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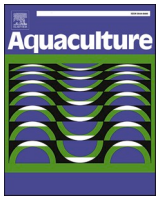

Informed choice: The role of knowledge in the willingness to consume aquaculture products of different groups in Germany

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ABSTRACT

Translating the agricultural eco(logical)-intensification model to European aquaculture hosts the potential for sustainably providing local food for local communities. Using online and printed surveys, we investigated the relationship between social factors such as age, gender, and education to seafood consumption behavior and the perception of aquaculture production. The frequency of seafood consumption was significantly lower in young and female respondents, whereas respondents with a higher level of education consume more frequently. Furthermore, high-frequency seafood consumers had a significant preference for wild-caught fish. Young and female respondents also perceived sustainability of aquaculture lower, whereas the level of education had a significantly positive relation to the attitude towards aquaculture. To foster the acceptance of eco-intensified aquaculture production, we suggest that communication efforts need to be group-tailored, focusing on the reduced environmental impacts, increased animal welfare, and novel products like seaweed to meet the values of the German consumer groups.

1. Introduction

Sustainability, defined in the Brundtland (1987) report by the United Nations Commission as the use of resources to meet "the needs of the present without compromising the ability of future generations to meet their own needs", has become an overarching concept in all aspects of contemporary human life: ranging from mobility to resource production and consumption. In the light of the climate crisis, younger generations, as seen in the 'Fridays for Future' movement, are reinforcing this former call for a stronger balance by asking for more mindfulness for their future among politicians and the older generations. As part of this sustainability movement, people in developed countries are increasingly choosing food according to its environmental (e.g. organic, carbon footprint, recyclable packaging), social (e.g. improvement of worker's welfare, access to health services, and school education), and economic (e.g. guaranteed minimum price and access to international markets) sustainability criteria that include aspects of animal welfare and local production (Annunziata and Scarpato, 2014; Lucas et al., 2021). Consumers' attitudes towards sustainable food are often based on personal values, perceived barriers and the confidence of information received (Corrin and Papadopoulos, 2017; Sanchez-Sabate and Sabaté, 2019). Scientists have observed that especially ecology-oriented, female and young consumers are more likely to shift to a meat-reduced, vegetarian, or vegan lifestyle in western countries (Gvion, 2020; Kymalainen et al., 2021; Pribis et al., 2010). However, the effects of sustainability concerns among different consumer groups in relation to their seafood consumption are rarely studied.

Seafood is often linked to cultural preferences (coastal communities vs. land), health beliefs, and consumption habits driven by respective cultural settings (childhood) (Carlucci et al., 2015; Jacobs et al., 2015). Furthermore, it is very diverse in terms of production method (wild vs. farmed) and in relation to the accessible variety of available species groups (finfish, shellfish, algae) (Carlucci et al., 2015; Laborde et al., 2020). Food from the sea contributes 17% to the globally available animal protein and in contrast to fisheries, aquaculture hosts a great potential for sustainable growth (Costello et al., 2020). To achieve this in Europe, where food production is dominated by agriculture, aquaculture production needs to be sustainably boosted, without compromising social and economic benefits while reducing the impact on the environment. This is timely, as for instance from the economic perspective the European Union (EU, 28 member states) has a trade deficit of 33% to date and relies heavily on the import of seafood from non-EU countries

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(EUMOFA, 2020) that renders the EU vulnerable in terms of marine food security. However, concepts on how to implement sustainable growth in aquaculture are rare and criticized for focusing too much on economic growth and not meeting the environmental and social Sustainable Development Goals (SDG) (Cisneros-Montemayor et al., 2021; Farmery et al., 2021). Eco(logical)-intensification, an agricultural model, "to feed the world now and in the future, while maintaining and enhancing ecosystems functions" (Tittonell, 2014). This concept includes different models but basically applies the "harnessing ecosystems services for food security by using e.g. nutrient cycling or biological pest control (Bommarco et al., 2013). Translated to aquaculture it might be a solution for such a sustainable growth of the EU's aquaculture sector. This could mean, e.g. applying circular economy in a farm-to-fork value chain (Maiolo et al., 2021; Schebesta and Candel, 2020) reusing valuable resources such as cuts from fish processing for fish diets (Hoerterer et al., 2022; Vázquez et al., 2019). These sustainable aquaculture products will most likely cost extra for consumers therefore it is necessary to highlight the benefits in audience tailored communication efforts, assuming that consumers can make an informed choice when purchasing seafood. For instance, socio-economic interests, environmental concerns, aesthetic aspects as well as moral, emotional, and personal values all influence the public's acceptance and perception of aquaculture to a different extent (Alexander et al., 2016; Freeman et al., 2012; Mazur and Curtis, 2008; Thomas et al., 2018). Furthermore, the majority of consumers are often uninformed about contemporary aquaculture practices and the benefits of aquaculture products in terms of environment, health, and quality of the products (Bronnmann and Hoffmann, 2018; Feucht and Zander, 2015).

The aim of the study was to identify the socio-demographic factors that influence seafood consumption behavior, the knowledge base on and attitude towards aquaculture of different groups on a showcase basis in Germany. To achieve high relevance and applicability of this study, the authors addressed especially younger age groups (25 years and younger and 26 to 39 years) by placing questionnaires at a conference for young scientists and by a citizen science project with high school students.

2. Material and methods

2.1. Participants

The study was set at two international conferences and in a large online survey addressing the different consumer groups characterized by different age groups and different presumed knowledge about aquaculture. At first, we attended the 'International Conference for YOUNG Marine Researchers' (ICYMARE) 2019 in Bremen which was characterized by participants who were all aged under 40 years (see Table 1). At the Aquaculture Europe Conference AE2019 in Berlin, we conducted a subsample addressing specifically research experts and practitioners from the aquaculture sector with higher average age (26 years and older). At last, we included high school scholars following a citizen science approach under the 'HIGH school of Science and Education at the AWI' (HIGHSEA at the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven) program. The students translated and adapted the existing questionnaire to German used at the ICYMARE and distributed it as an online survey among the public with a lower average age (25 years and younger).

2.2. Questionnaires

The study's methods resemble a set of potential quantitative and qualitative approaches from a social science stance (Kelle, 2014; Levitt et al., 2018). All methods were pre-tested and outcomes of the first surveys were further refined. The foundation for this study were 442 online and printed questionnaires with the same design and questions, which were distributed in English at the ICYMARE and AE2019 conferences and via email in German language by the HIGHSEA scholars following the snowball principle. The questionnaires were used as an explorative survey method to collect self-reported qualitative (Thronicker et al., 2019) and quantitative data within different social groups in a national context by combining predetermined and open-ended questions (Altintzoglou et al., 2017).

Table 1
Socio-demographic characteristics of survey respondents of the HIGHSEA online survey and at the ICYMARE and AE2019 conferences.

Socio-demographic characteristic	Subclassification	Public	Science		Total
		HIGHSEA	ICYMARE	AE2019	
Age	**n**	**331**	**29**	**2**	**362**
	25 years and younger	44%	27%	0%	42%
	26–39 years	22%	73%	100%	27%
	40 years and older	34%	0%	0%	31%
Gender	**n**	**326**	**28**	**2**	**356**
	Female	50%	89%	100%	53%
	Male	50%	11%	0%	47%
Level of Education	**n**	**322**	**27**	**2**	**351**
	School	49%	0%	0%	45%
	Vocational	13%	0%	0%	12%
	Academic	38%	100%	100%	43%
Distance to sea	**n**	**332**	**26**	**2**	**360**
	Close (walking distance)	17%	31%	0%	18%
	Relatively close (by car)	65%	58%	100%	64%
	Relatively far	14%	12%	0%	13%
	My country is landlocked	5%	0%	0%	4%

ICYMARE: International Conference for Young Marine Researchers September 24–27 2019 in Bremen; AE2019: Aquaculture conference of the European aquaculture society October 7–10 2019 in Berlin; HIGHSEA: 3-year scholar program of the Alfred Wegener Institute in Bremerhaven.

The first part consisted of five predetermined questions of which three were based on the concept of the 5-point Likert-scale and adapted to the ordinal data collected in this study (Allen and Seaman, 2007) and two based on categorical data which were ranked later. After Almeida et al. (2015), the respondents were asked to indicate their frequency of seafood consumption on a 5-point scale ranging from 1 = "never" to 5 = "at least once a week" and the options "I don't know" and "prefer not to answer". The respondents were asked to self-assess their knowledge about aquaculture production based on a 5-point scale ranging from 1 = "no experience" to 5 = "excellent knowledge" as well as to state their perception of sustainability of fish farming based on a 5-point scale ranging from 1 = "not sustainable" at all to 5 = "very sustainable". Furthermore, the respondents were asked to give their preference in seafood origin in the in the categories "wild", "aquaculture", "unknown", "no preference") and their attitude towards aquaculture by agreeing to positive, neutral and negative statements. The general attitude towards aquaculture was based on specific positive ($n = 3$), negative ($n = 4$), or neutral ($n = 1$) statements the respondents were asked to agree with. The statements addressed social, economic, and environmental aspects of aquaculture practices (see Fig. 1).

Open-ended questions were used to capture the attitude towards aquaculture, as respondents were able to comment on "other", and in addition in the HIGHSEA survey "How do you define sustainability?". To analyze these open-ended questions, we applied a qualitative content analysis (Bryman, 2004), which can be used on digitized survey data, protocols, and interview transcripts that are the output of the semi-structured interviews, focus groups, workshops,and questionnaires.

In the second part, socio-demographic characteristics were collected and evaluated, since we expected that distance to the sea, level of education (Anacleto et al., 2014), gender, and age (NSC, 2019) affect the frequency of seafood consumption as well as knowledge and perception

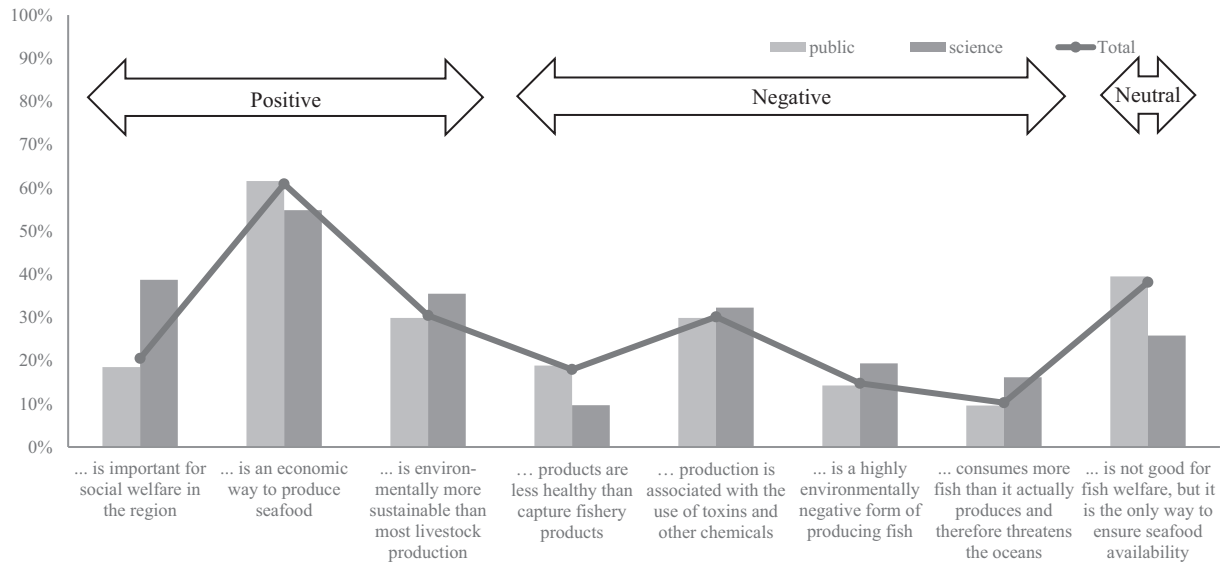

Fig. 1. Percentage of agreement to statements "Aquaculture…" of questionnaire respondents from public (n = 277) and science community (n = 31). Arrows with "positive", "negative" and "neutral" indicate the statements' connotations. Multiple answers possible (n = 724 of 308 answered questionnaires).

of aquaculture. The county of origin was asked in the ICYMARE and AE2019 questionnaires but was excluded from the HIGHSEA questionnaire, due to the German language and distribution range. The level of knowledge is related to the proximity to aquaculture farms (Freeman et al., 2012; Mazur and Curtis, 2008; Thomas et al., 2018) and frequency of seafood consumption (Aarset et al., 2004; Almeida et al., 2015), thus points out to the role of prior exposure (Ladenburg and Krause, 2011).

Overall, the reach and response rate differed strongly between the addressed audiences. At the ICYMARE both printed and online versions of the questionnaire were provided but whereas 46 of 50 printed versions were filled, only six respondents used the online version (N = 52) and 29 respondents stated Germany as their country of origin. At the AE2019 also both versions were provided but due to logistic reasons, we only were able to retrieve the online versions (N = 5), whereas only two respondents stated Germany as their country of origin. The HIGHSEA questionnaires had a high response rate (N = 385). However, 51 questionnaires were incomplete and therefore excluded from the data. The number of analyzed questions differs between questionnaires because some respondents choose not to answer one or two of the demographic characteristics (n = 17).

2.3. Regression and data analysis

A generalized linear regression model with a significance level of $P < 0.050$ was used to test the relationship between continuous response variables and predictors such as consumer demographics (Agresti, 2007). Continuous response variables were defined as preference of the origin of consumed seafood (ranked: 1 = "aquaculture", 0 = "no preference", −1 = "wild", answers with "unknown" were not included), the frequency of seafood consumption (5-point scale: 1 = "never" to 5 = "at least once a week") and the attitude towards aquaculture (ranked: 1 = positive, 0 = neutral or − 1 = negative). The ordinal data on the respondents' self-assessment on knowledge about aquaculture (5-point scale 1 = "no experience" to 5 = "excellent knowledge") and the perception sustainability of aquaculture (5-point scale 1 = "not sustainable" at all to 5 = "very sustainable") in relation to the demographic groups was analyzed with Kruskal-Wallis One Way ANOVA on ranks based on the medians and 25% and 75% percentiles using the Dunn's method for All Pairwise Multiple Comparison Procedures with an overall significance level of $P < 0.050$. The demographic groups were defined as age groups of 25 *years and younger*, *26–39 years* and *40 years and older*, gender identification as *female* or *male* and education in *school*, *vocational training*, and *academic*. Furthermore, the questionnaires were categorized by the presumed level of knowledge about aquaculture from low in the *public* (HIGHSEA respondents) to high in the *science* community (ICYMARE and AE2019 respondents). The linear regression model was fitted with all potential predictors. Predictors with no correlations to the response variables were sequentially eliminated from the results based on p-values ($P \geq 0.050$). Analysis was conducted using SigmaPlot statistical software (12.5, Free Software Foundation, 2020).

3. Results

We focused on how the socio-demographic factors age, gender, and education (see Table 1) and frequency of seafood consumption affect the knowledge about, perception of, and attitude towards aquaculture in Germany. The age distribution in the study was slightly skewed towards the *25 years and younger* age group (42%), whereas the age groups *26–39 years,* and *40 years and older* represent a similar amount of respondents (27% and 31%, respectively). Further identified as *female* (53%) and had a high level (55%) of education. Due to the geographical focus of this study, in the following results, we present only the data from respondents, who stated Germany as their country of origin.

Respondents from the questionnaire addressing the public answered, "How do you define sustainability?" in 95 of 385 questionnaires and we counted how often keywords were used. 'Resources', 'protect', and 'nature' or related words were mentioned most often and each occurred in 25% of the answers. 'Lasting' and 'intrusion' occurred in 20% and 17% of the answers given by the respondents, respectively. 'Balance', 'food', 'damage' and 'consume' occurred in 9% of the answers. 'Generation', 'production' and 'environment' were used in 7% of the answers. 'Life', 'regeneration' and 'handling' were used in 6% of the answers.

3.1. Seafood consumption behavior, preference and attitude towards aquaculture in relation to age, gender, and education

Overall (N = 385), 60% of respondents consume seafood "at least once a month" (high-frequency). However, the frequency of seafood consumption significantly differs in relation to age, gender, and level of education (see Table 2) and increases with age (linear regression, t = 7.024; $P < 0.001$). It is noticeable that 18% of the respondents aged *25 years and younger* stated that they "never" consume seafood and 52% of

Table 2
Frequency of stated seafood consumption in relation to age, gender, and education.

		n	Never	Less than once a year	Less than once a month	At least once a month	At least once a week	P
Total		385	12%	7%	20%	31%	30%	
Age	25 years and younger	152	18%	10%	26%	27%	19%	
	26–39 years	96	8%	11%	22%	40%	19%	< 0.001 (S)
	40 years and older	114	5%	0%	10%	33%	52%	
Gender	Female	166	16%	10%	23%	25%	25%	0.002 (S)
	Male	159	7%	5%	18%	37%	33%	
Education	School	159	16%	10%	23%	25%	25%	
	Vocational	42	7%	10%	17%	45%	21%	
	Academic	150	7%	4%	17%	37%	36%	< 0.001 (S)

n = number of answers given per group; linear regression was used to identify statistical differences with significance level $P < 0.050$ (S) and $P \geq 0.050$ (NS).

the respondents aged *40 years and older* consume seafood "at least once a week". In relation to gender, *female* respondents consume seafood less frequently compared to *males* (linear regression, $t = -3.103$; $P = 0.002$). Similar to age, the frequency of seafood consumption increases with the level of education (linear regression, $t = 4.110$; $P < 0.001$), whereas 16% of respondents with *school* education "never" or rarely consume seafood. Regarding respondents with a higher level of education, more respondents with *academic* background consume seafood at a higher frequency than respondents with *vocational* training.

Interestingly, overall ($N = 364$), only 7% of the respondents prefer "aquaculture" products compared to 31% who prefer "wild" products (see Table 3). However, 37% have "no preference" or it depends on the type of seafood product they buy (e.g. smoked salmon, fish fingers, etc.). One quarter stated that they do not know whether the products they buy are from aquaculture or the wild ("unknown"). Noteworthy, the preference for "aquaculture" or "wild" products was not correlated to age group, gender, or education (linear regression; $P = 0.050$). However, respondents that consume seafood "at least once a month" (high-frequency) have a lower preference for "aquaculture" products and at the same time prefer i.e. "wild" seafood compared to respondents that consume "less than once a month seafood" (low-frequency) (linear regression, $t = -2.537$, $P = 0.012$). Moreover, 64% of low-frequency consumers state not to prefer a certain origin compared to high-frequency consumers (31%).

3.2. Knowledge and perception of aquaculture production in the public and science community

A central issue of the questionnaires was placed on capturing the existing knowledge about aquaculture, the perceived sustainability of aquaculture (Table 4), and the plurality of attitudes on aquaculture (Table 5).

Overall, the knowledge about aquaculture from survey participants' self-assessment based on a 5-point scale of 1 ("no experience") to 5 ("excellent knowledge") had a median of 2.0 (1.0–3.0) among all German respondents ($N = 300$), with no differences between the three age groups (One-way ANOVA on ranks, $P = 0.730$) and gender (One-way ANOVA on ranks; $P = 0.136$). Furthermore, the self-assessment of the existing knowledge base significantly increased (One-way ANOVA on ranks, $P < 0.001$) with the level of education from *school* education and *vocational* training (2.0 (1.0–3.0) and 2.0 (1.0–2.25), respectively) to *academic* education (2.0 (2.0–4.0)) and from the *public* (2.0 (1.0–3.0) to the *science* community (4.0 (2.0–4.0)).

The rating of the sustainability of aquaculture among all German respondents had a median of 3.0 (2.0–3.0) ($N = 339$) with significant differences between the age groups and gender. The age group of *40*

Table 4
Self-assessed knowledge base and the perception of the sustainability of aquaculture production.

		Knowledge		Sustainability	
		n	Median	n	Median
Total		300	2.0 (1.0–3.0)	339	3.0 (2.0–3.0)
Age	25 years and younger	125	2.0 (1.0–3.0)	146	2.0 (2.0–3.0)a
	26–39 years	81	2.0 (1.0–3.0)	90	2.0 (2.0–3.0) ab
	40 years and older	92	2.0 (1.0–3.0)	101	3.0 (2.0–3.0) b*
Gender	Female	162	2.0 (1.0–3.0)	174	2.0 (2.0–3.0)a
	Male	134	2.0 (1.0–3.0)	157	3.0 (2.0–4.0) b**
Education	School	129	2.0 (1.0–3.0)a	149	2.0 (2.0–3.0)
	Vocational	30	2.0 (1.0–2.25) a	36	3.0 (2.0–3.0)
	Academic	131	2.0 (2.0–4.0) b**	143	3.0 (2.0–3.0)
Audience	Public	269	2.0 (1.0–3.0)a	311	3.0 (2.0–3.0)
	Science	31	4.0 (2.0–4.0) b**	28	2.5 (2.0–3.0)

n = number of answers given per group; Kruskal-Wallis One-way ANOVA on ranks, values given as medians and the 25% and 75% percentiles, values with different letters within the same columns of one group are significantly different (Dunn's method, $P \geq 0.050$), *$P < 0.050$; ** $P < 0.001$.

Table 3
Stated preference of production method of seafood in relation to age, gender, education, and frequency of seafood consumption.

		n	Aquaculture	No Preference	Wild	Unknown+	P
Total		364	7%	38%	30%	25%	
Age	25 years and younger	139	5%	35%	27%	34%	
	26–39 years	91	9%	44%	25%	22%	0.287 (NS)
	40 years and older	111	9%	29%	41%	21%	
Gender	Female	175	7%	34%	33%	26%	0.527 (NS)
	Male	161	7%	35%	30%	27%	
Education	School	146	7%	29%	30%	34%	
	Vocational	40	8%	44%	31%	17%	0.243 (NS)
	Academic	144	5%	30%	38%	28%	
Seafood consumption	Less than once a month	119	9%	44%	22%	25%	0.012 (S)
	At least once a month	225	6%	32%	35%	27%	

n = number of answers given per group; linear regression was used to identify statistical differences with significance level $P < 0.050$ (S) and $P \geq 0.050$ (NS); + the category unknown was not included in the linear regression analysis.

Table 5
Attitude towards aquaculture in percentage.

		Attitude				
		n	*positive*	*neutral*	*negative*	P
Total		338	52%	22%	26%	
Age	25 years and younger	124	52%	19%	29%	0.650 (NS)
	26–39 years	81	53%	30%	17%	
	40 years and older	103	56%	15%	29%	
Gender	Female	151	50%	24%	26%	0.487 (NS)
	Male	151	58%	17%	26%	
Education	School	132	48%	20%	33%	0.016 (S)
	Vocational	32	56%	25%	19%	
	Academic	135	60%	20%	20%	
Audience	Public	277	53%	20%	26%	0.908 (NS)
	Science	31	52%	25%	23%	

n = number of answers given per group; linear regression was used to identify statistical differences with significance level $P < 0.050$ (S) and $P > 0.050$ (NS).

years and older ranked aquaculture with a median of 3.0 (2.0–3.0) significantly more sustainable (One-way ANOVA on ranks, $P = 0.033$) than the median of 2.0 (1.0–3.0) in the age groups *25 years and younger* and *26–39 years*. *Male* respondents rank sustainability of aquaculture production with a median of 3.0 (2.0–4.0) significantly higher (One-way ANOVA on ranks, $P < 0.001$) than *female* respondents (2.0 (2.0–3.0)). The level of education and audience (*public*, *science* community) did not affect the sustainability ranking (One-way ANOVA on ranks, $P = 0.918$).

Overall, 52% of respondents ($N = 338$) have a positive attitude towards aquaculture, which was not influenced by age, gender or the audience. However, respondents with a high level of education have a significantly more positive attitude towards aquaculture than those with *school* education (linear regression, $t = 2.414$, $P = 0.016$). However, the overall attitude did not differ among the *public* (HIGHSEA, $n = 277$), and the *science* community ($n = 31$) (linear regression, $t = 0.155$, $P = 0.908$).

Interestingly, 39% of respondents from the *science* community ($n = 31$) agree with the positive statement that 'aquaculture is important for social welfare in the region', whereas only 19% of public respondents ($n = 277$) agree (total 21%). The majority (61%) of the respondents from all groups agree with the positive statement that 'aquaculture is an economic way to produce seafood'. Comparing terrestrial livestock production with aquaculture, 35% of the science community and 30% of the *public* agree with the positive statement that 'aquaculture is more sustainable than terrestrial livestock production'. More public than *science* respondents agree with the negative statement that 'aquaculture products are less healthy than capture fisheries' (19% and 10% respectively). In contrast, more respondents from the *science* community agree with the negative statements that 'aquaculture is a highly environmentally negative form of producing fish' (19% and 14% respectively) and 'aquaculture consumes more fish than it actually produces and therefore threatens the oceans' (16% and 10% respectively). Approximately one-third (30%) of all respondents agree with the negative statement that 'aquaculture production is associated with the use of toxins and chemicals'. *Public* respondents agree in 40% of the answers with the statement that 'aquaculture is not good for fish welfare, but it is the only way to ensure seafood availability', whereas fewer *science* respondents agree with this statement (26%).

In the option "other", the respondents were able to give their statement, which 29% of the *science* community and 7% of *public* respondents did. The answers given in the option "other" could be grouped into four categories (see Table 6). Categories (1) 'The sustainability of aquaculture depends on the culture system (IMTA, RAS, intensity), cultured species and regionality.' and (3) 'Aquaculture is not sustainable because of pollution by antibiotics and the spread of parasites, impacts on wild populations.' are centrally addressing environmental issues. In contrast,

Table 6
Categorized comments on the option "other" in the question about the attitude towards aquaculture.

Category	Statement
(1) The sustainability of aquaculture depends on the culture system (IMTA, RAS, and intensity), cultured species and regionality.	*"Aquaculture, if done in a multi-trophic and local scale can be a very sustainable alternative for seafood"* *"for some species already very sustainable and good; but improvements needed for other species"* *"It all depends on the methods/type of aquaculture"* *"There are semi-intensive AQ systems. AQ can be a sustainable way for fish production, more research and improvement of nutrition, animal welfare has to be done"* *"[…] I think it depends on the manner in which it is done. […]"* *"Aquaculture is a diverse field; I prefer some production methods to others."* *"Aquacultures are only ecological reasonable as organic aquacultures"*
(2) Aquaculture is necessary to ensure food security.	*"Aquaculture can be necessary to other regions"* *"it's a necessity"* *"Aquaculture if done right can be beneficial to feeding humans. […]"* *"The main point is that the fish price and the quality is right"* *"Aquaculture is a useful addition to traditional fishing)"*
(3) Aquaculture is not sustainable because of pollution by antibiotics and the spread of parasites, impacts on wild populations.	*"negative effects due to use of antibiotics and spreading of diseases and parasites"* *"they use antibiotics in aquaculture and thus pollutes the ocean"* *"spread of parasites, farmed fish are fed fish"* *"[…] If toxins, overpopulation, wrong waste management occurs, aquaculture can be detrimental to the environment"* *"Aquaculture must be ecologically compatible, otherwise it damages and threatens wild fish, for example, salmon in western Canada"*
(4) Respondents are uninformed	"There is too little information on the subject." "No knowledge available"

category (2) 'Aquaculture is necessary to ensure food security.' addresses primarily societal and economic issues. Only a few respondents in the *public* survey stated that they (4) '[…] are uninformed'. Respondents mentioned that aquaculture "can be sustainable if…" or "some aquaculture practices are sustainable, others need to be improved…" showing that both, positive and negative attitudes of aquaculture are centrally correlated to the production method, scale, and environment (Category 1). The respondents are also aware that aquaculture is important for food security (Category 2) "…if done right…" and "necessary to other regions". The *public*, as represented by the HIGHSEA survey, displays an overall more negative attitude and agrees more with the negative aspects, i.e., focusing on the negative environmental impacts, the use of toxins and chemicals associated with aquaculture production, pollution and the threat to wild populations (Category 3).

4. Discussion

The questionnaire was developed to look in more detail at various aspects that relate to the social acceptance of aquaculture in Germany. In addition, these questionnaires also enquired about the common understanding of sustainability to achieve a better understanding, of what consumers and stakeholders assume what sustainability should entail. The central focus was placed on younger generations (70% of

respondents were under the age of 40 years) and their levels of acceptance, which does not represent the age group distribution in Germany as a whole, where 43% contribute to the under the age of 40 years groups and 57% to the 40 years and older group (DESTATIS, 2021). With these results, we derived recommendations on how to potentially improve and tailor information availability for fostering acceptance of eco-intensification measures of aquaculture. As relevant social factors, we identified age group, gender, and educational level that are discussed in more detail according to their influence on the response parameters below. Moreover, we discuss the implications of the subsample in relation to the direct influence of increased knowledge on the change of attitude towards aquaculture.

4.1. Influence of social factors on seafood consumption behavior

There appears to be a discrepancy between the voiced preference for wild fish and the actual higher consumption rate of farmed fish that somewhat mirrors the findings of López-Mas et al. (2021). Indeed, our results showed that preference for seafood of a certain production method (wild vs. farmed) was not influenced by age, gender, or education, but rather by the frequency of seafood consumption. High-frequency seafood consumers (respondents that consume seafood more than once a month) prefer wild seafood, while low-frequency seafood consumers (respondents that consume less than once a month) are more likely to have no preference. However, as seen in this study, Germans consume less frequently seafood (65% at least once a month) than the average European (70%), but expose the same preference for wild (31%) and aquaculture (9%) products (Eurobarometer, 2018). The younger age group of under 40 years (born after 1980) stated to consume seafood less frequently than the 40 years and older group, which is in contrast with the NSC (2019) report that stated that the fish consumption was higher in the younger age groups. By large, female respondents show similar preferences as the younger age groups, consuming less seafood. Furthermore, respondents with a high level of education are more likely to eat seafood at least once a month. This can be explained by seafood usually being associated with a healthy lifestyle and especially more educated and older aged people have a better understanding of the health benefits of certain products (Bjørndal et al., 2014), which leads in turn to a higher seafood consumption rate (Heuer et al., 2015).

The result that younger and female respondents consume less seafood might be related to the increased awareness of environmental issues of food production and the modern lifestyle of Europeans (Kymalainen et al., 2021; Verbeke et al., 2007b). Several young and noteworthy especially female respondents stated that they do not consume seafood at all, which reflects the outcomes of the NSC (2019) report and the global trend of meat reduction due to moral and environmental reasons (Gvion, 2020; Koch et al., 2019; Pribis et al., 2010). In contrast to this observable trend among young age groups, it is noteworthy that especially in the older and more educated consumers, possible health benefits, taste, and consumption habits might be an underlying motivation for a prevailing high seafood consumption (Cantillo et al., 2021; Carlucci et al., 2015; Eurobarometer, 2018).

4.2. Perception of sustainability and the attitude towards aquaculture

In order to communicate the benefits of seafood produced in eco-intensified aquaculture production, we need to understand how the different consumer groups perceive and interpret sustainability and the positive and negative dimensions of aquaculture production. Scientists are much more aware of the tradeoffs between the benefits and costs in the ecological, social, and economic dimensions of aquaculture production than the public (Bacher et al., 2014; Chu et al., 2010). The current prevailing societal narrative of aquaculture to date focuses more on the environmental dimensions of sustainability and to a much lesser extent on the social and economic domains (Freeman et al., 2012). The diversity of responses in this study showed that not only academic but also all social groups within a society (e.g. politicians, decision-makers, ordinary citizens, children, etc.) need a better (common) understanding of sustainability. ‘Resources’ and ‘nature’ were most often mentioned as central definitions for sustainability, and surprisingly little attention was voiced on social (and economic) factors, rather only related to ‘generation’, ‘food’ and ‘impact’. In this regard, science is expected to support and become involved in processes of social learning to comply with these new demands (Siebenhüner, 2004). However, the concept of sustainability, its dimensions, and its definition is complex and often viewed one-sided by different stakeholder groups (Béné et al., 2019; Lawley et al., 2019; Risius et al., 2017). For instance, economic stakeholders often focus on economic and environmental sustainability whilst neglecting the social dimension (Hoerterer et al., 2020). Similar to the findings of Lawley et al. (2019), the assumed greater involvement in the topic of seafood production of the scientific community was positively related to the ranking of sustainability.

This somewhat persistent narrow perception of sustainability in the public is reflected in the respondents' agreement with aquaculture statements. Public and science respondents alike mainly voiced negative environmental concerns such as the degree of pollution of the marine environment, use of antibiotics and other chemicals. This coincides with other studies, where environmental risks and impacts are noted to be a major concern and act as an ethical and moral barrier for consumption of aquaculture products (Bacher et al., 2014; Bergleiter and Meisch, 2015; Chu et al., 2010; Feucht and Zander, 2015; Mazur and Curtis, 2008). As shown in this study, the public is not as aware of social benefits of aquaculture such as social welfare (see Fig. 1) and food security (see Table 6) as the informed groups of scientists (Bacher et al., 2014; Krause et al., 2020; Schlag and Ystgaard, 2013). In Whitmarsh and Wattage (2006) the public perceived minimizing environmental damage as the most important objective in the salmon farming industry, whereas maintaining employment, improving product quality, avoiding conflicts with other resource users, and ensuring fair prices were perceived as less important with very little variations between the surveyed areas. Indeed, Aarset et al. (2004), Verbeke, et al. (2007b), and Feucht and Zander (2015) showed that there is a perception-reality gap between actual environmental impacts of aquaculture production and the health benefits and nutritional value of aquaculture products, rendering attitude towards aquaculture products more negative, especially fish.

In this study, the public respondents from Germany stressed the importance of health issues (“wild-caught fish is healthier than aquaculture fish”) and animal welfare as well as the price for the product. This links to the findings across Europe that health benefits and higher animal welfare standards are a central driver for seafood purchase and consumption, but often negatively associated with aquaculture products (Cantillo et al., 2021; Carlucci et al., 2015; Feucht and Zander, 2014; Rickertsen et al., 2017). Concerning the price of seafood, previous studies have shown that high prices can be a barrier to seafood consumption (Carlucci et al., 2015). However, consumers of southern countries such as Portugal appear to be more willing to pay for sustainable salmon, compared to consumers from Norway (Misund et al., 2020). In contrast, German consumers are less willing to pay more for sustainable products or will not purchase a product if the price is higher (Bronnmann and Hoffmann, 2018). However, improved information about animal welfare (Stubbe Solgaard and Yang, 2011), local, domestic, or European production (Zander and Feucht, 2017), or ‘natural’ production methods (Risius et al., 2017), such as pond aquaculture could increase the willingness to pay extra for sustainable aquaculture products.

Despite that the younger age groups and female respondents from the public audience ranked the sustainability of aquaculture as low, the attitude towards aquaculture was overall positive (>50%). This is in contrast to previous studies where consumers from different countries and backgrounds had a more negative attitude towards aquaculture and aquaculture products (Rickertsen et al., 2017; Verbeke et al., 2007a).

Respondents with higher education or science background have an even more positive attitude towards aquaculture. This suggests that a higher level of knowledge might lead to a positive attitude towards aquaculture, but its ripple effects on sustainable consumption behavior are not clear (Almeida et al., 2015; Feucht and Zander, 2015; Richter and Klockner, 2017).

In summary, the public needs improved knowledge on aquaculture production and the interwoven plurality of sustainability dimensions therein to order to understand the manifold processes that take place and how these are embedded in our economies, environment, and societies. Such systemic worldviews offer scope towards transformative pathways of future marine food production across Europe. In its wake, forming linkages between different mindsets, worldviews, cultural belief systems of sustainability create both conceptual and cultural challenges.

4.3. Does information lead to informed choice?

More often, consumers are rather driven by moral and ethical reasons in their seafood purchasing and consumption behavior, such as values and (culturally rooted) daily habits, than by scientific reasoning that acknowledges environmental, social, and economic benefits of local, domestic or European aquaculture (Schlag and Ystgaard, 2013). That said it is crucial to know how and in what ways improved scientific knowledge affects seafood-purchasing decisions. This will allow tailoring better communication pathways to inform about the benefits of eco-intensified aquaculture products that are based on scientific findings as well as endorsing the respective consumer's values, culture, and habits.

In this study, the majority (77%) of the public respondents self-assessed to have a low level of knowledge about aquaculture, whereas the knowledge of the science community respondents was higher. Furthermore, the level of education can be positively correlated to the knowledge about aquaculture, which might be related to a higher general level of knowledge including knowledge about aquaculture. However, some public respondents voiced that they are uninformed and are not able to agree with the statements about aquaculture. Pretesting showed that the degree of knowledge about aquaculture did not affect the perception of aquaculture. In contrast, previous studies showed that the level of knowledge is related to the proximity to aquaculture farms (Freeman et al., 2012; Mazur and Curtis, 2008; Thomas et al., 2018) and the frequency of seafood consumption (Aarset et al., 2004).

In the exploratory survey at the ICYMARE aquaculture session, three respondents changed their attitude more positive due to improved knowledge about sustainable aquaculture, while the other eight respondents did not change their attitude. No one changed the perception towards more negative, suggesting that improved information about the sustainability of aquaculture practices and its products could only have positive effects on the perception. However, previous studies have shown that information and improved knowledge could also lead to a shift in consumers' decisions against aquaculture products (Claret et al., 2016; Feucht and Zander, 2015). Due to the small number of respondents, the results offer only on a very exploratory scale that there are potential shifts possible in the perceived impacts of aquaculture. These exploratory results indicate that more research is warranted to fully understand the role of improved scientific information in everyday decision-making of food consumption. However, the engagement with trustworthy knowledge holders (scientists presenting aquaculture-related research results) led to a topical perception shift, indicating a learning process on the individual level.

4.4. Implications for a future acceptance of aquaculture products from the eco-intensification approach in Germany

The premise of this study was that social change towards acceptance of eco-intensification measures in aquaculture would benefit from a better understanding of sustainability thinking among ordinary citizens and especially younger age groups. It is not sufficient for only experts to be knowledgeable about eco-intensification measures in aquaculture. Research insights need to be tailored to the specific needs of the respective audiences in order to develop relevant or meaningful outputs (Krause and Schupp, 2019). What constitutes relevance or meaningfulness is part of an ongoing negotiation process between academia and society and may vary widely for different social groups and contexts, and different scientific disciplines alike (Hornidge, 2014). For contextualization of research findings towards the social realities of stakeholders, the requirements of actors from scientific and societal realms need to be understood in order to design a targeted output (Regeer and Bunders, 2003).

In the case of communicating the benefits of eco-intensified aquaculture production, this study's results conform to previous studies (Risius et al., 2017; Schlag and Ystgaard, 2013; Zander and Feucht, 2017). Tailored communication per consumer group should highlight research insights on new developments reducing environmental impacts, animal welfare, and nutritional and health benefits of locally produced seafood products addressing values and habits of the respective groups. In the German context, it might be crucial to communicate the benefits of the application of circular economy in the production of feeds for Europe's most popular fish species like trout (Maiolo et al., 2021), salmon (Vázquez et al., 2019), sea bream and sea bass and the technological advancement for monitoring environmental interaction (Burke et al., 2021; O'Donncha and Grant, 2019). Indeed, the current pandemic and the recognition of how vulnerable globalized food systems are has acted as an accelerator for regional, circular economy thinking (Kaiser et al., 2021). However, communication alone will not be sufficient, since consumers want to rely on the aquaculture industry to follow sustainable standards (Banovic et al., 2019; Feucht and Zander, 2015), produce reliable labeling (Carlucci et al., 2015; Risius et al., 2017), without giving too complex information (Bronnmann and Hoffmann, 2018; Cantillo et al., 2021; Reinders et al., 2016).

It is noteworthy that this study revealed that especially the younger age groups consume less frequently or no seafood than the older groups. This reduction might be mainly due to moral and ethical reasons (Verbeke, et al., 2007b), and emphasizing benefits of eco-intensifications measures for animal welfare, no pollution, and absence of drugs and hormones as well as sustainable fish feed might be crucial for communication for this respective age group (Schlag and Ystgaard, 2013; Zander and Feucht, 2017). Aquaculture advocates, belonging mostly to the older age groups, should leave preconceived notions such as assumed positive consumer behavior changes if messaging health benefits of seafood consumption (Jacobs et al., 2015), but rather uptake young and critical consumers' interests that revolve more strongly around vegetarian or vegan lifestyle. Scherer and Holm (2020) proposed that advocating eating lower trophic levels of seafood might tap into the potential of locally produced marine resources, which acknowledges the raising demand for regionalization of food production. In order to accommodate the trend of a plant-based diet among the “consumers of tomorrow”, aquaculture advocates should promote the production and consumption of novel plant/algae based aquaculture products, such as seaweed. At the ICYMARE aquaculture session some respondents stated that the sea grapes (*Caulerpa lentillifera*) presented by Stuthmann et al. (2019) were interesting to them as a novel food. Production of seaweed is in many ways considered sustainable by not using fished resources as finfish production, as its reputation as a functional food, and its potential for ecosystem services (Buchholz et al., 2012; Garcia-Poza et al., 2020).

5. Conclusion

The presented findings mirror previous studies, in which age, education, and location of stakeholders influenced the preferences towards a more sustainable lifestyle (Black and Cherrier, 2010; Kapferer and Michaut-Denizeau, 2019; Schoolman et al., 2014) and the willingness to accept higher prices of sustainable products (De Pelsmacker et al., 2005;

Stubbe Solgaard and Yang, 2011).

However, the results of this and previous studies do not clearly indicate that consumers will choose a more sustainable product based on provided information on the benefits of aquaculture products from eco-intensified production. Even though consumers state that sustainability is important for them, their purchase behavior is often run along by values, habits, lifestyle, convenience, and trust in information sources and not (solely) by scientific reasoning (Carlucci et al., 2015; Feucht and Zander, 2015; Gaviglio and Demartini, 2009; Jacobs et al., 2015). Instead of relying only on a bottom-up transformation through consumers' decision to purchase and consume sustainable aquaculture products, the aquaculture industry should also intrinsically aim for a successful transformation to an eco-intensified European aquaculture sector (Almeida et al., 2015; Bergleiter and Meisch, 2015; Lawley et al., 2019; Richter and Klockner, 2017). This might enhance the trust of the consumers in sustainable and especially environmentally friendly production of food from the seas.

Overall, more factors have to be considered when the aquaculture industry wants to boost sustainable production in Europe. Current and unforeseen developments such as the COVID-19 pandemic host the potential to change environmental awareness, sustainable consumption, and social responsibility (Kaiser et al., 2021; Severo et al., 2021).

Furthermore, the aspiration for economic growth and increased consumption should be seen more critically, especially in the light of the younger generations having other values than the older generations. Wanting to produce more to sell more, might be the wrong strategy facing lower seafood consumption rates among the younger age group now and in the future. Initiatives like the Blue Growth Agenda launched by the EU are very important. However, these risk delivering only a part of the promise as they focus strongly on economic dimensions but overlooking other aspects necessary for sustainable seafood production (Eikeset et al., 2018). Scientists (see Ertör and Hadjimichael, 2019) and organizations such as the High Level Panel for a Sustainable Ocean Economy (HLP or the Ocean Panel), which was created in 2018 advocates blue degrowth in order to reduce environmental impacts, securing a future worth living for generations to come.

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Ethics statement

This study was in accordance with the regulations of the German Research Foundation (DFG) and the Council for Social and Economic Data (RatSWD), as all collected information was anonymous and non-sensitive and participants are not identifiable. Participants were explicitly informed about and consented to the aim of the study, the methodology and about what data will be collected, processed, stored and published. All data were collected, stored and processes in compliance with the General Data Protection Regulation (GDPR).

CRediT authorship contribution statement

Christina Hoerterer: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Jessica Petereit:** Conceptualization, Methodology, Validation, Investigation, Writing – review & editing. **Gesche Krause:** Conceptualization, Methodology, Validation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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