An assessment of the stressors impacting Atlantic salmon stocks in UK - England

Background

Most Atlantic salmon (*Salmo salar,* hereafter salmon) stocks are in depleted states in England, with only five out of the 42 Principal Salmon Rivers (PSRs) meeting or exceeding their Conservation Limits (CLs) in 2023 (Cefas et al., 2024). Consequently, urgent transformative management action is required to alleviate stressor impacts on these stocks.

Recent and ongoing conservation and management initiatives include the implementation of fisheries and environmental regulations to protect and restore salmon stocks in England. Notably, salmon fisheries exploitation in domestic waters has been substantially reduced, with no commercial exploitation by net fisheries and high levels (~95%) of catch-and-release fishing in recreational rod fisheries since 2019. As such, only 259 out of a total of 5,188 rod-caught salmon were retained in 2023.

In 2024, the North Atlantic Salmon Conservation Organization (NASCO) requested that Parties/Jurisdictions undertake assessments of the stressors impacting salmon stocks (NASCO, 2024). Accordingly, the assessment presented below had three objectives: (1) review and collate questionnaire responses to inform the assessment of stressor impacts on salmon stocks in England, based on the approach applied by Natural Resources Wales; (2) apply a classification system to evaluate the major threats to English salmon stocks, based on the approach of Forseth et al. (2017) and Gillson et al. (2022); and (3) identify the three top-ranked stressors affecting salmon stocks in England.

Methods

A classification system based on the approach developed by Forseth et al. (2017) and Gillson et al. (2022) was applied to determine the relative impact of stressors on English salmon stocks at present and projected over the next decade. Thus, the effects axis describes the assessed current impact of each stressor on salmon, and the development axis represents the projected change over the next decade. Combined, the effects and development axes form a 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.

Nineteen stressor categories were identified as relevant to English salmon stocks based on expert opinion and a review of the literature (Table S1). A questionnaire that enabled the scoring and assessment of the perceived effects, potential future development, and the level of knowledge/confidence for each stressor was designed and then distributed to governmental and non-governmental experts (Table S2). Consultation with these experts ensured the involvement of specialists who understand the issues salmon face at the catchment-scale and their inclusion in determining priority stressors and the co-delivery of future management actions. Scores for each stressor in each of the 42 PSRs were provided by at least one Environment Agency fisheries officer responsible for the management of the river stock, and one or more external stakeholder/s in most cases. In total, 114 respondents (47 Environment Agency staff and 67 external stakeholders) provided stressor scores to inform the assessment (Table S3). This approach enabled the aggregation of catchment-scale scores to inform both regional- and England-wide assessments. In doing so, the geographic variation in stressor impacts could be evaluated, taking into account differences in catchment characteristics. Median scores were calculated for each PSR to minimise the influence of extreme values, and then the mean of these medians was calculated across rivers to derive an overall national score for each stressor (Table S2). Each stressor was subsequently assigned into one of the four major impact groups (Figure 1, Table S4). The three top-ranked stressors nearest the top right-hand corner of the classification system were assessed to have the greatest overall impacts on salmon stocks in England.

Results

The three top-ranked stressors impacting salmon stocks in England based on catchment-specific assessments were: (1) climate change, (2) water quantity, and (3) predation. Other perceived expanding high impact stressors were agricultural pollution, waste-water pollution, and habitat alteration (Figure 1).

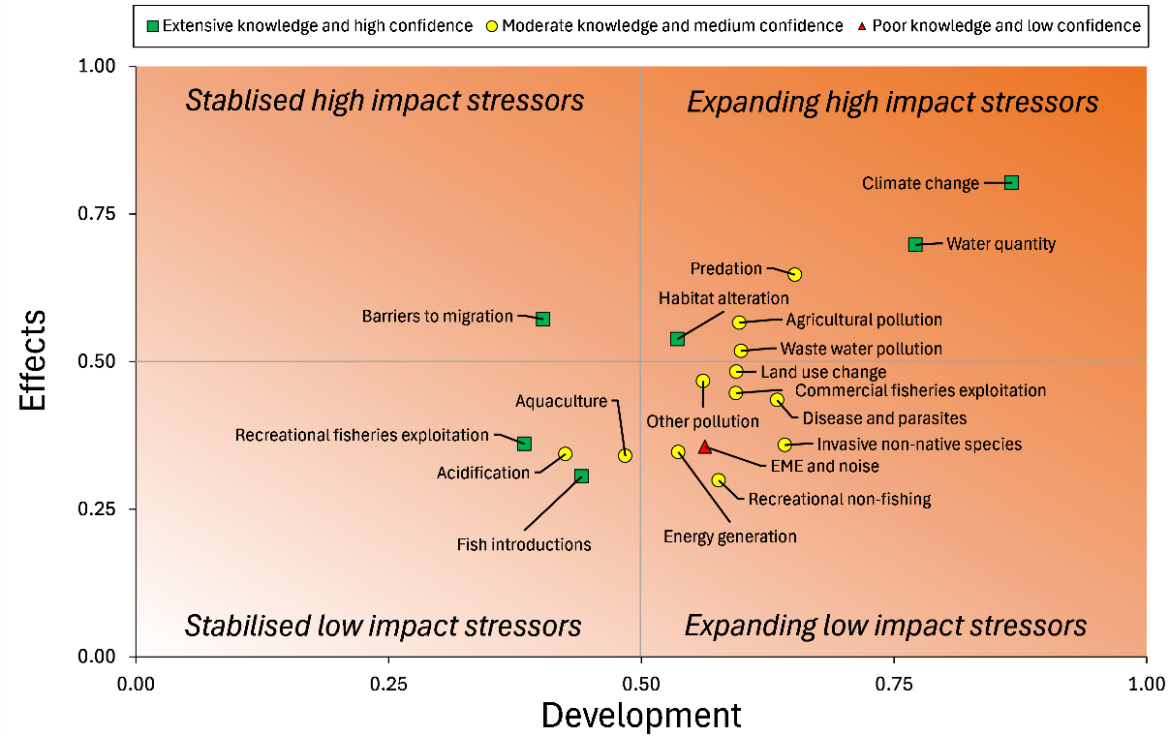

Figure 1. Summary plot showing the position in the classification system of the 19 stressors based on mean median scores across the 42 Principal Salmon Rivers in England, indicating those with extensive knowledge/high confidence (green squares), moderate knowledge/medium confidence (yellow circles), and poor knowledge/low confidence (red triangle). The gridlines delineate the categories used in the ranking, with the names of the four major impact groups shown in italics.

Climate change ranked highest on the effects and development axes, representing the stressor considered to be having the greatest overall impact on salmon stocks in England. Respondents expressed concerns about the effects of climate change on water temperature, river flow, and broad-scale oceanographic changes in the marine environment. Water quantity was ranked as the second highest stressor impacting English salmon stocks, with droughts, floods and abstraction identified as key issues. Predation was ranked third, with birds, mammals, and fish identified as the main predators of salmon. Agricultural pollution was the fourth top-ranked stressor, with organic enrichment, eutrophication, and sedimentation considered to be the biggest issues.

Future development

The next stage of this work is to confirm which stressors England will focus on in the 'Conservation Commitments' document and to engage with stakeholders to develop appropriate mitigation measures for the prioritised stressors. Some questions under consideration are:

1) As climate change is a ubiquitous stressor that exacerbates the impacts of other pressures, should its impacts be tackled in isolation, or considered in relation to each stressor?
2) Predation is a natural process, but it can be exacerbated by anthropogenic factors, such as barriers to migration increasing vulnerability to predation events. Therefore, would it be more fruitful to prioritise anthropogenic rather than naturally occurring stressors?
3) What mitigation measures for the prioritised stressors are suitable and achievable, and how can their effectiveness be assessed?

As this assessment was based on expert opinion, a more quantitative approach to evaluate stressor impacts on salmon stocks in England would be beneficial. Relevant datasets that would enable quantitative analyses to be undertaken have already been identified (Cefas, 2024), and ultimately an interactive map to assist fishery managers to identify specific local issues and develop targeted management actions could be developed (e.g., Fiske et al., 2024).

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 category	Example pressures within category
Energy generation	Hydropower, tidal lagoons, tidal barrages, power stations, wind farms, water source heat pumps, wave power, petrochemical
Water quantity	Extreme high and low flow events (i.e., floods and droughts), water abstraction
Agricultural pollution	Sediment, dissolved oxygen, contaminants, bio-chemical oxygen demand, pH, nitrate, ammonia, phosphate, eutrophication, pesticides
Waste water pollution	Consented discharges, unconsented discharges, combined sewer overflows, contaminants, sea outfalls, pharmaceuticals, septic tanks
Acidification	Atmospheric deposition, catchment geology
Other pollution	Metals, hazardous substances, contaminants, urban and road run-off, episodic pollution events, petrochemicals
Barriers to migration	In-channel structures, modified channels, culverts
Habitat alteration	Quality and quantity of available suitable habitats
Land use change	Afforestation, deforestation, urbanisation, agricultural intensification
Disease and parasites	*Gyrodactylus salaris*, saprolegnia, sea lice, red vent syndrome, gill disease, red skin disease
Aquaculture	Marine trout and salmon farms, freshwater trout and salmon farms
Fish introductions	Salmon stocking, trout stocking, coarse fish stocking
Predation	Predatory mammals, birds and fish
Invasive non-native species	Pink salmon, non-native crayfish, American mink, mitten crab
Recreational fisheries exploitation	Rod fisheries, heritage fisheries; illegal, unreported and unregulated fishing
Commercial fisheries exploitation	Coastal net fisheries, high sea fisheries, by-catch, illegal, unreported and unregulated fishing
Climate change	Water temperature, river flows, marine prey abundance and distribution, changes in oceanic currents
Recreational non-fishing activities	Canoeing, wild swimming, other water-based recreation
Electromagnetic energy and underwater noise	Artificial lighting, electromagnetic fields, underwater noise

Table S2. Classification of the different stressors along the (a) effects and (b) development axes for English salmon stocks averaged across the 42 Principal Salmon Rivers.

Criteria and scoring		Energy generation	Water quantity	Agricultural pollution	Waste water pollution	Other pollution	Acidification	Barriers to migration	Habitat alteration	Land use change	Disease and parasites	Aquaculture	Fish introductions	Predation	Invasive non-native species	Recreational fisheries exploitation	Commercial fisheries exploitation	Climate change	Recreational non-fishing	EME and noise
(a) Effect axis characteristics considered																				
1. Impact on eggs, fry, and parr	0: None–10: High	1.98	7.23	6.32	5.13	4.55	2.83	4.32	5.89	5.15	2.43	1.56	2.29	5.98	3.50	1.62	1.35	8.04	2.05	1.08
2. Impact on smolts	0: None–10: High	2.94	6.70	5.02	4.49	4.00	2.60	5.80	4.23	3.70	2.70	2.69	2.21	6.57	2.17	1.74	3.95	7.33	1.51	2.72
3. Impact on adults	0: None–10: High	2.81	6.77	4.70	4.60	3.77	2.11	6.42	5.04	4.02	4.46	2.83	1.81	4.96	2.00	4.62	6.30	7.77	2.02	3.35
4. Habitat types affected (marine/estuarine/freshwater)	0: None, 1: One, 2: Two, 3: Three[1]	2	2	2	2	2	2	2	2	2	3	2	2	3	2	3	2	3	2	3
5. Effectiveness of implemented mitigation measures	1: Very effective, 2: Moderately effective, 3: Not very effective, 4: Not effective	3.11	3.12	2.89	2.95	2.96	3.18	2.62	2.75	3.00	3.50	3.51	2.99	3.43	3.61	2.37	2.93	3.56	3.48	3.02
Effects Score (maximum 37)	Sum of effects questions 1-5	12.83	25.82	20.94	19.17	17.29	12.71	21.15	19.90	17.87	16.10	12.60	11.30	23.94	13.27	13.35	16.52	29.70	11.06	13.17
Compiled relative effect (0–1)	Sum of effects questions 1-5 divided by 37	0.35	0.70	0.57	0.52	0.47	0.34	0.57	0.54	0.48	0.44	0.34	0.31	0.65	0.36	0.36	0.45	0.80	0.30	0.36
(b) Development axis characteristics considered																				
1. Likelihood of stressor becoming more prevalent in next 10 years	0: Nil–10: Extremely	4.83	8.05	5.64	5.86	4.89	2.93	3.31	4.98	5.63	5.62	3.63	3.27	5.91	5.93	3.29	5.40	8.88	4.76	4.94
2. Projected effectiveness of planned measures to reduce impacts in the next 10 years	1: Very effective, 2: Moderately effective, 3: Not very effective, 4: Not effective	2.68	2.75	2.71	2.52	2.96	3.02	2.33	2.52	2.68	3.26	3.15	2.90	3.21	3.06	2.10	2.90	3.25	3.31	2.94
Development Score (maximum 14)	Sum of development questions 1 and 2 (maximum 14)	7.51	10.80	8.36	8.38	7.86	5.95	5.64	7.50	8.32	8.88	6.78	6.17	9.13	8.99	5.38	8.31	12.13	8.07	7.88
Compiled relative development (0–1)	Sum of development questions 1 and 2 divided by 14	0.54	0.77	0.60	0.60	0.56	0.42	0.40	0.54	0.59	0.63	0.48	0.44	0.65	0.64	0.38	0.59	0.87	0.58	0.56
(c) Knowledge and confidence characteristics considered																				
1. Knowledge base for effects evaluation	1: Extensive, 2: Moderate, 3: Poor	2.08	1.80	1.83	1.94	2.24	2.11	1.49	1.76	2.04	2.24	1.99	1.79	1.87	2.11	1.64	2.27	1.81	2.17	2.54
2. Confidence in projected development	1: High, 2: Medium, 3: Low	2.36	2.11	2.23	2.31	2.58	2.45	2.08	2.04	2.34	2.57	2.43	2.01	2.32	2.36	1.90	2.44	2.11	2.36	2.52
Knowledge and confidence score	Sum of development questions 1 and 2 (range 2-6)	4.44	3.90	4.06	4.25	4.82	4.56	3.57	3.80	4.38	4.81	4.41	3.81	4.19	4.46	3.55	4.71	3.92	4.52	5.06
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)	2	1	2	2	2	2	1	1	2	2	2	1	2	2	1	2	1	2	3

[1] Habitat types affected: these scores were rounded up to the nearest whole number to avoid presenting fractions for this criterion.

Table S3. A summary of the number of questionnaire respondents for each Principal Salmon River in England.

Region	River	Number of Environment Agency respondents	Number of external stakeholder respondents
North East	Coquet	1	1
	Tyne	1	9
	Wear	1	1
	Tees	1	0
	Yorkshire Esk	2	6
Southern (chalkstreams)	Itchen	1	2
	Test	2	2
	Hants Avon	1	4
	Stour	1	0
	Piddle	2	0
	Frome	2	1
South West	Axe	1	1
	Exe	1	2
	Teign	1	2
	Dart	1	5
	Avon (Devon)	1	0
	Erme	1	2
	Yealm	1	3
	Plym	1	1
	Tavy	1	1
	Tamar	1	3
	Lynher	1	1
	Fowey	1	0
	Camel	1	0
	Torridge	1	0
	Taw	1	3
	Lyn	1	1
Midlands	Severn	2	3
North West	Ribble	1	3
	Wyre	1	0
	Lune	1	2
	Kent	1	0
	Crake	1	0
	Duddon	1	0
	Esk (Cumbria)	1	0
	Irt	1	1
	Ehen	1	0
	Calder	1	1
	Derwent	1	3
	Eden	1	3
	Esk (Border)	1	0
	Leven	1	0
National	*All rivers*	*47*	*67*

Table S4. A summary of the stressor rankings, average development and effects scores, and impact group categorisation (colour coded by knowledge and confidence score; green = extensive knowledge and high confidence, yellow = moderate knowledge and medium confidence, and red = poor knowledge and low confidence). Stressors ranked by impact group and decreasing ordination distance from top right of the category box.

Rank	Stressor	Mean development score	Mean effects score	Impact group	Distance from top right of category box
1	Climate change	0.87	0.80	Expanding high impact	0.24
2	Water quantity	0.77	0.70	Expanding high impact	0.38
3	Predation	0.65	0.65	Expanding high impact	0.50
4	Agricultural pollution	0.60	0.57	Expanding high impact	0.59
5	Waste water pollution	0.60	0.52	Expanding high impact	0.63
6	Habitat alteration	0.54	0.54	Expanding high impact	0.66
7	Barriers to migration	0.40	0.57	Stabilised high impact	0.44
8	Disease and parasites	0.63	0.44	Expanding low impact	0.37
9	Invasive non-native species	0.64	0.36	Expanding low impact	0.38
10	Land use change	0.59	0.48	Expanding low impact	0.41
11	Commercial fisheries exploitation	0.59	0.45	Expanding low impact	0.41
12	Other pollution	0.56	0.47	Expanding low impact	0.44
13	EME and noise	0.56	0.36	Expanding low impact	0.46
14	Recreational non-fishing	0.58	0.30	Expanding low impact	0.47
15	Energy generation	0.54	0.35	Expanding low impact	0.49
16	Aquaculture	0.48	0.34	Stabilised low impact	0.16
17	Acidification	0.42	0.34	Stabilised low impact	0.17
18	Recreational fisheries exploitation	0.38	0.36	Stabilised low impact	0.18
19	Fish introductions	0.44	0.31	Stabilised low impact	0.20