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1 ***Environmental and socio-political shocks to the seafood sector: what does this mean for resilience?***
2 ***Lessons from two UK case studies, 1945-2016***

3
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22
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41 **1. Introduction**

42 Fisheries products have become globally traded commodities which has led to increasing
43 degrees of export dependency for producing regions (Brookfield et al, 2005; Salz and MacFayden,
44 2007; Jones et al, 2014). Such dependency generates several social and economic risks which become
45 accentuated at times of challenge to supply or demand (European Commission, 2010; Campling et al.,
46 2012; Jennings et al., 2016). The complexities inherent in the relations of exploitation and
47 commodification (Campling et al. 2012) are also influenced by extra-sectoral factors, such as natural
48 ecological shifts in productivity and politically-influenced free-trade agreements. Jennings et al. (2016)
49 suggested that sectoral-based analyses for fisheries often overlook important elements such as links
50 with environmental changes, human health and fish welfare. Recognising this transdisciplinary
51 complexity, the present work examines how two export-orientated sectors of major significance to the
52 UK, farmed Atlantic salmon (an aquaculture product) and North-east Atlantic mackerel (a capture
53 fishery) have responded to ecological, environmental and socio-political shocks, and how they have
54 maintained their microeconomic (i.e. sectoral) and macroeconomic (regional) viability.

55 The seafood industry is mediated by complex relationships within and across national
56 boundaries (Jennings et al., 2016). Producing regions, such as Scotland, may be part of a larger nation-
57 state (in this case the United Kingdom) whilst engaging with wider trading partnerships, such as the
58 European Economic Area (Österblom et al., 2015). Although individual companies compete for market
59 share, they may also collaborate for mutual benefit (Havice and Campling, 2017), e.g. on product
60 labelling, trading of fishing quotas or production standards (Sumaila et al., 2016). Furthermore, because
61 of the limited scope for further expansion of most capture fisheries, aquaculture has been identified as
62 a “focus area” with significant scope for further expansion, giving the seafood industry a dual nature,
63 composed of fisheries and aquaculture.

64 In this multidisciplinary examination of these two seafood sectors, this work applies both a
65 sectoral and a regional (UK) perspective. As the UK is currently a member of the EU, both these sectors
66 have to abide by both national and EU-level policies, the latter regulated through the Common Fisheries
67 Policy (CFP) (European Commission, 2013). The North-east Atlantic (NEA) mackerel and salmon

68 farming sectors were chosen for this study based on their importance to UK seafood production: NEA
69 mackerel is consistently the most landed species by Scottish vessels, accounting on average for 28% of
70 landings by weight and 18% of landings by value (Seafish, 2015); Atlantic salmon is the most important
71 reared fish in the UK, accounting for nearly 99% of the total UK aquaculture production by weight in
72 2012 (MGSA, 2014), and the most sold, imported and exported seafood product by value (Seafish,
73 2015b). The specific objectives of this study were to investigate: 1) how these two sectors have
74 responded to environmental, economic and geopolitical shocks which accompanied and influenced their
75 development; 2) to identify how structural differences or similarities between these two sectors have
76 influenced their ability to respond to these shocks; 3) to examine whether the degree of consolidation
77 within these two sectors has conferred economic resilience and how such resilience may influence their
78 future development. Consolidation is here defined as the aggregation at production level of multiple
79 firms through *Concentration and Centralization, foreign direct investment (FDI), and Association* as
80 defined by Havice and Campling (2017). Resilience is here defined and understood within the
81 conceptualization proposed by Brand and Jax (2007) of ‘ecological-economic’ resilience, and following
82 the definition of Perrings (2006). More generally, the term resilience can be traced to the post-classical,
83 ‘engineering-analogue’ meaning (Holling, 1996) introduced by Holling (1973) (Chandler, 2014).
84 Therefore, in this work the term ‘resilience’ describes the ability of a sector to adapt to exogenous
85 shocks. However, as it will be argued in the conclusions, this work also identifies a trend of rising
86 exposure to shocks linked to the expansion of these two sectors.

87 **2. Methods: Applying Transdisciplinary**

88
89 A three-day expert workshop was held in August 2015 to collectively analyse data and
90 literature on both sectors and to identify “red flags” linked with changes in production and trade flows.
91 For the purposes of this study, “red flags” were defined as elements which could be susceptible to future
92 abrupt temporary and, or permanent changes (i.e. risks). This approach has been used to identify key
93 risk factors across a wide-range of disciplines e.g. in medical diagnosis (Henschke et al., 2013; Martino
94 et al., 2013), domestic violence (Austin and Drozd, 2012), terrorism financing (Gordon, 2011) and
95 corporate fraud (Brazel et al., 2012; Yucel, 2013). However, there is currently no specific, well-defined

96 methodology for “red flag analysis” and therefore, in this instance, it was used as part of an expert-led,
97 qualitative approach.

98 The experts were comprised of seven researchers and two PhD students, in fisheries and
99 aquaculture and included ecologists, biologists, economists and social scientists from a range of
100 research organisations. The workshop was split into two components: data collection and analysis.

101

102 2.1 *Data collection*

103 Contextual information and production/landings data for each industry was collated and
104 analysed. The workshop participants with a life-sciences background were split into two smaller groups
105 (one focused on salmon, the other on mackerel) based on relevant expertise, and data was collected and
106 written up separately by each group, then fed back to the larger group for analysis. Social scientists
107 worked within both teams, and acted as transdisciplinary links to identify social and economic
108 differences/similarities between the two sectors, based on the published literature reviewed. Information
109 on the history of the development of both industries were obtained through searches of the Aquatic
110 Sciences and Fisheries Abstracts (ASFA, 2016) database spanning 1971-2015. Governmental grey
111 literature was examined when relevant to sectoral and national policies associated with or influencing
112 these industries.

113 Production data for farmed Atlantic salmon came from the on-line databases FishStatJ (Version
114 2.12.4; 1950-2013) and Eurostat (www.ec.europa.eu) as well as reports from the Scottish Salmon
115 Producers Organisation (SSPO). Information on market trends was retrieved from FAO Globefish
116 (www.globefish.org). Data on the landings of NEA mackerel were taken from FishStatJ (Version
117 2.12.4, 1950-2013) and the UK Sea Fisheries Annual Statistics (MMO, 2015). Trade-flow information
118 came from the Fisheries Commodities Production and Trade dataset (1976-2011). Further contextual
119 information for mackerel was obtained from official stock assessment reports generated by ICES
120 (www.ices.dk) and the UK Sea Fisheries Annual Statistics (MMO, 2015). Information was compiled
121 regarding: international and national actors (i.e. firms operating at the production level and their
122 associations), domestic policies and objectives for industry development, industry characteristics (e.g.
123 composition and size) and markets (both international and domestic). During the collection of

124 contextual information, ecological, social and political shocks which had affected the industries were
125 identified, as well as how the sector had responded.

126

127 2.2 *Data analysis*

128 During the data analysis component of the workshop, the participants were brought back
129 together into one larger facilitated group to discuss findings, to collectively identify ‘red flags’ (those
130 elements of the industry which may be affected by shocks to the sector) and to assess, for each ‘red
131 flag’, whether the regional sector had limited, some or strong resilience to the identified shocks (Table
132 1). The expert judgements (backed up by information and data collated in the previous component)
133 derived from this part of the workshop were then entered into a traffic light plot.

134

135 - *Table 1 About here* -

136

137 The analytical process presented here is of interest to multidisciplinary studies. The replicability
138 of this expert-panel approach is, thus, not as immediate as formal quantitative methodologies, and is
139 influenced by the regional focus of the sectors. Qualitative approaches are also difficult to synthesize
140 into single summary metrics but offer an opportunity to better understand the cause-effect relationships
141 of complex, transdisciplinary structures as fisheries production systems.

142 **3. Farmed Atlantic salmon – case study of large-scale aquaculture**

143 Driven by increasing global demand (Braekkan and Thyholdt, 2014) the world-wide output of
144 farmed salmon has grown steadily since the early 1980s, reaching > 2.2 million tonnes in 2013 (a 400-
145 fold increase), with Atlantic salmon accounting for around 91% of the production (Figure 1).

146 - *Figure 1 About Here* -

147 Aquaculture now provides around 67% of the global production of all salmon species
148 (FishStatJ, 2014) with Atlantic salmon farms concentrated in Norway, Chile and the UK (within the
149 UK salmon farming is predominantly based in Scotland). Outside of these countries, production of
150 Atlantic salmon is increasing, but remains relatively low. Although the industry was initially small-

151 scale, the industry is dominated by a few trans-national corporations (Marine Harvest, 2015, Asche et
152 al., 2013). Appendix D shows in detail the concentration and internationalization of the markets across
153 the largest producing countries. In some instances, for example the UK, value-addition takes place in
154 the country of origin, but the product is often exported fresh or frozen for processing, especially to
155 countries with lower labour costs, such as Poland (Ciszewska-Mlinarič et al 2014). Some of these export
156 flows are also influenced by trade-tariffs: e.g., fresh or frozen Norwegian salmon attracts a lower tariff
157 (0%) than the smoked product (15%) when imported into the EU (European Commission, 2016).
158 Salmon farming is thus highly internationalized with actors operating across national boundaries either
159 at the production, trade or both levels (Figure 2).

160 - *Figure 2 about here* -

161 The UK is the third largest global producer of farmed salmon at ~180,000 tonnes in 2014
162 (FishstatJ, 2014). During its expansion in the UK, the industry received substantial investments in
163 research and development which have led to improvements in animal health and welfare, as well as
164 product quality (Alexander et al, 2014). Along with effective marketing, this has secured ‘Scottish
165 salmon’ as a recognisable premium-brand within the global market. More recently, adoption of
166 certification programmes, such as the Royal Society for the Prevention of Cruelty to Animals (RSPCA,
167 2016) and Welfare Standards and Global Good Agricultural Practice (GAP, 2016), have helped further
168 standardise production across the industry. These standards encompass animal health and welfare but
169 also incorporate technological advances designed to mitigate negative environmental and social impacts
170 (RSPCA, 2015).

171 Aquaculture in Scotland is under-pinned by the framework document ‘A Fresh Start: The
172 Renewed Strategic Framework for Scottish Aquaculture’ (Marine Scotland, 2009). For salmon, the
173 Scottish industry set itself a growth target of reaching 210,000 tonnes output by 2020, a 30% increase
174 from 2012, a target also incorporated into Scotland’s National Marine Plan (Scottish Government, 2015;
175 MGSA, 2014). The overall objective is to generate new, sustainable jobs, especially in rural areas
176 (Alexander et al., 2014), and to improve exports, with a new target set at £7.1 bn for 2017 (up from
177 £3.7bn in 2007) (SSPO, 2014).

178 3.1 *Salmon as a traded commodity and its significance to the UK*

179 Recently salmon has become the largest single seafood product consumed in the UK,
180 contributing 15% of total seafood consumption by volume and 26% by value (Seafish, 2015). Producers
181 have seen a continued increase in domestic demand for both imported and domestically grown salmon,
182 despite an overall long-term decrease in national household expenditure on seafood (EUMOFA, 2015).
183 However, the export market is an essential component, accounting for 73% of the domestically farmed
184 product (DEFRA, 2014; Globefish, 2015). Salmon is exported to approximately 55 countries (Scottish
185 Government, 2015), mainly in the EU (France, Ireland, and Poland) but also to the USA. Sales to new
186 markets, such as China have also been increasing reaching 6.3% of production in 2013 (DEFRA, 2014).

187 3.2 *Responses to shocks affecting salmon aquaculture*

188 For farming systems, disease represents a major risk which can significantly and sometimes
189 abruptly affect production. Whilst considerable progress has been made in the use of vaccines and
190 probiotics to prevent outbreaks, some infections have had significant impacts on the farmed salmon
191 sector. Major outbreaks of viral Infectious Salmon Anaemia (ISA) in particular have caused high
192 mortalities in affected farms, starting in Norway in 1984 (See Appendix A). The 1998 ISA outbreak in
193 Scotland led to major changes in the way farmed salmon is produced in the UK. According to Hastings
194 et al. (1999), the outbreak cost more than £20 million to eradicate but led to the development of
195 improved prevention and control procedures, ultimately strengthening the resilience, of the production
196 sector to disease, i.e. the ability to adapt to maintain its level of service delivery. The ISA outbreak that
197 affected Chile in 2007 is considered to have had an even greater impact (EFSA 2012) and the crisis was
198 exacerbated by irregularities in monitoring and assessment within the control framework (Barton and
199 Floysand 2010). Ultimately the outbreak led to a significant restructuring of the Chilean sector and a
200 direct loss of 1,866 jobs (Marine Harvest 2008). Globally, the Chilean epidemic led to a shortage of
201 farmed salmon causing price increases and a temporary restructuring of the market (Asche, 2009;
202 EFSA, 2012).

203 There are several examples of geo-political shocks which have led to economic problems for
204 the salmon farming industry. In 2010 the Norwegian Nobel Committee awarded the Peace Prize to Liu
205 Xiaobo, a Chinese human rights activist and this led to non-tariff border measures being
206 disproportionately applied by China against Norwegian salmon - a tool popularised as the 'Dalai Lama
207 effect' (Sverdrup-Thygeson, 2015). Measures applied by the Chinese authorities included more
208 frequent sanitation and veterinary testing of Norwegian salmon and a more restrictive licensing regime
209 (political shock). These measures were predicted to have long-term consequences for Norwegian trade
210 because, along with oil, seafood is a major Norwegian export (Chen and Garcia, 2015). The negative
211 impact on Sino-Norwegian trade was however less severe than originally predicted. Norway actually
212 managed to increase its exports to China through the identification of new channels including airports
213 and ports which did not previously import salmon, and by re-routing through third-parties e.g. Vietnam.
214 However, this has also led to market distortion with increasing volumes of salmon being smuggled and
215 quality degradation, which in turn has led to a deterioration of Chinese consumer confidence in the
216 product (Chen and Garcia, 2015). Other salmon exporting countries seem to have benefited from the
217 non-tariff border measures since the quantity and value of Scottish salmon exports to China actually
218 increased from a very low level in 2009 to nearly 10,000 tonnes in 2013 (with a value of ~£50M). In
219 August 2014, Russia introduced a one-year trade ban on imports of agricultural products, raw materials
220 and food from the EU, USA, Canada, Australia and Norway as a response to sanctions sparked by the
221 crisis in the Ukraine (political shock). Russia was previously the main destination for seafood exports
222 from Norway and seventh in the list of major export partners of seafood for the EU (Motova and Natale,
223 2015). Farmed salmon was the top seafood commodity affected by this trade-ban (representing 48.3%
224 of the total seafood imports banned in 2013 with a value of €566M) (Motova and Natale, 2015). For a
225 while, Norway was able to circumvent the import ban by exporting via Belarus, but this loop-hole was
226 closed by the Russian government in 2016. The Russian embargo also affected the price of farmed
227 salmon causing it to drop by almost 9%, although this fall was short-lived (Holter, 2014; Globefish,
228 2014). Due to its diverse trade network, Norway was able to divert the majority of its surplus product
229 to the EU, particularly to established markets such as the UK and Portugal (Holland, 2015). For Scottish
230 producers, Russia had not been a strong export market and thus the Russian trade-ban had a negligible

231 impact on the UK industry, apart from the short-lived price fluctuation (Globefish, 2015). The response
232 of salmon producers to these geo-political shocks has been to redirect their export flows to existing and
233 emerging markets with untapped demand captured through lower prices (Globefish, 2015), a strategy
234 in line with the structure of the sector (Figure 2), and visible in the changes in trade patterns (see Figure
235 4 in section 5 for further discussion).

236 3.3 *Present and future perspectives for farmed Atlantic salmon*

237 Increasing demand for salmon, including in emerging markets with large populations, such as
238 Brazil, China and Russia (Braekkan and Thyholdt, 2014), and the limited and/or declining capacities of
239 capture fisheries (FAO, 2014), suggest that the expansion of demand for Atlantic salmon is likely to
240 continue. Indeed, the UK (mainly Scotland) plans to substantially expand its salmon production by 2020
241 (Scottish Government, 2015b). Similar increases are planned in established production centres (e.g.
242 Norway, Research Council of Norway, 2015) as well as new countries entering the sector (e.g. Ireland,
243 Australia, see Department of Agriculture, Food and the Marine, 2015; FRDC, 2015).

244 Recent trends in concentration (through further expansion of existing firms), and centralization,
245 are expected to continue, while new conflicts may arise due to space-competition with other capital-
246 intensive blue-growth activities (Johnson et al., 2012). Larger, highly capitalized companies with
247 production across multiple countries (e.g. Marine Harvest) have greater agility to hedge local risks
248 across multiple producing regions. However, and partly because of their export-oriented, large-scale
249 structure, these companies might expose the producing regions to further shocks, because of an inherent
250 mismatch between “[...] *the scale of management and the scale(s) of the ecological processes being*
251 *managed*” (Cumming et al., 2006, p.1), (Poppy et al.2014; Hospes and Kentin, 2014). Trade-wise, the
252 recent Brexit vote and the increasing competition from within the EU (increasing production in Ireland),
253 and other non-member countries, such as Russia, are introducing new sources of uncertainty, at a time
254 of overall demand growth. Finally, the future of salmon aquaculture will rely heavily on the stability of
255 fish oil supplies, mainly from the volatile Peruvian anchovies fisheries (Fox, 2014), which have recently
256 experienced rising price trends (Ytrestøyl et al. 2015), thus making feed prices a potential source of
257 future shocks. Despite considerable success with substitution and research into alternative sources, fish-

258 meal and fish-oil remain essential components in the pelleted feeds for salmon at present (Tacon et al.,
259 2011; Ytrestøyl et al. 2015).

260 **4. Large-scale capture fisheries: North-East Atlantic mackerel**

261 Mackerel is a medium-sized, pelagic shoaling fish which is widely distributed in the North-east
262 Atlantic. Within the EU, NEA mackerel provide the second highest capture landings by volume
263 (FishStatJ, 2014). In the UK, most of the pelagic vessels are based in Scotland and the majority of
264 Scottish landings are exported for human consumption (MMO, 2015). Historically, mackerel landings
265 increased in the mid-1960s, followed by a decline but then rebuilt and have since fluctuated between
266 400,000 and 800,000 tonnes per year (Figure 3). The national actors began to change dramatically in
267 2007 (Figure 3) as significant amounts of mackerel began appearing in Icelandic and Faroese waters
268 prompting these countries to begin commercial harvesting (Jensen et al, 2015).

269 - *Figure 3 About here* -

270 At producer level, the Scottish freezer-trawler pelagic fleet relies heavily on co-operation
271 through association (ICES, 2014b; Seafish, 2013). The fishery is mainly prosecuted by large freezer-
272 trawlers which account for 99% of the landings (by volume): they operate mid-water trawls or purse-
273 seines in seasonal fisheries for mackerel, herring (*Clupea harengus*) and blue whiting (*Micromesistius*
274 *poutassou*) (*pers. comm.* Ian Gatt, Scottish Pelagic Fishermen’s Association). Most of the vessels are
275 based in ports in the north-east of Scotland (Fraserburgh, Peterhead and Lerwick), are family-owned,
276 and are members of the Scottish Pelagic Fishermen’s Association (SPFA).¹ Compared with the salmon
277 farming sector the Scottish NEA mackerel sector therefore possesses stronger local ties and has a lower
278 influence of foreign ownership.

279 The internationally shared nature of the mackerel stock makes the fishery reliant on effective
280 public-sector-led multi-national agreements for issues such as the setting of catch quotas. Compared
281 with farmed salmon, this shifts the *locus* of decision-making from individual firms, to national and
282 international levels. Scottish interests are presently represented at EU level through the UK fisheries

¹ See Appendix B for a detailed list of vessels and ownership.

283 minister, whilst UK interests are represented by the EU in the North East Atlantic Fisheries Commission
284 (NEAFC), an international body whose members includes all the major producing countries: Norway,
285 Iceland, Denmark (on behalf of the Faroe Islands and Greenland), and Russia. Based on stock
286 assessments conducted by ICES, NEAFC allocates a quota to its members within their catching areas,
287 and, in the case of Russia, outside of their exclusive economic zone (Hannesson 2014). The EU quota
288 is then shared between the relevant countries, who in turn pass it on to their Producer Organisations to
289 allocate among vessels.

290

291 *4.1 The NEA mackerel fisheries as a traded commodity and its significance to the UK*

292

293 In 2014, mackerel represented the most economically important single species for UK fishing
294 vessels with landings at 128,200 tonnes, worth £105.5 million representing around 17% of the total
295 national landings by value (MMO, 2015). Of this, 97% by weight was landed into Scottish ports and a
296 further 29,300 tonnes was landed to UK ports by foreign vessels. An almost equal amount (159,800
297 tonnes) was landed into foreign ports by UK (mainly Scottish) vessels, making the Scottish pelagic fleet
298 one of the most profitable within the UK (MMO, 2015). Catches of NEA mackerel have also increased
299 since the mid-2000s, as a result of increases in stock abundance (ICES, 2015).

300 The UK mackerel industry has traditionally been export oriented, although the export
301 destinations have changed over time (Figure 4). In the 1970s, factory ships from the Soviet Union would
302 visit Western Scotland, and other parts of the UK, to take on-board fish caught by local vessels (the so-
303 called Klondike fishery, Beare and Reid, 2002). This remained a common practice until the end of the
304 1980s when the break-up of the Soviet Union led to the demise of the Klondike fisheries (Connell,
305 1983). During the following two decades, NEA mackerel continued to play an important role in UK
306 seafood exports, mainly to Western and Eastern Europe but also to some non-European countries
307 (Seafish, 2015). As of 2016, the Netherlands was the most important market for UK mackerel catches,
308 followed by Nigeria (MMO, 2015). Significant amounts were still being exported to Russia, although
309 this trade-flow was caught up in the embargoes imposed by that country on EU Agricultural and Food
310 products. Despite health-related promotions by the UK government to encourage consumption of oily
311 fish (Levy, 2015), NEA mackerel has continued to suffer from low levels of domestic consumption,

312 both by sales volume and value (Seafish, 2015), making it increasingly important for UK producers to
313 identify new and maintain existing export markets.

314 *- Figure 4 About here -*

315 As previously mentioned, the UK pelagic fleet is located mainly in ports in eastern Scotland,
316 which are outside of the most socio-economically fragile areas of the country. Even in Shetland, the
317 mackerel industry is located in a region with above-average income and relatively low rates of
318 unemployment (EDUS, 2011). Within these areas the pelagic sector provides significant high-value
319 employment, mainly through crew-share systems (Marine Scotland, 2013), whilst the associated
320 transport and processing operations provide further employment, both *in situ* and in the rest of Scotland
321 (Seafish, 2006). The largest pelagic ports by landing volumes are also in areas with potentially more
322 alternative employment, which is an important factor considering the seasonality of this fishery and the
323 sector's vulnerability to external shocks (e.g. export embargoes).

324

325 4.2 Responses to shocks affecting the NEA mackerel fisheries

326

327 In the early 2000s, an ecological shock occurred as the spatial distribution of the mackerel
328 stocks began to change (Hannesson, 2014; ICES, 2014; Hughes et al., 2015; Jensen et al, 2015). This
329 has led to an international dispute (political shock) which has, in turn, led to over-harvesting in relation
330 to the recommended total allowable catches advised by ICES. The series of disputes between the EU,
331 Norway, Faroes and Iceland has been dubbed the *Mackerel Wars* and remains only partially resolved
332 (Hannesson, 2014; Jensen et al, 2015). The underlying cause of the biological change is unclear and has
333 been linked with climate (Astthorsson et al. 2012, Hughes et al. 2015), although other analyses favour
334 a density-dependent range expansion driven by an overall increase in stock abundance (van der Kooij
335 et al. 2015). As mackerel started appearing in their waters, and despite a new regional agreement in
336 2008 between the EU, Norway and the Faroe Islands, unilateral action was taken in 2009 by Iceland
337 and the Faroe Islands to increase their catches. A lack of agreement on the Management Plan led to
338 unilateral quotas being set, which taken together, are higher than the total recommended catch indicated
339 by the scientific advice (ICES 2014). In 2014, the EU, Norway, and the Faroes approached ICES with
340 a draft request on a revised long-term management plan which ICES evaluated as being consistent with

341 the precautionary approach (ICES 2014). Prior to these events the NEA mackerel fishery was generally
342 regarded as being well-managed, despite prosecutions of some skippers/owners for quota-busting (STV
343 News, 2012 and the Shetland Times, 2012), and the major fisheries had been awarded Marine
344 Stewardship Certification (MSC) in 2009. Because of the international situation, MSC decided to
345 suspend certification for the pelagic trawl, purse-seine and hand-line NEA mackerel fisheries. As of
346 2015, the main European fisheries formed a new collaborative organisation, the Mackerel Industry
347 Northern Sustainability Alliance (MINSAs) with the purpose of going through re-assessment. This was
348 successful and MSC certification was reinstated as of May 2016, despite Iceland still not being party to
349 the 2014-2018 Coastal States Agreement Management Plan, although it should be noted that a
350 Condition to the MSC Certification was raised in this regard (Acoura Marine Ltd., 2016).

351 The conflict over the international management of the mackerel fisheries illustrates a major
352 difference with salmon farming. In capture fisheries, although the individual companies are smaller,
353 they operate within international fisheries frameworks negotiated by state level actors (Figure 5). To
354 some extent this encourages collective action to solve mutual problems (e.g. through the creation of
355 MINSAs) but it also means that the companies are largely powerless if the international relationships,
356 on which the fisheries agreements are based, become dysfunctional.

357

358 - *Figure 5 About here* -

359

360 Although the setting of unilateral mackerel quotas by Iceland and Faroes has had some effect
361 on Scottish landings, the impacts of other recent “political” shocks have been more significant. The
362 Scottish mackerel industry has suffered due to the loss of markets caused by the 2014 Russian seafood
363 embargo and the collapse of the Ukrainian economy (*pers. comm.* Ian Gatt, Scottish Pelagic
364 Fishermen’s Association) (Figure 6). Although Russia was a relatively un-important market for Scottish
365 farmed salmon (described in section 3.1) it was the third largest importer of mackerel from the UK
366 accounting for 10,508 tonnes in 2014 (MMO, 2015). Following the ban on EU seafood imports, the UK
367 government examined options for increasing exports to new and traditional markets such as China,
368 United States, Nigeria, and Turkey. Globefish (2014) reported that this had been partly successful,

369 although a drop in prices was observed, an occurrence normally associated with over-supply
370 (IceFishNews, 2015). The active role of the UK government and the focus on extra-EU markets suggests
371 that there is little un-tapped domestic demand for mackerel making the UK NEA mackerel fisheries
372 heavily dependent on foreign markets.

373 The disruption of trade-flows has primarily affected UK and EU producers, whilst the new
374 entrants, Iceland and the Faroes, have benefited (Motova and Natale, 2015). As a consequence, UK
375 producers have directed some of their product to another historic market, Nigeria, but the sudden in-
376 flow of seafood products to that country has caused the Nigerian government to introduce restrictions
377 aimed at limiting the outflow of currency. Although these restrictions were partially lifted in 2015, the
378 recent collapse of oil prices has also impacted Nigerian purchasing power for imported products.

379

380 4.3 *Present and future perspectives for NEA mackerel*

381

382 Sustainable yields of NEA mackerel are predicted to be around 700,000 tonnes per year (ICES,
383 2015). However, MSY yields predicted by ICES are lower than the present combined harvest so fishing
384 mortality, needs to be reduced. The most recent stock assessment from ICES shows that although the
385 spawning stock biomass is well above $B_{msy-trigger}$, it has begun to decline (ICES, 2017). In December
386 2015 the EU, Norway and Faroe Islands reached an agreement for a revised mackerel management plan
387 which enacted a 15% cut in quotas in 2016 and also allows a 15% share for other coastal states (DEFRA,
388 2015b). However, Iceland remains disengaged from the latest negotiations, thus increasing the source
389 of uncertainty for the UK sector.

390

- *Figure 6 about here* -

391 As of 2016/2017, the social impacts of the recent shocks on the UK mackerel industry appear
392 to have been relatively limited because the industry and policymakers have been able to adapt quickly.
393 The loss of the Russian market represented approximately 20% of the primary pelagic processors' turn-
394 over but the well organised UK industry was able to respond rapidly, leveraging Scottish and UK
395 government support to find new outlets (Ian Gatt, *pers. comm.*). The UK government has also supported
396 moves to allow 'banking' of quota which cannot be exported due to the Russian embargo (Defra, 2015).

397 More recently, the EU and Norway have initiated talks for allowing duty-free seafood imports from
398 Norway, which might cause further friction between EU-members (SPPO website, Aug 2015). If the
399 alternate export markets, such as Nigeria, become further restricted due to concerns over currency
400 outflow, falling oil income, and the former market (Russia) continues to be supplied by the new entrants
401 (Iceland and Faroes), there may be longer term problems for marketing mackerel caught by the UK
402 fleet.

403 It is also possible that the spatial distribution of the stock could revert to its former pattern, in
404 which case harvesting by the new entrants might cease (Astthorsson et al. 2012). However, the long-
405 term sustainability of the mackerel fisheries will only be guaranteed if binding international agreements
406 on quota-sharing can be reached between all the nations fishing on this stock. In addition, the “*Mackerel*
407 *Wars*”, have clearly demonstrated that the fisheries management plans were not robust to such changes.
408 This is somewhat surprising, and worrying, given that such distribution changes might have been
409 anticipated as mackerel have historically appeared in Icelandic waters during warmer periods
410 (Astthorsson et al. 2012). Furthermore, future changes in the distribution of many fish species have
411 been predicted in response to anticipated climate change (Rutterford et al., 2015; Montero-Serra, 2014;
412 Cheung et al., 2012).

413 **5. Results: identifying similarities and differences in response between the salmon and mackerel** 414 **sectors.**

415
416 The results of the “red flag” analyses (Table 2) identify several similarities and differences in
417 how the two sectors have been able to respond to the shocks described above, and how these responses
418 are related to the different structural organisations of the two sectors. Although both sectors have
419 become highly, although differently, concentrated they experienced two different forms of aggregation:
420 concentration (salmon), and association (NEA mackerel). In contrast to Norway, where the state was a
421 major share-holder in salmon feed and farming operations (until 2014), and in research facilities
422 (Rainbird and Ramirez, 2012; Huemer, 2012), expansion in the UK took place with more limited direct
423 state-intervention. The UK Atlantic salmon farming industry has become consolidated mainly through
424 commercial buy-outs resulting in a few companies with a large element of foreign direct investment

425 (FDI), although some UK-owned operators still exist. Salmon farming also operates largely under
426 national environmental standards which differ between countries. In contrast, the UK NEA mackerel
427 fishery became highly concentrated mainly as a result of government-assisted programs which were
428 designed to reduce fishing capacity. The UK NEA mackerel sector is now a highly controlled (through
429 association), domestic industry comprised of vessel-owner companies, fishing an internationally shared
430 stock which is regulated by agreements between states.

431 *-Table 2 About here-*

432 In terms of employment, the Atlantic salmon sector is characterized by employer-employee
433 relationships where workers are waged employees. Although sector-specific data are not available for
434 NEA mackerel, the pelagic fleet traditionally uses a share system, where each crew member receives a
435 share of the catch, after running costs are paid (McCall Howard, 2012). The system makes fishermen
436 self-employed, risk-sharing associates with the vessel owner to maximize the catch (McCall Howard,
437 2012).

438 An additional difference in the labour relations between these two sectors is the spatial extent
439 and flexibility of their operations. Fish farms are fixed in their location and, because of the logistical
440 problems in moving large volumes of live fish from farm to processor, their downstream value chain
441 operations (e.g. gutting and packing plants) are often located near production units (Alexander et al.,
442 2014). Farm workers often reside locally in the communities where the production is based. Landing of
443 NEA mackerel is less spatially constrained so that Scottish vessels landed about 50% of their catch into
444 non-UK ports (MMO, 2015). For mackerel landed into UK ports, the majority of value-added
445 processing operations are also located in more populated areas of Scotland (Garret, 2010), thus reducing
446 the economic impact of the sector's supply chain to the immediate areas around the producing ports.
447 The UK fishing sector as a whole also tends to employ workers from a wider range of localities,
448 including internationally (MMO, 2015). As a consequence of these employment patterns, the farmed
449 salmon sector will generate more localized negative employment impacts during times of crisis (Pita et
450 al., 2010), as exemplified in the cases of the Chilean collapse of 2008/2009 (Asche et al, 2009) and

451 recent restructuring by Marine Harvest in Scotland (Fish Update, 2016) and Gregs Seafood's in
452 Shetland (Fish Update, 2016b).

453 On the supply-side, both sectors rely on healthy natural ecosystems to maintain their
454 production. However, shocks to certain capture fish stocks do affect the production of farmed Atlantic
455 salmon because the sector still relies on fish-oil (and to a lesser extent fish-meal) which is produced
456 mainly by Latin American, German, and Danish industrial fisheries (Ytrestøyl et al. 2015; Fox, 2015;
457 GlobeFish, 2013). The outlook for fish oil, as well as for soybean protein (another important food source
458 for Atlantic salmon), remains one of increasing prices due to constrained supply (GlobeFish, 2013), for
459 example fish-oil prices have increased by 221% in real terms between 2003 and 2013 (Globefish, 2013).
460 Research into alternate sources, such as genetically-modified terrestrial crops, is being actively
461 supported by policy makers and the industry but acceptability of GMO products in food-production
462 remains particularly controversial in countries such as Scotland (Tocher, 2015; Scottish Government,
463 2015). However, if sufficient progress into alternatives is not made, a sudden increase in input prices
464 could cause problems for further expansions in salmon farming. Companies farming in Norway and the
465 UK are likely to try and offset the increases in feedstock prices by reducing labour costs through
466 increased automation and efficiency savings, particularly given the comparatively high labour costs in
467 these countries, with direct impacts on employment levels in local communities. The NEA mackerel
468 fishery, on the other hand, has to cope with the natural stock volatility, including fluctuating recruitment
469 and changes in fish growth rates, although in recent years there has been a run of strong year-classes
470 (ICES, 2017; Jansen and Burns, 2015).

471 From the demand-side, there exist several differences between the farmed salmon and NEA
472 mackerel sectors, especially in terms of the domestic market. For farmed salmon there still appears to
473 be untapped demand in the UK, EU and emerging markets and the Scottish product in particular enjoys
474 a high market status, although prices have declined as overall supply has increased. Producers of farmed
475 Atlantic salmon therefore seem able to find outlets for increased production which has helped reduce
476 the negative impacts from crises, such as recent trade-embargoes (Globefish, 2015). Overall the global
477 increase in production has driven prices down, but increased the marketability of the product (Globefish,

478 2015). However, this places one of the main drivers for increases in UK production outside of its
479 control, so that the Scottish industry will be somewhat susceptible to supply/price fluctuations driven
480 by changes in the volumes produced in the other main salmon farming countries, such as Norway and
481 Chile.

482 The difference between UK domestic demand for salmon and mackerel is a result of Atlantic
483 salmon becoming increasingly seen as a staple within the UK diet (Seafish, 2015c). For NEA mackerel,
484 the internal UK market appears to be largely saturated despite recent health-motivated marketing
485 campaigns encouraging more domestic consumption of oily fish (Levy, 2013). The NEA mackerel
486 sector has therefore not been able to stimulate domestic demand to the same extent as for farmed salmon
487 and thus relies mainly on export markets.

488 Although the analysis above highlighted significant differences in how the two sectors have
489 responded to historical shocks, this work also identified a number of similarities. Firstly, both sectors
490 supply seafood mainly for human consumption rather than industrial use. Although the EU still has
491 some uncapped demand for salmon, both sectors are now looking towards emerging markets for outlets
492 for their medium-term expansion. Scottish salmon farmers have been focussing on the potential of
493 China, Russia, and Middle Eastern countries (Alexander et al., 2014) whilst for mackerel, the
494 connections with West Africa have already been described. Both sectors are therefore becoming
495 increasingly reliant on exporting to potentially geopolitically unstable and economically volatile
496 regions. These countries have also shown a willingness to use trade-sanctions as a tool linked with
497 political disputes largely un-connected with the export product itself (Sverdrup-Thygeson, 2015). From
498 the supply-side, both sectors display a high degree of inter-firm control, as defined by Havice and
499 Campling (2017) and employ capital-intensive practices, which increases barriers for local new
500 entrants. At the same time, the market concentration/association, following the consolidation at the
501 production stage, have made it possible for both sectors to exhibit resilience to the recent shocks.

502 Finally, both sectors are based within geographical areas which depend heavily on seafood
503 production (Brookfield, 2005) but there is a substantial difference between the geographical
504 distributions of the two workforces. As mentioned previously most workers on the salmon farms live

505 locally whereas Scottish East Coast fishers are traditionally quite mobile (Coull, 1991). Many operate
506 from west-coast bases, often on a near-permanent basis, with weekend commuting by road to their
507 homes (Coull, 2005; Pita, 2010). The producing areas of NEA mackerel have already experienced a
508 partial diversification to other sectors (within and outside the seafood sector, see e.g. Graziano et al.,
509 2017), and are geographically closer to major economic centres. One last point concerns the result of
510 the Jun 2016 Brexit referendum. When the UK leaves the European Union, there will undoubtedly be
511 substantial implications for fisheries management and seafood trade. However, because of the minimum
512 two-year timeline for re-negotiations following the triggering of Article 50, and the multitude of options
513 available to the engaged parties, this could not be considered further in the present paper.

514 **6. Discussion and Conclusions**

515 This work investigated how the two major high-volume seafood sectors in the UK have
516 responded to several historical environmental, economic and geopolitical shocks which have impacted
517 their development. Although aquaculture is often thought of as being quite different to capture fisheries,
518 this analysis found that both Scottish salmon farming and the Scottish NEA mackerel capture fisheries
519 share some characteristics which have allowed them to be resilient to the major environmental and
520 socio-political shocks which have affected them in recent years. Despite the different ways in which the
521 two sectors are organised, the findings suggest that the main reason for their resilience is that they have
522 both developed into highly inter-firm controlled, and internationally-oriented industries. Most of the
523 demand shocks which have arisen from trade embargoes have been absorbed through effective
524 marketing), by utilising spare demand across multiple countries (i.e. examples of Association and
525 Chain-Governance, Havice and Campling, 2017), hedging environmental risks across multiple
526 producing regions (FDIs and Concentration, through increased intensity of capital), or by working with
527 government agencies to negotiate new opportunities as either blocks of industries (Association) or large
528 regional actors (Centralization). In these cases, the results were made possible because these seafood
529 sectors are characterized by relatively few, well-organized, and financially stable players with the
530 resources and leverage to respond to the issues, i.e. from consolidation in these sectors. The impacts of
531 these shocks on the total output from these sectors has therefore been relatively small, suggesting that

532 these two sectors have been effective at maintaining seafood production and their contribution to overall
533 food security in the face of these challenges. However, there were differences in the manner in which
534 government intervened. Scottish government support for salmon farming has been mainly through
535 indirect measures to improve efficiency, such as the Scottish Marine Plan and changes to the way farm
536 site applications are evaluated. The planned increases in production originated from the industry and
537 are expected to be achieved mainly through private investments, whether foreign or domestic. In
538 contrast, the Scottish NEA mackerel fishery has been supported through more direct intervention by the
539 UK and Scottish governments, at the request of the producers' associations, through help with finding
540 new export outlets and in negotiating quota-banking arrangements at EU level.

541 The main lesson to have emerged from the analysis is that consolidation, both occurring in the
542 past (mackerel) or at present (salmon) at production level appears to be a powerful route for
543 strengthening sector resilience, but this should not be taken to mean that bigger is always better.
544 Although consolidation appears to have conferred resilience for these two highly-industrialised, export-
545 focussed sectors, this work has not examined the counter-factual i.e. whether less-consolidated seafood
546 production sectors would be less resilient (Crona et al., 2016). The relationship between export-oriented
547 production and the more-globalised risks that this exposes the sectors to, suggests that resilience in itself
548 is a complex relational state, one that belongs to the understanding of the complexities faced, rather
549 than to the acquisition of a permanent tranquillity (Brand and Jax, 2007; Chandler, 2014).

550 Indeed, producers may achieve similar resilience in different ways, for example by more agile
551 exploitation of local markets, and further research is needed to understand how less-consolidated
552 businesses have dealt with previous internal and external shocks.

553 The case of the UK mackerel fishery shows that national, owner-based firms can be extremely
554 successful, but the resilience of the pelagic sector overall seems to benefit from their co-operation via
555 strong Producer Associations. Furthermore, the benefits of consolidation do not automatically confer
556 ecological sustainability. Without effective management, resource over-exploitation can occur in almost
557 any fisheries system (Longhurst, 2010).

558 The multidisciplinary approach taken in this study seemed particularly effective in analysing
559 an industry which cuts across environmental, ecological, economic and political spheres, and it is well

560 placed within emerging approaches in ecosystem-based management and analysis of seafood sectors
561 (e.g. Jennings et al., 2016; Voss et al., 2016).

562 Based on this experience, five further research questions are formulated, which would benefit
563 from similar multi-disciplinary analysis:

- 564 1) Have smaller-scale, export-oriented seafood sectors been affected by similar shocks and if
565 so, how did they react?
- 566 2) Does size influence the regional and sectoral economic capacity to cope with shocks? Are
567 less consolidated, more locally-oriented sectors more or less resilient?
- 568 3) Are there alternatives to consolidation which will increase the resilience of the seafood
569 production sector?
- 570 4) How can such resilience be successfully embedded within coherent (*sensu* Jordan and
571 Halpin, 2006) seafood production and rural development policies?
- 572 5) How can government best support the development of a resilient seafood sector and so
573 promote seafood security?

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