model (none). Also given is the difference in the expected log pointwise predictive density (elpd_diff) between the top-ranked and the other model, the standard error of the difference (se_diff) between the two models, the expected log pointwise predictive density (elpd_loo), the standard error of the expected log pointwise predictive density (se_elpd_loo), the difference between expected log pointwise predictive density and the non-cross-validated log posterior predictive density (p_loo), the leave-one-out information criterion (looic), and the standard error of the leave-one-out information criterion (se_looic).

Discussion

Monthly counts of adult salmon returning to the Rivers Dee and Tamar from March to May in 2020 were within the range of monthly counts observed over the preceding 6 years, indicating that the numbers of fish available for capture in 2020 were comparable to those available for capture in the preceding 6 years.

Declared angling effort before 16 June in 2020 was significantly lower than in the preceding 6 years. This was not the case after 16 June, where angling effort in 2020 was significantly higher than in 2018, and it was also similar to 2019. Rod catches during lockdown in 2020 were significantly lower than in the preceding 6 years, but this was not the case for other periods of the year when declared rod catches were higher than in 2014, 2015, 2018, and 2019, and similar to 2016. Therefore, declared angling effort and rod catches in 2020 were likely to have been constrained in the early part of the season when COVID-19 restrictions were most severe. Consequently, declared rod catches during the lockdown period in 2020 should be adjusted to account for the possible influence of the COVID-19 pandemic on angling activity.

Since anglers report the date when salmon are captured, specific adjustments can be made to declared rod catches during the COVID-19 lockdown period from the 23 March to the 12 May in 2020. Three options to adjust early season declared rod catches were considered:

1) Apply river-specific raising factors derived from a statistical model that quantifies the difference between declared rod catches from the 23 March to the 12 May in 2020 (i.e., the lockdown period) and mean declared rod catches over the same time period in the preceding 6 years.
2) Apply a raising factor based on the ratio between the declared rod catches from the 23 March to the 12 May in 2020 and the mean declared catches over the same period in the preceding 6 years calculated over all rivers combined.
3) Substitute river-specific declared rod catches from the 23 March to the 12 May in 2020 with mean declared rod catches over the same period in the preceding 6 years.

Option 1 was chosen because it was considered to be more sensitive than option 2 (i.e., it was river-specific) and not as naïve as option 3 (i.e., it could estimate a rod catch in a river in 2020 even if one had not been recorded in the preceding 6 years). The statistical model used to apply option 1 is a log-Normal hurdle model in which the hurdle sub-model is described by log10 + 1 of the river-specific mean rod catch in the preceding 6 years, and the log-Normal sub-model is described by a random intercept of River and an effect of Year indicating whether or not the rod catches were for 2020 or the mean of the preceding 6 years. The adjusted declared rod catches in 2020 for rivers without fish counters and/or traps resulting from the application of option 1 are shown in Figure A4.

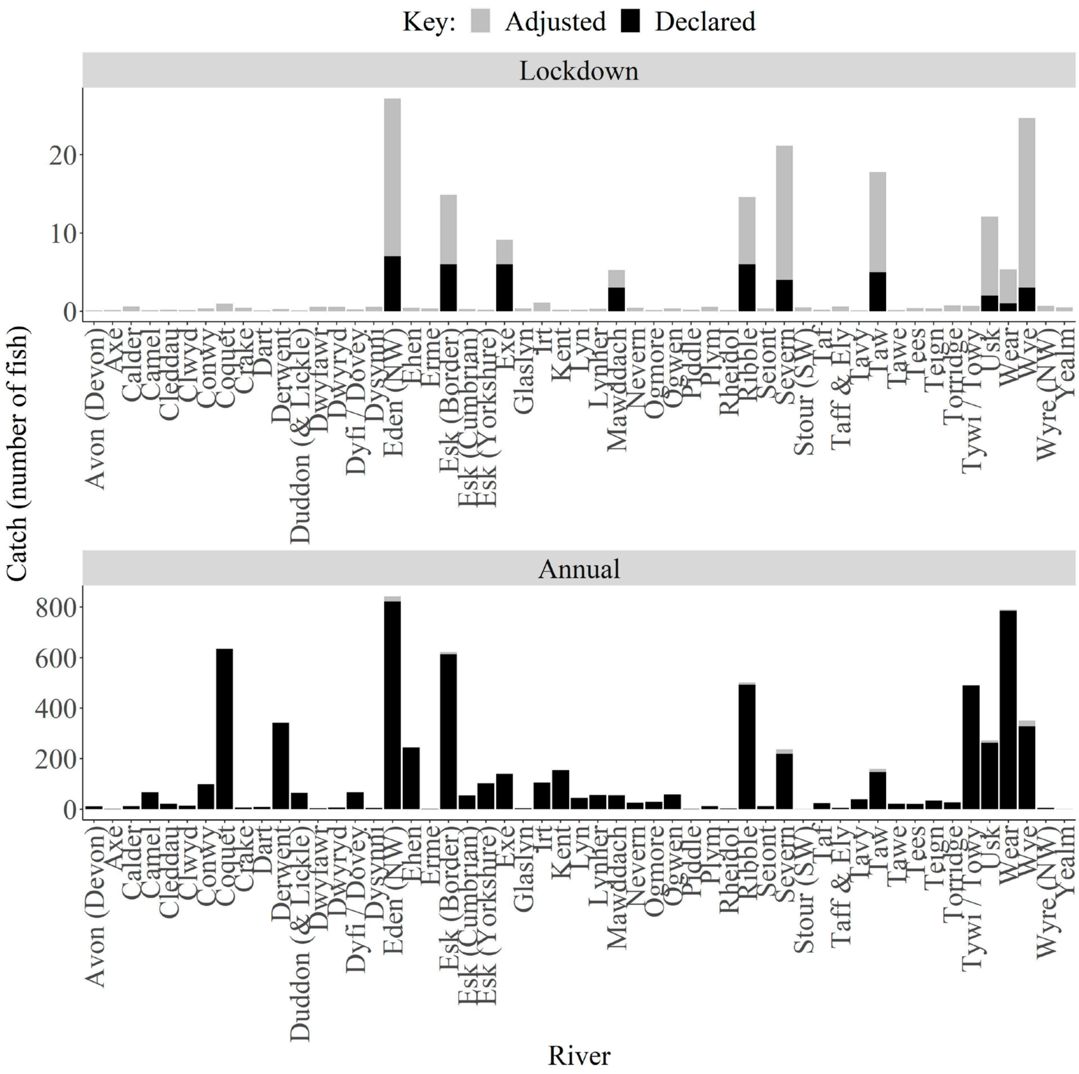


Figure A4. Bar plots showing the declared and adjusted rod catches during the lockdown period (top) and annually (bottom) in 2020 for the principal salmon rivers without fish counters and/or traps.

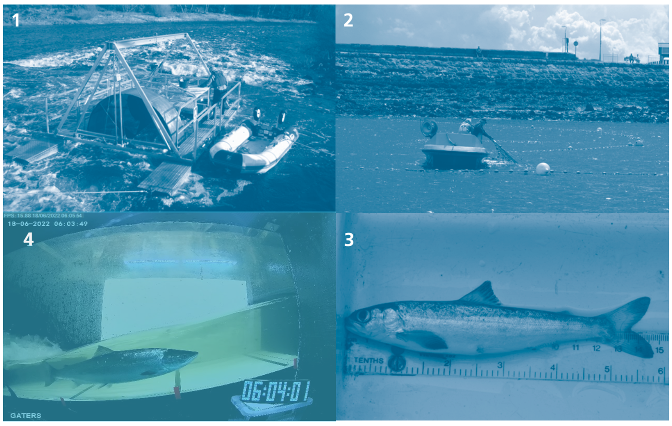
No adjustments to declared rod catches from the 23 March to the 12 May in 2020 were made to 11 principal salmon rivers (Tyne, Test, Itchen, Hampshire Avon, Frome, Tamar, Fowey, Lune, Leven, Teifi, and Dee) with fish counters and/or traps that provide RSEs because these are the primary data used in the derivation of egg deposition estimates. In addition, declared rod catches over this time period in 2020 were not adjusted on 11 rivers (Exe, Teign, Dart, Avon-Devon, Erme, Taw, Torridge, Lyn, Wye, Usk, and Mawddach) where modelled rod exploitation rates already accounted for annual changes in angling effort, and therefore included any effects of COVID-19 restrictions on angling activity.

Once the declared rod catches from the 23 March to the 12 May in 2020 for the other principal salmon rivers were adjusted, the standard procedure to generate egg deposition estimates was applied based on the following assumptions:

1) The adjusted declared rod catches from the 23 March to the 12 May in 2020 corrected for the impacts of the COVID-19 pandemic on angling activity.

2) All additional rod caught fish in the early part of the season (i.e., obtained from ‘1’ above) were corrected for catch declaration rates and considered to be MSW salmon of average weight and fecundity.

3) 100% catch-and-release rates were applied to all additional fish caught.



Front cover images (clockwise from top left)

1 – Rotary screw trap on the River Tyne (photo courtesy of Environment Agency)
2 – T net at South Shields (photo courtesy of Environment Agency)
3 – Salmon smolt from the River Frome (photo courtesy of Game and Wildlife Conservation Trust)
4 – A Salmon swimming over the Gaters Mill fish counter on the River Itchen. (photo courtesy of Dom Longley, Environment Agency.)

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