

Table 1: Red-flag analysis for the Atlantic salmon and NEA mackerel production sectors.

Element	<i>RED – Factors for which the sector has limited resilience</i>	<i>AMBER – Factors for which the sector has some resilience</i>	<i>GREEN – Factors for which the sector has strong resilience</i>
<i>Adaptability of production in relation to environmental shocks – How well prepared is the sector for future environmental shocks?</i>	Based on historical performance sector production fell for substantial periods of time when faced with environmental shocks	Based on historical performance sector production recovered after a moderate period of time when faced with environmental shocks	Based on historical performance sector production recovered within a short period of time when faced with environmental shocks
<i>Adaptability of production in relation to market shocks – How likely is the sector to be able to respond to future shocks in demand?</i>	Based on historical performance sector production fell for substantial periods of time when faced with market shocks	Based on historical performance sector production recovered after a moderate period of time when faced with market shocks	Based on historical performance sector production recovered within a short period of time when faced with market shocks
<i>Stability of supply chain of inputs – How likely is the sector to be able to respond to changes in its inputs?</i>	Based on historical performance sector production fell for substantial periods of time when faced with input shocks	Based on historical performance sector production recovered after a moderate period of time when faced with input shocks	Based on historical performance sector production recovered within a short period of time when faced with input shocks
<i>Relationships – Does the way the sector is organised promote resilience to negative environmental and market shocks?</i>	Based on historical performance the organisation of the sector substantially harmed its ability to recover from negative environmental and market shocks	Based on historical performance the organisation of the sector was neutral in aiding its ability to recover from negative environmental and market shocks	Based on historical performance the organisation of the sector substantially aided its ability to recover from negative environmental and market shocks
<i>Employment - Does the way in which the sector employment is structured create resilience at the global level?</i>	Based on historical performance the organisation of the sector substantially harmed its ability to maintain employment at the global level	Based on historical performance the organisation of the sector was neutral its ability to maintain employment at the global level	Based on historical performance the organisation of the sector substantially aided its ability to maintain employment at the global level
<i>Employment - Does the way in which the sector employment is structured create resilience at the local level?</i>	Based on historical performance the organisation of the sector substantially harmed its ability to maintain employment at the local level	Based on historical performance the organisation of the sector was neutral its ability to maintain employment at the local level	Based on historical performance the organisation of the sector substantially aided its ability to maintain employment at the local level
<i>Expansion - How sustainable is the future growth of sector?</i>	Based on an overall consideration of production and market opportunities the sector is likely to face substantial problems in expanding further	Based on an overall consideration of production and market opportunities the sector is likely to face some problems in expanding further	Based on an overall consideration of production and market opportunities the sector is likely to be able to expand further in a sustainable manner

Note: A substantial period of time was defined as 5-10 years; a moderate period of time as 2-5 years and a short period as < 2 years

Table 2: Red-flag analysis for the Atlantic salmon and NEA mackerel production sectors

Element	Atlantic salmon	NEA mackerel
<i>Adaptability of production in relation to environmental shocks – How well prepared is the sector for future environmental shocks?</i>	UK farms generally well managed in relation to infectious disease control although chronic problems persist with parasites such as sea-lice and amoebic gill disease. In general production has been sustained or expanded through use of pharma and through development of regional treatment plans. The UK sector has not seen dramatic disease related drops in production as have occurred in Chile.	The stock is presently in a healthy condition but is being over-harvested. The proposed EU, Norway, Faroes management plan is considered precautionary by ICES, but Iceland is still not included. The UK fishery thus operates under trans-national fisheries management agreements which have been shown to be responsive to changes in stock abundance, but lack sufficient flexibility to respond to changing stock distribution. Problems of dealing with future environmental shocks thus appear to be largely political.
<i>Adaptability of production in relation to market shocks – How likely is the sector to be able to respond to future shocks in demand?</i>	Salmon is a higher value product with growing global appeal and demand, generally regarded as good for human health. Scottish-reared salmon is recognised as a premium brand. Recent geopolitical shocks have been largely overcome through market flexibility, especially for the larger multi-national producers.	Mackerel is a lower-value, higher-volume product with limited domestic (UK) spare demand and limited alternative export markets. Recent events have shown that such export focussed sectors are vulnerable to geopolitical events outside of the sectors influence. Although the sector has good working relationships with the Scottish, UK and EU administrations, it remains vulnerable to future shocks affecting demand.
<i>Stability of supply chain of inputs – How likely is the sector to be able to respond to changes in its inputs?</i>	Salmon farming is still heavily reliant on externally sourced fishmeal and fish-oil for feed despite efforts to find alternatives and success in reducing the overall levels of these components in feeds. The supply fishmeal and fish-oil is subject to shocks such as the 2015/16 El Niño event which affect supplies from the major industrial fisheries. Since such events may become more likely due to climate change, the development of more sustainable aqua-feeds is seen as critical by the industry. In the past the sector has responded to increased input prices by developing more efficient feeds and husbandry.	The pelagic industrial fisheries operate offshore so fuel is a major input cost. In the short-term, fuel prices have decreased significantly reducing operating costs for the catching sector. However, low oil prices have also affected the purchasing power of some of the countries mackerel are exported to, such as Nigeria. The sector would likely be negatively affected by future fuel price increases although this might be offset with more customer demand from oil producing countries. In the longer-term it is unclear how much can be done to reduce greenhouse-gas emissions in the fleet as this will depend on the development of alternative marine propulsion technologies.
<i>Relationships – Does the way the sector is organised promote resilience to negative environmental and market shocks?</i>	The trans-national organisation of salmon farming has allowed the management of global risk increasing the overall sector resilience, but local vulnerable economies can be strongly affected by decisions taken at corporate level, decisions over which local or national authorities have little control. A significant fraction of production still comes from national companies operating within single jurisdictions. These will have less flexibility to switch production between locations in response to shocks. The industry does however co-operate to jointly fund	The pelagic sector in the UK is well-organised and consolidated (and also within the EU) with strong trade associations which have allowed the sector to work effectively with UK and Scottish governments to limit the impact of negative shocks. The Pelagic Advisory Council is embedded within, and influential on, the EU fisheries management system. Outside of the EU there are problems linked to the political disputes over mackerel management with new entrant countries such as Iceland (and to some extent Faroes). In the past the sector

<p>Employment - Does the way in which the sector employment is structured create resilience at the global level?</p>	<p>research e.g. Scottish Aquaculture Innovation Centre, for mutual benefit. Of concern is production operating under differing national standards rather than the industry promoting higher standards throughout its operations.</p>	<p>organisation has been effective in securing sustainability certification for the bulk of the NEA mackerel fisheries.</p>
<p>Employment - Does the way in which the sector employment is structured create resilience at the local level?</p>	<p>The trans-national organisation of many of the larger production companies has allowed them to mitigate overall impacts by increasing production in areas less affected by historical shocks.</p>	<p>The pelagic sector in the NE Atlantic operates within regional waters although the products are widely exported. We were unable to find data on global employment structure of the downstream sector.</p>
<p>Expansion - How sustainable is the future growth of sector?</p>	<p>The sector has a largely employed work-force drawn from local populations within remote rural areas. In the UK many of these areas are on the Scottish west coast and islands and are classed as 'economically fragile' with relatively few alternative employment opportunities. Companies also employ at graduate level, for example as animal health managers and either employ, or sub-contract, at post-graduate level e.g. veterinary officers. Processing plants are generally located closer to slightly larger towns with better transport links for product export. However, there is limited resilience to decisions to cut the work-force, for example recent re-structuring within Marine Harvest's Scottish operations.</p>	<p>The catching sector is comprised of owner vessels with share-paid work-force drawn from wide geographical area, including overseas. The fishery is seasonal although good earnings can be made within each season. The actual fishery is short and quotas can be fully taken up in a few weeks of fishing so labour flexibility is naturally high. Labour reductions and fluctuations therefore probably have less concentrated effects on the local economies compared with salmon farming. The post-catch processing tends to be concentrated in plants closer to larger population centres and with better transport links for exporting the product but also wider alternative employment opportunities in the event of a down-turn.</p>
<p>Expansion - How sustainable is the future growth of sector?</p>	<p>Expansion in UK is presently limited by a lack of suitable new marine sites but this could potentially be overcome by allowing larger capacity at existing farms, development of more exposed sites or through the development of land-based systems. Expanding marine capacity at existing sites could however lead to environmental or health issues. Increased site exposure considerably increases engineering costs and potentially losses from storms. Exposure risks to harmful organisms such as algal blooms and jellyfish are not well understood for sites further offshore. Land-based rearing has the potential for much greater environmental control but at increased economic cost and must still comply with local planning regulations.</p>	<p>The sector has been expanding up till 2014 due to an increase in the stock size but it is acknowledged that this is likely part of a cycle and the stock is beginning to show signs of declining. In the long-term there is probably limited scope for further expansion unless there is a regime-shift in productivity. The strategic goal is therefore to achieve sustained exploitation rather than further expansion. Some further growth in earnings could be attained through value added and the main NEA mackerel fisheries recently re-attained MSC certification which should help protect market share.</p>

4 **APPENDIX A**

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6 **Table A: Major outbreaks of infectious salmon anaemia (reproduced from EFSA, 2012)**

Year	Country	Reference
1984	Norway	Thorud and Djupvik, 1988
1996	Canada	Mullins et al., 1998
1998	Scotland, UK	Rodger et al., 1998
2000	Faroe Islands	Christiansen et al., 2001
2001	USA	Bouchard et al., 2001
2007	Chile	Godoy et al., 2008 Mardones et al., 2009
2009	Scotland, UK	Murray et al., 2010

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19 **APPENDIX B**

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Table B: Pelagic vessels in the Scottish Pelagic Fishermens Association (Based on MMO UK Register of fishing vessels >10m in length Pelagic Fishermen's Association)

Vessel	Owner/Operator	Producer Org.	Home Port
Adenia II LK193	Adenia Fishing Co. Ltd., Anderson family	Shetland FPO	Whalsay, Shetland
Altaire LK429	Interfish & Duncan and Ramsay families	Shetland FPO	Northmavine, Shetland
Antarctic II LK145	Aurora Marine Ltd., Fiskebas Fishing Co.	Shetland FPO	Whalsay, Shetland
Challenge FR226	Tait family	Klondyke Fishing Co.	Fraserburgh
Charisma LK362	Charisma Fishing Co Ltd. – partner and crew owned	Shetland FPO	Whalsay, Shetland
Chris Andra FR228	Tait family	Klondyke Fishing Co.	Fraserburgh
Forever Grateful FR249	Excelsior Fishing	Scottish Fishermens Org.	Fraserburgh
Havilah N200	Glenluce Fishing Co., Orr family	Northern Ireland FPO Ltd.	Kilkeel, N. Ireland
Kings Cross FR380	Lunar Fishing Co Ltd. & Wiseman Fishing Company Ltd. (Wiseman family)	Lunar Group	Peterhead
Lunar Bow PD265	Lunar Fishing Co Ltd., Buchan family	Lunar FPO	Peterhead
Ocean Quest BF77	Westward Fishing Co. (Tait, Watt and West families)	Scottish Fishermens Org.	Fraserburgh
Ocean Venture FR77	Westward Fishing Co. (Tait, Watt and West families)	Scottish Fishermens Org.	Fraserburgh
Pathway PD165	Lunar Fishing Co Ltd., Buchan family	Lunar FPO	Peterhead
Quantus PD379	Buchan family	Scottish Fishermens Org.	Peterhead
Research LK62	Research Fishing Co. Ltd., share owned	Shetland FPO	Whalsay, Shetland
Resolute BF50	Agent Westward Fishing Co. (West family)	Scottish Fishermens Org.	Gardenstown
Stefanie-M N265	Stefanie-M Fishing Co. Ltd. (McCullough family)	Anglo-North Irish FPO	Belfast, N. Ireland
Sunbeam FR487	James Duthie, Caley Fisheries	Scottish Fishermens Org.	Fraserburgh
Taits FR227	Tait family	Klondyke Fishing Co.	Fraserburgh
Unity FR165	Unity Fishing Co. (Bellany family)		Fraserburgh
Zephyr LK394	Zephyr Fishing Co., Irvine family	Shetland FPO	Whalsay, Shetland

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24 **APPENDIX C: Further considerations on the workshop: Implementing transdisciplinarity:**
25 **tensions and opportunities**

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27 Analysing the sectoral and regional economic sustainability of two globalized sectors such as
28 farmed Atlantic salmon and NEA mackerel necessarily generated the need to explore and link socio-
29 ecological nexuses governed by different scientific idioms, such as ‘political science’, ‘research
30 communities’, and ‘definition of actor’. Despite our attempt to utilize social scientists to bridge
31 disciplines, we encountered some tensions within each group. The main areas of debate were around
32 reaching a mutual understanding of the terminology used by different researcher communities. A few
33 examples of this were: the definition of ‘consolidation’ (or ‘concentration’ as sometimes it had been
34 called) at production level, and definitions actor roles and scope. A significant outcome of the inter-
35 disciplinary workshop was the opportunity for mutual learning across disciplines which often have little
36 communication.

37 During our workshop, the major difficulties encountered were of two kinds. The first kind,
38 which could be labelled *horizontal*, was between natural scientists whose work focuses on the two
39 different sectors. These difficulties spurred mainly from understanding the socio-economic differences
40 and similitudes of the two sectors, especially when it came to depicting the role of government. The
41 second kind of difficulty can be labelled *vertical*, in that it arose between social-scientists and natural
42 scientists. Even though the workshop hosted two transdisciplinary scholars used to working with both
43 social and ecological modelling, still, the vocabulary and the role of demand in determining the
44 pressures over the production sectors were the major points of misunderstanding. Both differences were
45 overcome by precisely defining each problematic term (e.g. *consolidation*), and by creating a
46 cooperative environment. The overall positive atmosphere and commitment by the participants was a
47 key factor in overcoming these issues.

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49 **APPENDIX D**

Table D: The main Atlantic salmon producing companies and their contribution to the total national production in Norway, UK and Chile. Adapted from Marine Harvest (2015)

Top producing companies	% production		
	Norway	UK	Chile
Marine Harvest	24%	32%	13%
Salmar	13%	-	-
Leroy Seafood	12%	-	-
Cermaq	5%	-	9%
Nordlaks	4%	-	-
Scottish Salmon Com.	-	20%	-
Scottish Seafarms	-	18%	-
Grieg Seafood	4%	12%	-
Cooke Aquaculture	-	11%	3%
Salmones Multiexport	-	-	10%
Empresas AquaChile	-	-	10%
Pesquera Los Fiordos	-	-	9%
National market share	Top 10 companies=71%	Top 5 companies=93%	Top 10 companies=77%

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