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Popoff, M; MacLeod, M; Leschen, W

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Attitudes towards the use of insect-derived materials in Scottish salmon feeds

Marine Popoff*, Michael MacLeod, William Leschen
*corresponding author, marine.popoff@gmail.com .

Marine Popoff: University of Edinburgh, Geoscience Department.
Michael MacLeod: Land Economy, Environment and Society Group, SRUC, Edinburgh, United Kingdom, EH9 3JG
William Leschen: Institute of Aquaculture, University of Stirling

Abstract

Fishmeal is an important source of high quality protein in aquaculture, but concerns about its cost and sustainability are making it a less attractive feed material. Replacing fishmeal with plant proteins can impact on the nutritional quality of farmed salmon. In theory insect meals could be substituted for fishmeal without affecting the quality of the fish produced. They could also provide a way of adding value to the bio-wastes used to rear the insects. However little is known about consumer or producer attitudes towards the use of insect meals. This paper reports findings of a survey of consumer attitudes in the UK, towards the incorporation of cultured insect larvae (maggots) - derived feed materials into commercial formulated fish feeds for the Scottish Salmon farming sector. It also investigates the attitudes of other stakeholders (salmon farmers, feed producers and fish retailers) via semi-structured interviews. Consumer attitudes towards the use of insect meal were found to be favourable (only 10% were opposed to the inclusion of insect meal in salmon feed n=180), with vegetable waste being the preferred waste stream for rearing insects. The interviews suggest that feed and salmon producers are in principle open to the use of insect meals, provided the feeds are proven to be safe and reliable. However producing insect meal in sufficient quantity, quality and at a price that is competitive with existing feed materials will be challenging.

Key words: Aquaculture, Atlantic salmon, insect-meal, consumer research, Scotland.

1. Introduction

Aquaculture is now one of the fastest growing food sectors and plays an increasingly important role in meeting global demand for fish (see Figure 1). However, successfully meeting future demand will largely depend on the availability of quality feeds in requisite quantities. Commercial formulated feeds are key to the success and sustainability of future aquaculture systems for fin-fish and shellfish – and in many cases accounting for 50-70% of the variable production costs depending on farming intensity (World Fish Centre, 2009).

Farmed-fish require relatively high levels of protein in their diets, although they vary depending on the species concerned. For instance carnivorous species such as the Atlantic salmon require much higher levels of protein than omnivores such as *Tilapia* (Huntington and Hasan, 2009). In the development of modern aquaculture, in the 1970s, fishmeal and fish oil were used as key feed ingredients, supplying almost a perfect balance of the 40 or so essential nutrients required to ensure good health and low feed conversion ratios (FCR). Generally, the fish meal/ fish oil component used in aquaculture diets comes from whole fish caught for that purpose and by-catch and/or other low-value species. FAO (2016, p46) report that 15.8Mt of fish (liveweight) was reduced to fishmeal and oil in 2014, out of the total global fishery production (capture and aquaculture) of 167Mt.

Since demand for fishmeal from the aquaculture sector is growing faster than supply (OECD/FAO 2015), world fish meal prices of varying grades and qualities are expected to continue increasing. In

the last four decades, prices have increased fourfold (Seafish, 2014a). This rise reached a record of $2,400 per t in 2014, mainly due to the sharp drop in anchovy catches in Peru - the world's largest exporter - caused by a rise in sea temperatures (Terazono, 2014). Hence in the next decade, the fish sector is expected to experience higher prices, but also higher production costs all in terms of fish-meal, fish oil and other feeds, and consequently of average farmed species (OECD, 2015)

Owing to rising demand and prices, increasing volumes of fishmeal (by 2012 up to 35% of world fishmeal production) is being produced from previously discarded fish by-products (Seafish, 2014b). Whilst this strategy offers clear benefits from a waste management perspective, it is also associated with drawbacks in the nutritional composition and quality of the resulting fishmeal. In general, such ingredients used in aquaculture then have more ash (minerals), an increased level of amino acids (such as glycine, proline, hydroxyproline) and less protein (Seafish, 2014b).

Given the above, alternatives to fishmeal are being sought that will provide low feed conversion ratios, maintain acceptable fish welfare and produce foods that are tasty and nutritious. While fish meal and fish oil have excellent nutritional compositions, they are not necessarily essential ingredients for a high quality fish feed, especially for non-carnivorous farmed species such as *Tilapia*. Other combinations of terrestrial ingredients specific to each fish species may also achieve this balance. As a result, fishmeal content has been reduced in commercial aquaculture feeds from an average of 23% in the 1990s to 10% by 2012 and replaced by sources from vegetable ingredients such as soy protein, corn and wheat gluten (CSF, 2014). However, most of those alternative protein sources compete with use for human consumption. In addition, they can alter the nutritional property of the final fish product, as they sometimes have unbalanced amino-acid profiles / omega-3 LC-PUFA, anti-nutritional factors and high fibre content. For this reason, other protein sources are required that create flexibility in diet formulation.

Insects reared on waste have been suggested as a potential alternative feed ingredient (Veldkamp et al., 2012; FAO, 2013). By reducing competition for plant protein, the use of protein derived from insects cultivated on low value organic wastes can represent a potential way of substituting digestible protein in farmed fish feeds, whilst also reducing demand for fishmeal and adding value to low grade bio-waste streams. This is particularly relevant as recent estimates indicate that approximately one-third of food produced for human consumption is lost or wasted globally, amounting to about 1.3 billion t every year (FAO, 2011). Considering this global waste challenge, the development of insect larvae-based feed ingredients can represent an opportunity to turn bio-waste into high quality saleable proteins. Those results however can vary with different production system methods, with fly larvae grown on a range of organic wastes being able to reduce the volume of that waste by up to 60% (PROteINSECT, n.d.). In comparison in a small-scale production facility in Ghana, insects reared on fruit waste can reduce their mass by up to 84% (Maquart, 2016). Table 1 shows the percentage of waste reduction for different types of biodegradable waste.

Table 1: Relation of studies of *Hermetia illucens* ability to convert different types of biodegradable waste into add-value products (Pastor et al. 2015)

Type of waste	**Waste reduction (%)**	**References**
Chicken manure	50	Sheppard *et al.* (1994)
Cow manure	79	Li *et al.* (2011a)
Municipal waste	68	Diener *et al.* (2011)
Coffee pulp	20	Lardé (1989, 1990)

Pig manure	28	Newton *et al.* (2005)

Consumer attitudes towards fish reared on insect materials are critical to their success, however, there is currently little evidence on consumer attitudes. Verbeke et al. (2015) showed that 68% of the sampled farmers, agriculture sector stakeholders and citizens from Flanders were willing to accept the use of insects as an animal feed ingredient (although the sample size was small (n=82) and recruited at an agriculture fair, and thus may not reflect the attitudes of the wider population). Notwithstanding the sampling issues, the findings in Verbeke et al. (2015) are consistent with those in the EC funded PROteINSECT project, which surveyed over 1,300 respondents across 71 countries in the UK, EU and the Far East between October 2013 and March 2014. This benchmark survey was promoted via the PROteINSECT website, through social media channels including bloggers, and via appropriate e-zines and websites (Smith and Pryor, 2014). This sampling framework may also have introduced some bias, as it excludes significant demographics such as older individuals or lower income households who don't make use of internet. Results showed that over 80% of consumers wanted to know more about using insects as feed, 52% were put off by the idea of eating insect-fed animal protein because they lacked sufficient knowledge on this topic, and 66% agreed that the larvae of flies are a suitable source of protein for animal feed (Undercurrent News, 2014; Reed Business Media, 2014). According to the PROteINSECT project "people are more accepting of the idea of insects in food and feed than we might have predicted" (Smith, 2014).

Scope of the paper

Veldkamp et al. (2012) suggested mass production for insects for inclusion in commercial animal feeds may be considered realistic by 2017 (with expectation of uses in fish feed being closest to reality). However there is still limited data available on the magnitude, frequency, impact and perception of managed feeding of insects to farm animals (Byrne, 2015). This paper seeks to fill this gap by examining attitudes to the use of insect meal in Scottish Atlantic salmon production. It investigates the attitudes of (a) consumers and (b) key stakeholders (retailers, feed producers and salmon producers) to the use of insect materials in salmon feeds.

Relevance of the study setting

Scotland is currently the third largest producer of Atlantic salmon globally, and produced 179,022 MT in 2014 (Marine Scotland, 2015). Production has trebled over the last 20 years (see Figure 2). Over the years, concern has been expressed about the impact of fishmeal and fish oil use in the production of salmon feeds. In 2006, "the UK reported the highest usage of fish meal and fish oil within salmon feeds - 36% and 28%, respectively" (Tacon, 2008)." Since then the UK government has expressed a commitment to support industry-led sustainable aquaculture growth (DEFRA, 2014).

2. Methodology

2.1 Stakeholder Interviews

Semi-structured interviews were undertaken with four industry stakeholders:

a) A commercial-scale insect producer.
b) One of Scotland's main aqua-feed producers.
c) One of the world's largest farmed Atlantic salmon producers.
d) One of Scotland's biggest fish retailers.

The purpose of the interviews was to investigate stakeholders' awareness and knowledge of insect farming, and their attitudes towards the use of insect-derived materials in salmon feeds.

Each of the interviews were held by phone on a one-to-one basis, and lasted between 20 - 40 minutes . The telephone mode offered several advantages as it is typically less expensive and time-consuming than face-to face in depth interviews. It does not suffer from geographic and other logistical demands of bringing the interviewer and interviewee in the same location and was convenient for scheduling a meeting (Roller and Lavrakas 2015). A semi-structured method was chosen because it allowed for both structure and flexibility, with discussions following their natural progression and varying according to spontaneous inputs raised by the interviewees. With the interviewee's permission, the interviews were recorded then transcribed and analysed.

2.2 Consumer survey

Following the stakeholder interviews, a consumer survey (n=200) was undertaken in July and August 2015 within the Edinburgh metropolitan area. The aim of the survey was to investigate (a) urban consumer's familiarity with current fishmeal composition and their perception of the challenges faced by the aquaculture industry, and (b) attitudes towards the use of insects in fish feed.

Initial scoping was based on the findings of the stakeholder interviews, discussions with other researchers. A draft questionnaire was designed and initial pilot testing was undertaken with two randomly selected consumers. The questionnaire was revised and then a second stage of pilot testing was undertaken with a further 20 consumers. The questionnaire was revised again in light of this. The resulting questionnaire (see Appendix A) was divided into three sections, which collected information on:

1. Current fish purchasing decisions, knowledge of fish-farming practices and of fishmeal.
2. Attitudes towards the use of insects in feed, and the type of waste materials used for feeding insects.
3. Demographic information.

The relevant survey population was identified using simple random sampling methods. To ensure access to the attitudes and concerns of a broad range of societal groups, participants were recruited at different times of the day in the above mentioned supermarkets. According to the Kantar World Panel (2015), Tesco, Asda, and Sainsbury's hold respectively 28.6%, 16.5% and 16.5% of total grocery market share in Great Britain; they were thus selected to recruit a representative sample of participants (Kantar World Panel, 2015). Compensation included 20GBP- worth voucher for seafood products offered to two randomly selected participants. The final questionnaire was administered by the same researcher to 200 participants face-to-face in different supermarkets and fishmongers across Edinburgh.

A drop-off/pick-up method was used at the fishmongers but was associated with a low response rate: 10 out of 40 surveys (with a target aimed at 20) were collected after two weeks. This number was judged too small to provide rigorous and scientifically-sound results; and those surveys were excluded.

Results were processed and analyzed using SPSS. For all performed analyses, the significance level $P<0.05$ was used as the threshold for statistical significance

3. Results

3.1 Stakeholder interviews

The information gathered from these interviews helped to adapt and refine the consumer surveys. Ultimately it also shaped an image of market demands and of potential hurdles insects could face in the fish-feed industry. (NEED couple more sentences here to summarize data)

Table 2: Summary of stakeholder interviews key findings

Company profile	Attitudes and perceived challenges
Insect producer - US based company - 17 employees - Founded 2009 - Plant designed for six t of organic materials recycled by flies on daily basis - Selling into specialty markets	- Company (as others) actively looking to expand (targeting production ~300t BSF larval meal by end 2015. May take 2-3 years to reach final target production level. - Safety is critical. This explains use of pre-consumer food waste as insect feed. - Best price for insect meal in bulk, frequently, can level at around USD 5.00 per pound. Today, ballpark numbers around USD 1300 per t. - Labour an important cost. Bigger plants and increased automation, utility/operational costs will reduce. Goal to be competitive - ultimately between fishmeal and poultry meal prices.
Aqua-feed producer - Headquarters Norway - 1,300 employees worldwide - Founded 1899 - Production around two million t feed for aquaculture species globally - Not a vertically integrated company, only produces complete feed	- With demand and limited supply, fishmeal prices will only go up in future. - Fish meal not essential in fish diets, a protein source which can be replaced. - However industry can only use raw materials that are safe, approved by legislation and price competitive. - Insect larvae production: Technology currently limited to relatively small scale, commercial pilot set ups. - Existing large scale commercial aquaculture feed producers up to 600,000t production per annum in one country - Competition: Unless an additional value benefit for including insect meal in commercial diets found, it will not exist. - Perceptions: Although certain animal derived raw materials widely used in other countries, supermarket chains may not want risk of bad publicity or conversely can use to promote ecologically sustainable resource renewal
Fish Farming Producer - Headquarters Norway - 10,700 employees worldwide - Founded 2006 - One of largest global seafood companies Specialty: Atlantic salmon	- Fish-farming industry relatively young compared to other food production sectors, plenty of space for development. - Currently only four major aquaculture feed producers globally, if one interested and willing to invest in insect production this increases chances of success. - Taste of farmed fish: Despite some variations in taste from different diets , fish reconstitute protein they eat from essential amino acids therefore insects in feed shouldn't have big impact on quality (or might improve taste for consumers). - Perceptions: Consumers generally won't have strong opinions on insect larvae used in fish feeds. As long as food is healthy, safe and contributes to reducing exploitation of wild fish stocks for fish meal consumers will be accepting.
Retailer - Headquarters UK - 476,000 employees worldwide - Founded 1919 - Multinational supermarket grocery and general merchandise retailer	- Consumers increasingly interested in the provenance of their food. - Difficulty in communicating and informing through labels because consumers tend to get nervous with novelty. - Therefore if insects to be used in feed, neither insect nor type of waste would be included on label. - Retailers operate with customers at forefront of their sales strategy, protecting/informing them regularly in order to engender consumer trust and loyalty. - If preliminary research indicates positive consumer attitudes towards alternative more sustainable ingredients in farmed fish/livestock feeds, then retailers may conduct further customer-based surveys/ interactions to confirm consumer support.

3.2 Consumer survey

The following section reports results from the consumer survey regarding attitudes towards the use of insects in fish feed, their perceived concerns and challenges.

The responses to questions 8, 9 and 10 indicate that consumers have limited knowledge of fishmeal composition and the issues raised by its production (see Table 2).

Table 2: Consumer's familiarity with current fishmeal composition and their perception of the challenges faced by the aquaculture industry.

Question	Yes (%)	No (%)	Number of responses
Q8. Do you think fish farming has any significant impact on the environment?	47%	53%	83
Q9. Farmed-fish are fed fishmeal. Do you know what it is made of?	22%	78%	39
Q10. Are you aware of any positive or negative issues arising from the production and use of fishmeal?	19%	81%	33

When asked "Would you eat farmed fish fed on an insect-based diet?" (Question 12) the responses were in general favourable (see Figure 3). Most respondents were prepared to eat insect-fed fish without having any concerns. Another 36% indicated they would be willing with reservations or under certain conditions, for example that price, safety and taste would remain unchanged. Finally 10% were unwilling to eat insect-fed fish. Reasons cited included impacts on fish health (both positive and negative) and the belief that insects could provide "a more natural diet". Meanwhile others participants believed insects were not a suitable feed ingredient. The results imply some confusion on the issues raised buy insect materials, which may reflect a lack of knowledge on the subject.

When asked if they had heard of the possibility of replacing fishmeal with insect materials (at the start of Section B) most respondents (91%) stated that they had not, however there does not seem to be any difference in attitudes towards insect materials between individuals who were previously aware of the concept and those who were not (see Figure 3).

The results were analyzed to see if there were differences in attitudes between different social groups (as defined by the UK National Statistics Socio-economic classification, Office for National Statistics 2010). However no statistically significant differences were found, perhaps reflecting the small size of the sub-samples.

When asked which waste materials they thought were suitable for use as insect feed, most favoured supermarket food waste and vegetable waste (see Figure 4), with a minority considering animal manure, abattoir waste or human sewage suitable. This trend was the same for different genders, age groups and occupations. When asked if the use of insect materials in the fish feed would affect their willingness to pay for the fish, most (75%) respondents said it would not have an effect. However, this was for the inclusion of insects fed vegetable waste. Inclusion of insects reared on other waste materials may have a more marked affect.

Finally, participants were asked two questions on their attitudes towards labelling. More than 80% replied they would want the label to say whether the fish has been fed insects. In parallel, 67% said they would want to know what type of waste the insect have been fed with.

4. Discussion and conclusion

The consumer survey indicated that most consumers would be willing to accept the use of insect materials in farmed salmon, which is consistent with the findings in Verbeke et al. (2015). Both of these studies are in contrast to the findings of the PROteINSECT project survey, in which 52% were opposed to the inclusion of insect-derived feeds. It may be that because consumers tend to know very little about feeds and their impact on the environment, they generally have no strong opinions about the subject, and purchasing decisions are guided by other factors.

Taste was rated (amongst other factors) a very important indicator for purchasing decisions. Other studies, such as Lock et al. (2014) indicate that fishmeal can be replaced with with insect meal without impacts on taste, odour, or texture. **As a result, we may conclude here that taste, in itself, will not be an obstacle to consumer's acceptance of insect-based feed.** The findings of this study also suggest that price was not considered as important as taste or health benefits for influencing purchasing decisions. However, insect and feed producing companies should be aware that most seafood consumers were not willing to pay a higher price for insect-fed products.

Often data showed that more information (for instance through continued public engagement) could increase awareness and likelihood that people will accept insect-based feeds. This is particularly the case for people who are uninformed, or misinformed, about the benefits of insect-feed (for instance regarding nutritional properties). Overall, no cross-sectional differences across the cohorts over time point in time were found. In addition, findings showed that vegetable waste was the insect feed preferred by consumers, though these preferences may change if different insect feedstocks lead to different outcomes in terms of the price and quality of the fish. Finally, respondents indicated wanting to know about insect-feed on their fish labels.

In order to replace current protein sources in feed, insect producers will have to produce large quantities of insect feed materials, of a high and consistent quality at a competitive price. Because most current insect larvae production companies have relatively low output, they tend to go into specialty markets such as zoos and reptile feeds that seek a product with specific nutritional profiles at a higher cost. However to access the aquaculture market, insect farmers will need increased automation of their systems to feed regular schedules, increase production levels and ultimately decrease labour costs. In addition, they will have to ramp up production and reach quantities of insect biomass that are sufficient to satisfy the protein demand of feed producers. The rate of expansion of this sector will depend, in part, on the attitudes of producers, retailers and consumers as well on future changes in EU legislation.

The interviews suggested that, in principle, salmon producers would not be opposed to the use of insect materials, provided they were traceable, safe, cost-competitive and did not impact on the quality of their produce. The competitive and integrated nature of the salmon feed and farming sectors means that uptake could be rapid, if and when insect materials started to be adopted.

At the moment the retail sector seems ambivalent, and would have to be confident of the market for insect-fed salmon before embracing it. The findings from this study provide some grounds for optimism, as consumers attitudes towards the inclusion of insect in fish feed were found to be generally favourable, with only about 10% of urban Edinburgh consumers opposed.

Currently, legislation represents a hurdle; with processed animal protein (PAP) being prohibited in farmed animal feed (with the exception of hydrolysed proteins from non-ruminants in feed for non-ruminants and non-ruminant PAP's in feed for aquaculture animals). Nevertheless, bans on the use of insects in animal diets in the European Community are expected to be lifted in the near future.

However, in order to be successful, insect material will have to represent a practical, low risk, value for money alternative to well-established feed materials. At present, cultivated insect materials appear to be not cost-competitive still compared to fish meals, but there may be considerable potential for reducing the price by increasing the scale and efficiency of production. The development of insect meals should be determined by the market, however, there may be a role for policy in removing regulatory barriers, improving consumer understandingand rewarding the social benefits of insect meals such as: (a) reducing the costs of waste management by utilizing and recycling waste streams, (b) reducing the social and environmental impacts of feed production and (c) increasing food availability.

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Appendix A: CONSUMER SURVEY TEMPLATE

Consumer attitudes in Edinburgh towards inclusion of insect in aquaculture feeds

Questionnaire

This short questionnaire is part of a project investigation being undertaken as part of my MSc. The overall aim of the project is to investigate people's knowledge of, and attitudes towards, the use of insects as feed in fish farming. It is an important part of the project, and I would therefore be very grateful if you could take 10 minutes or so to complete and return it.

If you are unable to answer all the questions, please complete it as far as you can. When completed, please either e-mail or post the questionnaire to us (contact details are given below).

You can enter our prize competition by sending us your contact details via email. Two winners will be chosen randomly and offered a £20 voucher each to use at a fishmonger in the city.

If you have any queries about this survey, or would like to find out more about the project, please feel free to get in touch.

Marine Popoff
SRUC
King's Building's
Edinburgh EH9 3JG

e-mail: marinepopoff@gmail.com

Section A

1. In an average month, how often do you eat finfish and/or shellfish? (either as the main component of a meal, or a fish-derived product)
   0 □ 1 - 2 □ 3 - 4 □ 5 - 6 □ 7- 8 □ 9 - 10 □ 11 or more

2. Please circle if you buy most often FARMED-RAISED or WILD CAUGHT fish

3. Can you explain why (in one word)?

4. What species do you eat most often?

5. How important are the following factors in influencing your decision when purchasing fish?

Health benefits	(Low) 1 - 2 - 3 - 4 - 5 (High)
Taste	(Low) 1 - 2 - 3 - 4 - 5 (High)
Easyness to prepare	(Low) 1 - 2 - 3 - 4 - 5 (High)
Price	(Low) 1 - 2 - 3 - 4 - 5 (High)
Sustainability ratings (eg. certification)	(Low) 1 - 2 - 3 - 4 - 5 (High)
Produced in Scotland	(Low) 1 - 2 - 3 - 4 - 5 (High)
Other (state)……..	(Low) 1 - 2 - 3 - 4 - 5 (High)

6. Do you usually look for products that are categorised or have been certificated sustainable?
   If so, please can you give specific examples: Yes □ No

7. Do you ask the person selling you the fish - in supermarket or elsewhere:
   1. Where the fish come from ? Yes □ No
   2. Whether they have been farmed or not ? Yes □ No
   3. If you do ask does the salesperson know to answer these questions? Yes □ No

8. Do you think fish farming has any significant impact on the environment? Yes □ No
   If so, please state: I don't know

9. Farmed-fish are fed fishmeal. Do you know what it is made of? Yes □ No

10. Are you aware of any positive or negative issues arising from the production and use of fishmeal? If so, please state: Yes □ No

Section B

With a growing population and concerns about fish stocks, the aquaculture industry has become an increasingly important source of fish. Aquaculture uses fishmeal that is partially made of species (such as eels) that are captured specifically for this purpose. In order to make the industry more sustainable, it has been suggested that fishmeal in Scotland could be partly replaced with feed materials derived from insects.

11. Had you heard this suggestion before ? Yes □ No

12. Would you eat farmed-fish fed on an insect-based diet?

Yes, because…..

Yes but …..

Maybe, if…..

No, because …..

13.

13. Insects for aquaculture feed can be raised on a range of waste materials. Tick the waste materials you think are suitable to be used

□ Vegetable waste
□ Food waste from supermarkets
□ Animal manure
□ Abattoir waste
□ Human sewage
□ All of the above
□ I don't know

14. Please circle your willingness to pay for product B:

Fish A	Fish B
Fed on current fishmeal	Fed partly with insects (which have been fed vegetable waste)
Price X	Price: LESS / EQUAL / MORE
	How much more / less?: …….

15. Should labels state whether or not fish have been fed insect-meal? Yes /No /Don't know

16. Should labels state the type of wastes fed to insects? Yes /No /Don't know

17. Do you have any other comments?…… (Next page)

Section C

I. What is your age

0 - 20 □ 21 - 35 □ 36 - 50 □ 51 - 65 □ 66 +

II. Gender

Male □ Female □ Other

III. Are you working presently?

No □ Yes: state your profession □ Student □ Retired

IV. Do you have any children?

Yes □ No

Figures

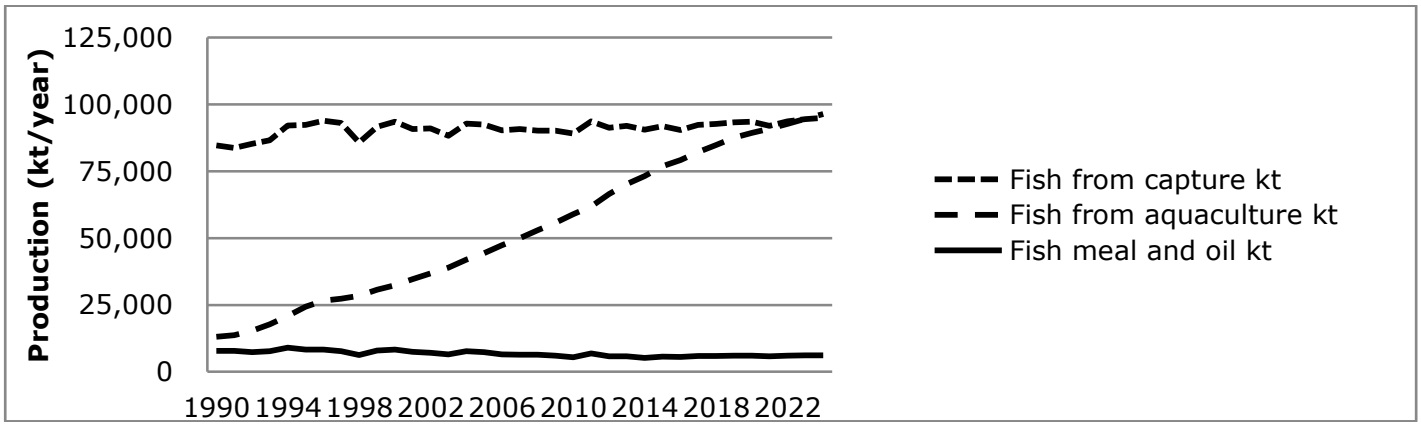

Figure 1. World production of fish (LW), fishmeal and oil.
Data extracted from OECD Stat, OECD-FAO Agricultural Outlook 2015-2024, 25/5/16

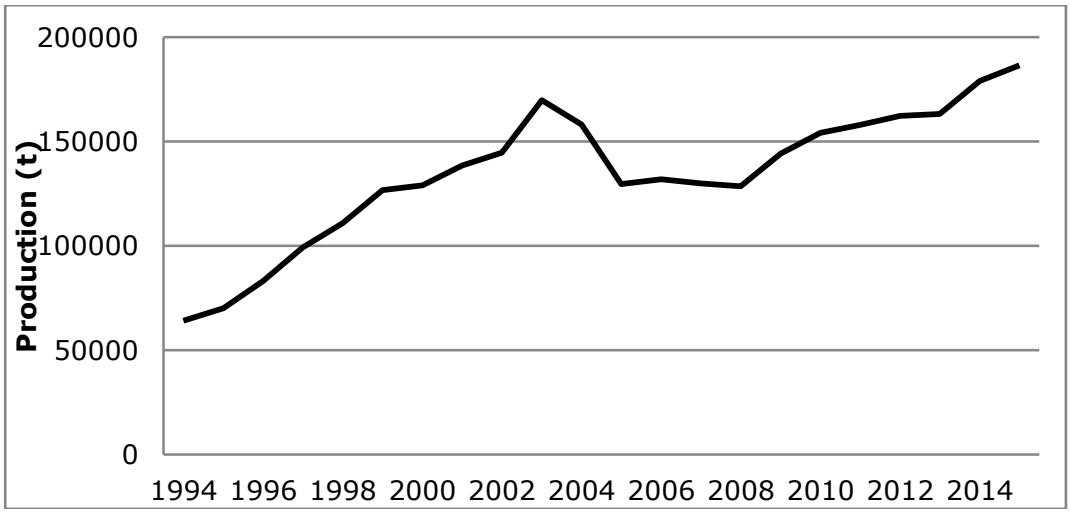

Figure 2. Farmed Atlantic salmon production in Scotland (data from Marine Scotland 2015)

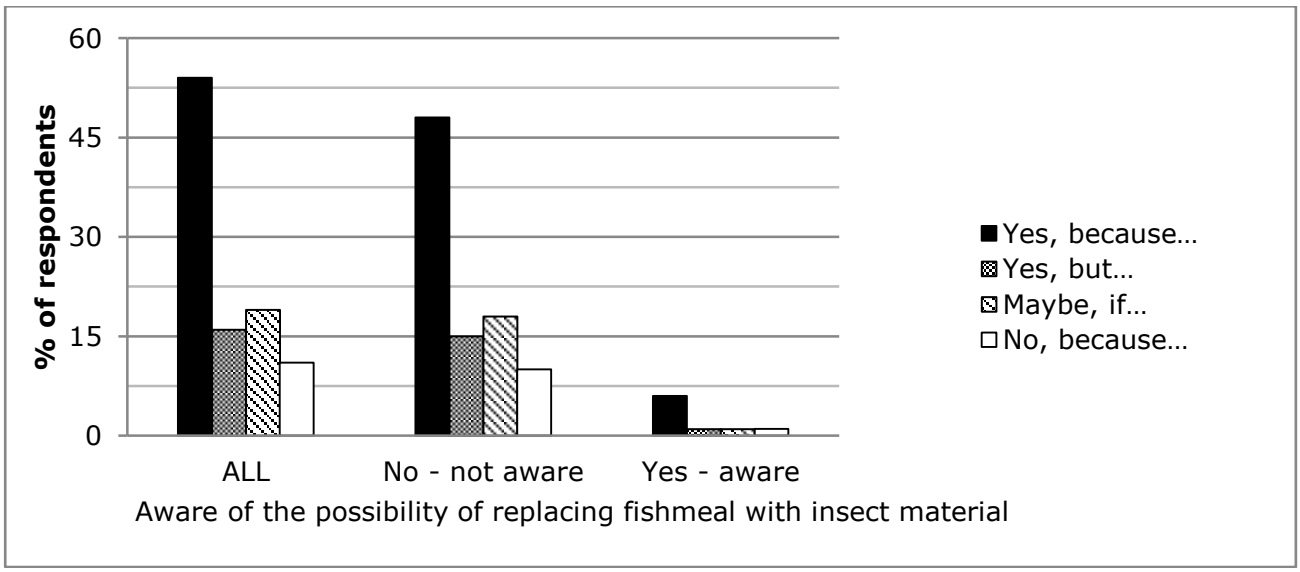

Figure 3. Responses to Question 12 "Would you eat farmed fish fed on an insect based diet?". The results are reported for two groups of respondents: those that had heard of the possibility of replacing fishmeal with insect materials ("Yes – aware"), and those that had not ("No – not aware"). (n=180)

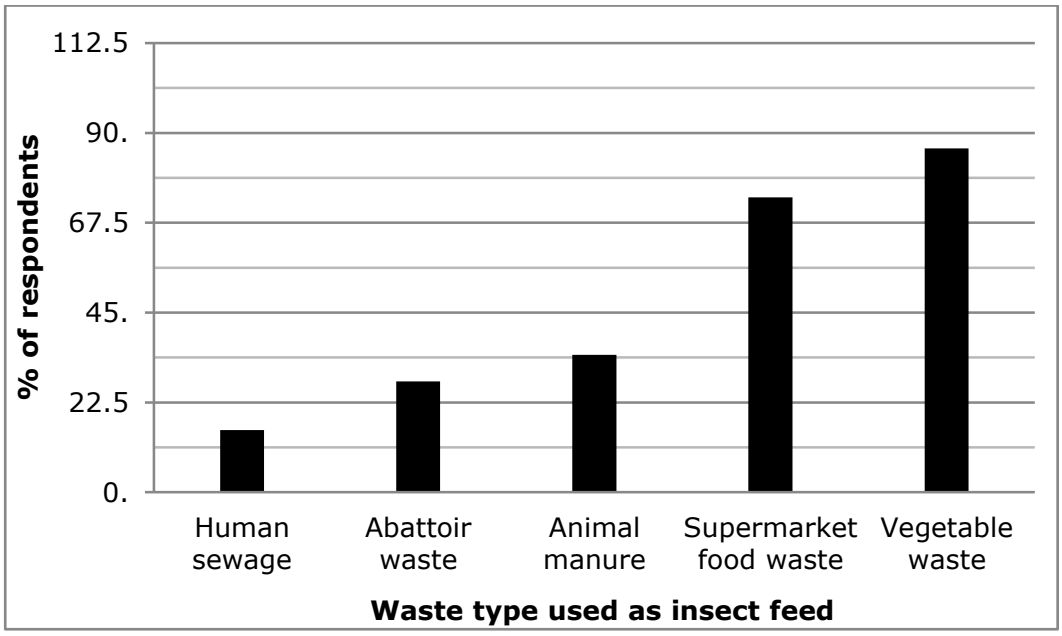

Figure 4. % of respondents that considered waste materials suitable for using as insect feed. (n=180)