An Assessment of the Stressors Impacting Atlantic Salmon Stocks in UK - Wales

Background

Atlantic salmon (*Salmo salar*, hereafter salmon) are a highly valued and iconic anadromous fish species in Wales. The total abundance of salmon in Wales, however, has markedly declined during the last three decades, and in 2023, Wales recorded the lowest catches of salmon since consistent records began in the 1970's. Stock assessments show all 23 Principal Salmon Rivers in Wales are now categorised as being 'At Risk' of failing their management objectives (CEFAS, EA & NRW 2024).

The poor status of stocks necessitates urgent and transformative action to alleviate the causes of decline. Wales already has a Plan of Action for Salmon and Sea Trout (here) which seeks to address these pressures, and this has driven conservation and management initiatives over the past five years. These measures have included the implementation of fisheries and environmental regulations to protect and restore salmon stocks. Notably, legal salmon fisheries exploitation in Welsh waters has been reduced to zero through the implementation mandatory catch and release byelaws on all fisheries. Wales has also invested heavily in measures to improve access by addressing barriers for migratory fish.

In 2024, the North Atlantic Salmon Conservation Organization (NASCO) requested that each jurisdiction conduct an assessment of the stressors impacting salmon stocks (NASCO, 2024). Accordingly, the assessment presented below was undertaken to assess those stressors impacting on salmon stocks in Wales and to identify the three top ranked stressors at the national level. This assessment will be used to inform both a revision of the Plan of Action for Salmon and Sea Trout and Welsh Conservation Commitments for the 4th NASCO reporting cycle.

Methods

The assessment undertaken used a semi-quantitative classification system based on the approach devised by Forseth et al. (2017) and Gillson et al. (2022).

This approach was applied to determine the relative impact of stressors on Welsh salmon stocks at present and projected over the next decade. Thus, the first dimension, the effects axis, describes the assessed effect of each stressor on salmon, and the second dimension, the development axis, represents the likelihood of development over the next decade. Combined, the effects and development axes form a 2-D classification system that can be used to categorise stressors into four major impact groups: (1) expanding high impact, (2) stabilised high impact, (3) expanding low impact, and (4) stabilised low impact.

Twenty-four stressor categories were identified as relevant to Welsh salmon stocks based on expert opinion and a review of the literature, and with reference to the Second State of Natural Resources Report (NRW 2020) and the State of Nature Report (State of Nature Partnership 2023) (Table S1).

Expert opinion was used to inform the assessment of the severity, extent, and potential future development of stressors impacting salmon stocks. A survey questionnaire was sent to Natural Resources Wales (NRW) fisheries technical staff as well as external stakeholders via NRW's Wales Fisheries Forum. The consultees were asked to assess each stressor's effects and development for *Wales as a whole*.

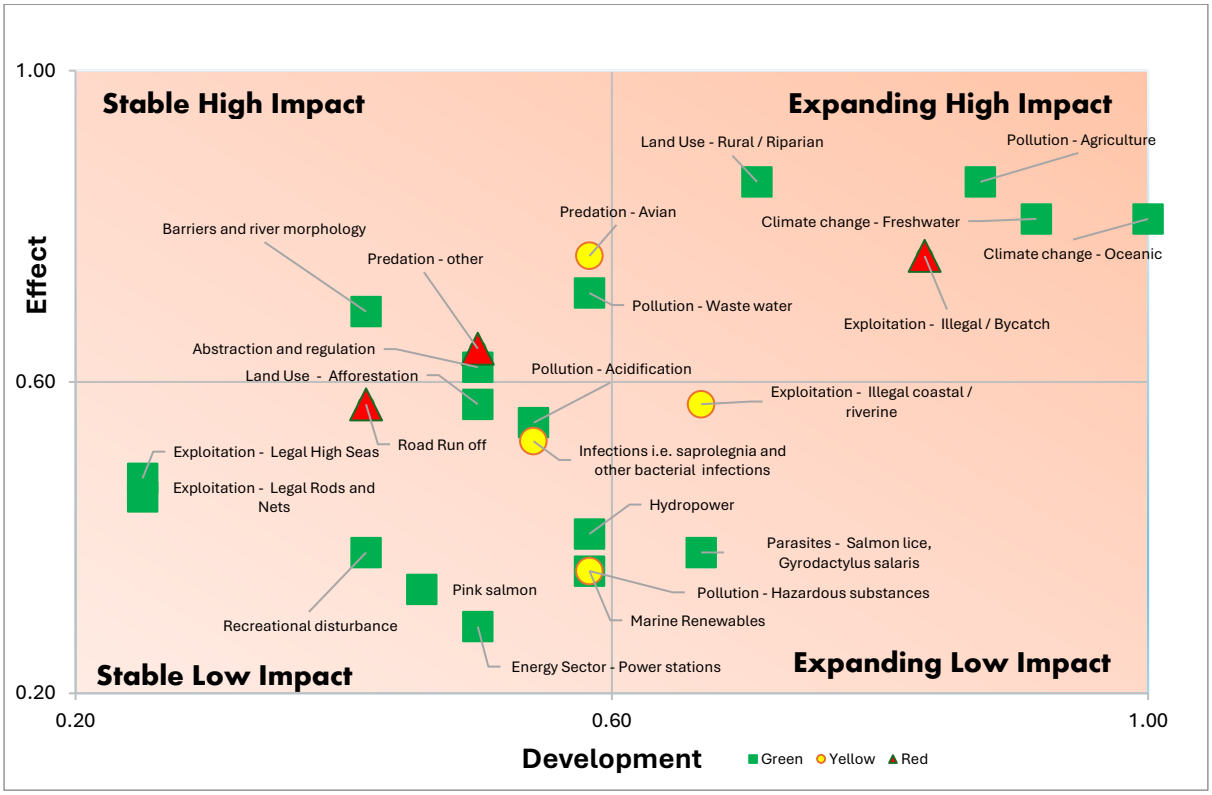
A total of 13 responses were received, comprising mostly NRW fisheries staff (9), as well as two from fishery representatives, one from a university and one from an NGO. Median scores were calculated for each stressor from these responses, and these were used to plot the 2-D effects / development (Figure 1, Table S2).

Each stressor was assigned to one of the four major impact groups, and they were ranked based on a combined effects x development score (Table S3).

Results

Overall, the top ranked stressors impacting salmon stocks in Wales were: (1) Climate Change (Ocean) (2) Agricultural Pollution, and (3) Climate change (Freshwater). Other perceived expanding high impact stressors were (4) high seas bycatch and (5) agricultural land use changes.

Figure 1: The national summary plot showing the location within the classification system of the 24 stressors based on mean scores across the 23 Principal Salmon Rivers in Wales, colour coded by knowledge and confidence score (green = extensive knowledge and high confidence, yellow = moderate knowledge and medium confidence, red = poor knowledge and low confidence).



Climate change impacts in the freshwater and marine environments both ranked highest on the development axis, and agricultural water pollution was perceived to have the highest effect score. Confidence in these assessments was high.

Many respondents also had concerns about the possible loss of salmon as bycatch in high seas pelagic fisheries, however the level of confidence in this assessment was low.

There was a high confidence in the assessment that changing agricultural land use was adversely affecting salmon stocks in Wales.

Given that the two stressors affecting salmon in the high seas are not directly something Wales can influence, it was agreed that the three top stressors should include those that can be directly influenced and managed within Wales. Hence the three stressors that will be prioritised for urgent and transformative action will be;

1. Climate change on freshwater systems,
2. Water quality (principally from agricultural sources) and,
3. Impacts of land use change on riparian and riverine habitats.

Future development

The next stage of this work is to develop appropriate mitigation measures for the prioritised stressors. Whilst NASCO requires each jurisdiction to develop a plan that addresses the top three stressors; in revising the Salmon and Sea Trout Plan of Action for Wales, we will also need to consider measures that address all key current and potential stressors. This will also need to consider how, and by whom, the issues outside of Wales are being addressed.

Our approach to identifying and prioritising appropriate and cost-effective measures will focus on those actions that can potentially address multiple stressors, as well as providing additional benefits to the wider freshwater ecosystem. Hence potential measures will include riparian tree planting, catchment river restoration and natural flood management to help address the impacts of climate change.

NRW is committed to the principles of Sustainable Management of Natural Resources (SMNR) (NRW 2020) and so will seek to engage with others, especially the rivers trusts, to develop evidence-based measures that address root causes wherever possible.

We will continue to collaborate with landowners and farmers to support improvements in habitat and implement more environmentally friendly agricultural practices. We will also seek to identify the most appropriate scale as which measures should delivered, and by whom.

In addition, in recognition of the limitations of this assessment, we believe a more quantitative approach to assessing the stressors effecting Wales would be beneficial.

References

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Supplementary information

Table S1. A list of the nineteen stressor categories identified as relevant to English salmon stocks based on expert opinion and a review of the literature.

Stressor Name	*Stressor Description*
Barriers and river habitat	Loss or degraded habitat and impacts on migration arising from new and historic man made in-channel structures, modified channels, culverts
Road Run off	Impacts arising from physical / chemicals contamination
Land Use Afforestation	Impact of tree-planting and afforestation including chemical, soils run off and peat loss
Land Use Rural / Riparian	Impacts from rural land management affecting riparian and in-river habitat as well as soil and sediment loss to rivers, including agricultural intensification
Invasive Non-Native Species (INNS)	General threat from INNS and specific threat of pink salmon
Parasites	Impacts of salmon lice and Gyrodactylus salaris
Infections	e.g. Saprolegnia, red vent syndrome, red skin disease, and other bacterial infections
Water Abstraction and regulation	Anthropogenic factors effecting flows such as reservoir releases and water abstraction
Pollution: Acidification	Comprising atmospheric deposition, catchment geology
Pollution: Agriculture	All pollutants arising from agricultural practices inc. slurry, sediment, nutrients, pesticides
Pollution: Wastewater	All pollutants arising from consented and unconsented wastewater discharges and septic tanks
Pollution: Hazardous substances	All chemical contaminants from consented and unconsented releases to the land or water
Exploitation: Legal Rods and Nets	Losses from regulated rod and net fisheries in freshwater, estuarine and coastal waters
Exploitation: Legal High Seas	Losses from regulated high seas net fisheries e.g. (West Greenland salmon fishery)

Exploitation: High Seas Bycatch or Illegal fishing	Losses from either unregulated / illegal high seas net fisheries or bycatch in pelagic net fisheries
Exploitation: Illegal coastal / riverine	Losses from illegal / unreported fishing in freshwater, estuarine and coastal waters
Recreational disturbance	Losses arising from any recreation activities that may disturbance or damage fish and their spawning grounds
Predation: Avian	Losses from bird predation in freshwater and estuarine environments
Predation: other	Losses due to mammalian or piscivorous predation in freshwater, estuarine and coastal environments
Energy Sector: Power stations	Losses from hydrocarbon or nuclear power station in freshwater, estuarine or coastal waters
Energy Sector: Marine renewables	Losses arising from marine and estuarine wind and tidal energy projects, e.g. lagoons, tidal barrages, power stations & wind farms
Energy Sector: Hydro power	Losses arising from hydropower schemes in the freshwater environment
Climate change: Freshwater	Climate driven changes in weather patterns affecting river temperatures and flows
Climate Change Oceanic	Climate driven changes in marine ecosystems including marine prey abundance and distribution, changes in oceanic currents.

Table S2. Classification of the different stressors along the (a) effects and (b) development axes for Welsh salmon stocks averaged across the 23 Principal Salmon Rivers.

	Criteria and scoring	Barriers and river morphology	Road Run off	Forestry	Land Use - Agriculture	INNS Pink salmon	*Parasites*	Infectious disease	Abstraction and regulation	Pollution Acidification	Pollution - Agriculture	Pollution - Waste water	Pollution - Hazardous substances	Exploitation - Legal Rods and Nets	Exploitation - Legal High Seas	Exploitation - High Seas bycatch	Exploitation - Illegal coastal / riverine	Recreational disturbance	Predation - Avian	Predation - other	Energy Sector - Power stations	Marine Renewables	Hydropower	Climate Change - Freshwater	Climate Change - Oceanic
a) Effect axis: characteristics considered																									
Number of rivers affected	0:0, 1: 1-5, 2: 6-10, 3: 11–15, 4: >15	4.00	4.00	2.00	4.00	0.00	0.00	2.00	2.00	2.00	4.00	3.00	1.00	2.00	2.00	2.00	4.00	1.00	3.00	2.00	1.00	1.00	2.00	4.00	4.00
2 Geographical distribution:	1: Local 2 :Scattered 3: Regional 4: National	3.00	4.00	4.00	4.00	3.00	4.00	3.50	4.00	3.00	4.00	4.00	2.00	3.50	4.00	4.00	2.00	2.00	4.00	4.00	1.00	2.00	2.00	4.00	4.00
3 Reductions in returning adults Typical effects due to reduced production capacity or reduced	1: Small reduction < 10% 2: Moderate reduction 10-25% 3: Large reduction 25–75% 4: Very large reduction > 75%	2.00	1.00	1.00	3.00	1.00	1.00	1.00	2.00	1.00	3.00	2.00	1.00	1.00	1.00	3.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	4.00	4.00
4 Number of lost or	1: 1-5, 2: 6-10, 3: 11–15, 4: >15	3.50	1.00	2.00	4.00	0.00	0.00	1.00	3.00	3.00	4.00	4.00	1.00	2.00	2.00	4.00	2.00	1.00	4.00	2.50	1.00	1.00	1.00	4.00	4.00
5 Implemented mitigation measures That have reduced the effects or likelihood of losing populations	1: Extensive, with large effects 2: Many, with good effects 3: Few, or measures with small effects 4: Very few/no, or measures without net effect	2.00	2.00	3.00	3.00	3.00	3.00	3.50	2.00	2.50	3.00	2.00	2.50	1.00	1.00	3.00	3.00	3.00	3.00	4.00	2.00	2.50	2.50	1.00	1.00
Sum (maximum 21)	**Sum of effects questions 1-5**	**14.50**	**12.00**	**12.00**	**18.00**	**7.00**	**8.00**	**11.00**	**13.00**	**11.50**	**18.00**	**15.00**	**7.50**	**9.50**	**10.00**	**16.00**	**12.00**	**8.00**	**16.00**	**13.50**	**6.00**	**7.50**	**8.50**	**17.00**	**17.00**
Complied relative effect (0–1)	Sum of effects questions 1-5 divided by 21	0.69	0.57	0.57	0.86	0.33	0.38	0.52	0.62	0.55	0.86	0.71	0.36	0.45	0.48	0.76	0.57	0.38	0.76	0.64	0.29	0.36	0.40	0.81	0.81
(b) Development axis: characteristics considered																									
1 Potential for effective measures Projection of present situation	1: Extensive and very effective measures planned 2: Several and effective measures planned 3: Some effective measures, or measures with small effects planned 4: Few/no effective measures planned	2.00	2.00	3.00	3.00	3.00	3.00	4.00	2.00	3.00	3.00	3.00	3.00	1.00	1.00	4.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00
2 Likelihood of further losses in adult returns Projection of present situation	1: Low 2. Moderate 3. high 4. very high	2.00	2.00	2.00	3.00	1.50	2.00	1.50	2.00	1.50	4.00	2.00	2.00	1.00	1.00	3.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	4.00	4.00
3 Likelihood of additional populations becoming critically endangered or lost	1: Low 2. Moderate 3. high 4. very high	1.00	1.00	1.00	2.50	1.00	3.00	1.00	2.00	2.00	3.50	2.00	2.00	1.00	1.00	3.00	2.00	1.00	2.00	1.00	1.00	2.00	2.00	4.00	4.00
Development Scores	Sum of development questions 1-3	5.00	5.00	6.00	8.50	5.50	8.00	6.50	6.00	6.50	10.50	7.00	7.00	3.00	3.00	10.00	8.00	5.00	7.00	6.00	6.00	7.00	7.00	11.00	12.00
Compiled development (0–1)		0.42	0.42	0.50	0.71	0.46	0.67	0.54	0.50	0.54	0.88	0.58	0.58	0.25	0.25	0.83	0.67	0.42	0.58	0.50	0.50	0.58	0.58	0.92	1.00
c(c) Knowledge and confidence characteristics considered																									
Knowledge How good is our knowledge on this issue?	Extensive = 1, moderate = 2, poor = 3	1.00	3.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	3.00	1.00	1.00	1.00	1.00	2.00
Uncertainty of projected development	Small = 1, moderate = 2, large = 3	1.00	3.00	2.00	2.00	1.00	2.00	2.00	2.00	1.00	2.00	2.00	2.00	1.00	1.00	3.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00
Knowledge and confidence score	Sum of development questions 1 and 2 (range 2-6)	2.00	6.00	3.00	3.00	2.00	3.00	4.00	3.00	2.00	3.00	3.00	4.00	2.00	3.00	6.00	4.00	3.00	4.00	5.00	3.00	3.00	3.00	2.00	3.00
Knowledge and confidence category (derived from knowledge and confidence score)	1. Extensive knowledge and high confidence (<4), 2. Moderate knowledge and medium confidence (4 to <5), 3. Poor knowledge and low confidence (5 to 6)	1	3	1	1	1	1	2	1	1	1	1	2	1	1	3	2	1	2	3	1	1	1	1	1

Table S3. A summary of the stressor rankings, average development and effects scores, and impact group categorisation, * including the three stressors deemed most appropriate to focus on in the Wales Conservation Commitment Plan. Stressors are colour coded by knowledge and confidence score; green = extensive knowledge and high confidence, yellow = moderate knowledge and medium confidence, red = poor knowledge and low confidence.

Rank	Stressor	Mean Development Score	Mean Effect Score	Combined score (development x effect)	Impact Group
1	Climate change - Oceanic	1.00	0.81	0.81	Expanding High Impact
2*	**Pollution - Agriculture**	**0.88**	**0.86**	**0.75**	**Expanding High Impact**
3*	**Climate change - Changing weather patterns / river temperatures**	**0.92**	**0.81**	**0.74**	**Expanding High Impact**
4	Exploitation - Bycatch	0.83	0.76	0.63	Expanding High Impact
5*	**Land Use - Agriculture**	**0.71**	**0.86**	**0.61**	**Expanding High Impact**
6	Predation - Avian	0.58	0.76	0.44	Stable High Impact
7	Pollution - Waste water	0.58	0.71	0.42	Stable High Impact
8	Exploitation - Illegal coastal / riverine	0.67	0.57	0.38	Expanding Low Impact
9	Predation - other	0.50	0.64	0.32	Stable High Impact
10	Abstraction and regulation	0.50	0.62	0.31	Stable High Impact
11	Pollution - Acidification	0.54	0.55	0.30	Stable Low Impact
12	Barriers and River Habitat	0.42	0.69	0.29	Stable High Impact
13	Land Use - Afforestation	0.50	0.57	0.29	Stable Low Impact
14	Infections i.e. saprolegnia and other bacterial infections	0.54	0.52	0.28	Stable Low Impact
15	Parasites - Salmon lice, Gyrodactylus salaris	0.67	0.38	0.25	Expanding Low Impact
16	road run off	0.42	0.57	0.24	Stable Low Impact
17	Energy Sector - Hydro power	0.58	0.40	0.24	Stable Low Impact
18	Pollution - Hazardous substances	0.58	0.36	0.21	Stable Low Impact
19	Energy Sector - Marine renewables	0.58	0.36	0.21	Stable Low Impact
20	Recreational disturbance	0.42	0.38	0.16	Stable Low Impact
21	Pink salmon	0.46	0.33	0.15	Stable Low Impact
22	Energy Sector - Power stations	0.50	0.29	0.14	Stable Low Impact
23	Exploitation - Legal High Seas	0.25	0.48	0.12	Stable Low Impact
24	Exploitation - Legal Rods and Nets	0.25	0.45	0.11	Stable Low Impact