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The seafood basket: Application of zero-inflated model to fish count purchase

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A R T I C L E I N F O

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A B S T R A C T

The study analyzed demand for fish in the United States by the number of species purchased from a basket of species, rather than the usual approach focusing on one single species. The basket includes largemouth bass, hybrid striped bass, bluegill, walleye, yellow perch, rainbow trout, Great Lakes whitefish, lake trout, barramundi, and tilapia. These results largely confirm that consumers purchase different fish species or a combination of them from time to time and that consumers pay little attention to green factors such as sustainability, 3rd party certification and hormone-free when purchasing seafood. It appears that the effects of green credence attributes may not apply generically to a collection of fish or that the utility of green characteristics to seafood demand may be declining. As for production systems, although a higher percentage of consumers indicated preference for wild-caught fish, the importance of farmed fish to them was found to increase fish purchased.

1. Introduction

There are >250 different species of seafood produced in the U.S., according to reports from the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture (National Marine Fisheries Service – NMFS, 2021; USDA, 2019). The species are categorized into fish, shellfish (crustaceans) and mollusks; each individual species with its characteristic biology and product forms. Thus, seafood consumers have a variety of products to choose from and they have preferences for different seafood types and purchase different species or a combination of them from time to time (Bronnmann et al., 2016; Buason and Agnarsson, 2020; Chidmi et al., 2012; Dey et al., 2017; Pérez et al., 2012).

In studies on diets, there is the contention that a diet is composed of various foods and nutrients, therefore it is more appropriate to study diet collectively to understand overall dietary patterns (Zhang et al., 2011). For example, in a study of distribution of usual intake for episodically consumed foods and energy, Pérez et al. (2012) observed that some subjects reported fish intake on some days but not others. The specific fish species are not specified suggesting that fish products consumed varied among consumers.

Several factors are very relevant to consumer purchases, and these include extrinsic and intrinsic attributes that provide cues to the consumer. For seafood, extrinsic cues include method of production – wild, farmed (aquaculture), price, environmental considerations, product origin, labeling, etc. (Brécard et al., 2009). There are also concerns about sustainability and environmental friendliness related to seafood production, food safety, health risks and benefits, etc. (Chen et al., 2015; Hallstein and Villas-Boas, 2013; Hilger et al., 2019; Risius et al., 2019; Uchida et al., 2014; Vitale et al., 2020; Xu et al., 2012; Yip et al., 2017; Zander and Feucht, 2018). Studies have found religious influence and seasonal effects in fish consumption such as during Christmas and Lent, the six-week period preceding Easter (Awuchi and Awuchi, 2019; Martinez-de-Ibarreta and Valor, 2017). Intrinsic attributes of seafood relate to the physical attributes such as species, taste, appearance, freshness, etc. (Hall and Amberg, 2013; Mitra et al., 2021; Nguyen et al., 2015; Quagrainie et al., 2008). Seafood thus can be considered an information-intensive and multifaceted product. With the diversity of

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species available to consumers in the marketplace, a pragmatic approach to modeling fish consumption is to do so collectively to accurately assess demand patterns (Bronnmann et al., 2016; Buason and Agnarsson, 2020; Nguyen et al., 2015).

This study analyzed demand for fish by the number of species purchased in 2019 from a representative fish basket of species from both wild and aquaculture sources. The species include largemouth bass, hybrid striped bass, bluegill, walleye, yellow perch, rainbow trout, Great Lakes whitefish, lake trout, barramundi, and tilapia, which are among popular species in the U.S. Largemouth bass, bluegill, walleye, yellow perch, Great Lakes whitefish, and lake trout are indigenous to the Eastern and Midwestern regions and the Great Lakes basin. Lake whitefish, lake trout, walleye, yellow perch, salmon and ciscoes constitute the main commercial, recreational and tribal fisheries of the Great Lakes valued at $7 billion (Great lakes Fisheries Commission – GLFC, 2014).

The objective of the study is to model U.S. demand for fish utilizing purchase count for a group of species representing both high- and low-priced species, and wild capture and farmed fish in the U.S. Buason and Agnarsson (2020) examined consumption of fresh salmon, frozen Salmonidae, fresh cod, frozen whitefish, and other seafood products using retail scanner data and confirmed the heterogeneity of consumer demand for seafood. In another study of fresh salmon, fresh white fish and other fresh fish products in France, Buason et al. (2021) utilized a count model of truncated multivariate Poisson log-normal distribution to examine the importance of loss-leader marketing strategies in the seafood market such as the loss-leader pricing strategy.

Studies have reported increased importance of sustainability and environmental friendliness i.e., green characteristics in seafood purchases (Ankamah-Yeboah et al., 2020; Chen et al., 2015; Roheim et al., 2018; Roheim and Zhang., 2018; Uchida et al., 2014). Therefore, this study specifically focuses on a collective basket of fish species and the importance of credence attributes compared to a single fish species, salmon. Demand is defined by positive purchase responses to at least one of the species in the basket. This demand approach provides insights into trends and understanding of seafood demand, which is valuable information for the fisheries and aquaculture sector.

2. Data sources and methodology

2.1. Data

Data for the study was obtained from an online survey of consumers conducted in 2020 by Qualtrics^{XM}, based in Seattle, WA, USA. The target sample was U.S. residents, aged 18 or older. The main objective of the survey was to assess consumers' seafood purchases in 2019, pre-Covid-19 pandemic. A draft survey instrument was first pretested and the feedback used to refine certain questions for a final survey instrument. The survey instrument had several parts but only portions relating to species purchased are analyzed in this study. We analyzed specific responses on species purchased, the importance of select attributes to fish choices, and demographics. A national survey presents challenges to obtaining price information for each species from across different locations, therefore participants were directly asked about the importance of price in seafood choice.

Online surveys have their challenges because of potentially different motivations for participation, especially where there is some reward system. Respondents who truly want to express their opinions are assumed to be more deliberate in responding to survey questions while others may not provide thoughtful and truthful responses and would quickly go through the survey (Baker and Downes-Le Guin, 2007; Dillman et al., 2014). Therefore, to secure reliable information that represents accurate reflection of respondents' preferences, we eliminated responses that showed evidence of multiple responses from the same individual as well as responses that were fully completed in <3 min. The estimated average time for completing the survey is about 7 min within a range of 3 to 10 min for a fully completed survey. This resulted in a total of 1416 responses.

2.2. Analytical framework and parameter estimation

The analysis of demand for fish as measured by the number of species purchased in 2019 is approached in four ways:

Model I: Demand for all 10 species - largemouth bass, hybrid striped bass, bluegill, walleye, yellow perch, rainbow trout, Great Lakes whitefish, lake trout, barramundi, and tilapia.

Model II: Demand for 6 predominantly aquaculture species (largemouth bass, hybrid striped bass, walleye, rainbow trout, barramundi[1] and tilapia.)

Model III: Demand for 4 predominantly wild capture food species (bluegill, yellow perch, Great lakes whitefish and lake trout).

Model IV: Demand for salmon (Atlantic and Pacific) for comparison outside the basket.

The distribution of fish counts purchased from the baskets and salmon are presented in Fig. 1. There are two distinct observations in the data collected - purchasers and non-purchasers of the species. However, we could also potentially identify two groups of non-purchasers - those that genuinely never purchase any of the species (structural zeros) and those that indicated they did not purchase any of the species during the reference period of 2019 (sampling zeros). Structural zeros would

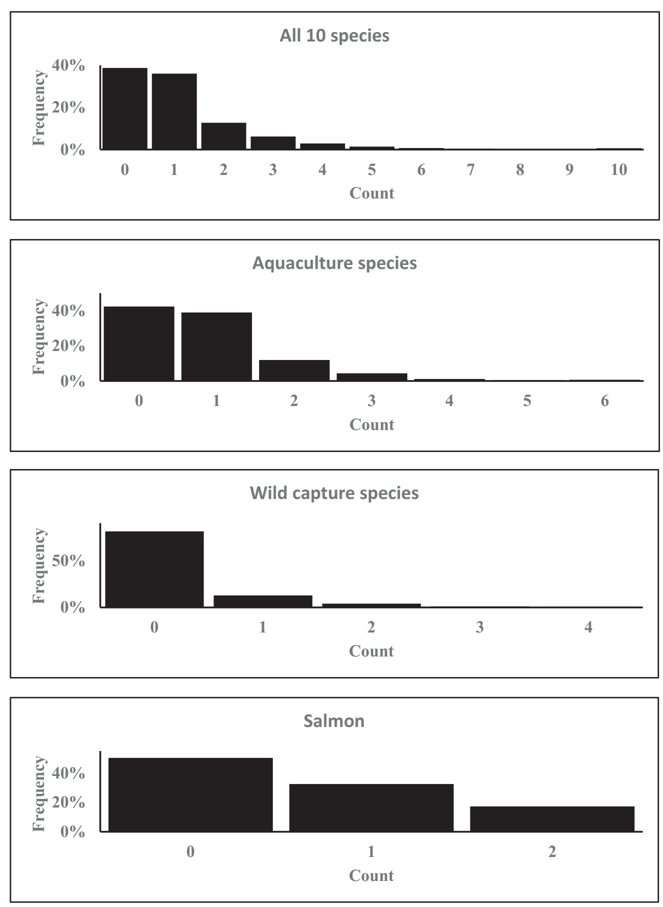

Fig. 1. Distribution of fish count purchased.

[1] Barramundi also called Asian sea bass is wild caught in the West Pacific region but is farmed in the US.

represent consumers in locations where the 10 species are not commonly available while sampling zeros could represent those that may have purchased any of the species prior to 2019 or even during 2020.

Modeling count data is prevalent in applied research on food, recreation, environment, sociology, engineering, and medical studies. Count data are commonly modeled with Poisson regressions but the existence of excess zeros has led to the use of different types of mixture models. The zero-inflated Poisson (ZIP) model is an example of mixture model routinely applied to data settings with excess zeros (Cameron and Trivedi, 1998; Lambert, 1992). Zero-inflated models accommodate data with both excess structural and sampling zeros. The excess zeros are addressed through two separate processes, which could have the same set of covariates, $\boldsymbol{x}$ or potentially different sets of covariates, $\boldsymbol{x}$ and $\boldsymbol{z}$. The first step in the process models the structural zeros commonly in the form of a cumulative normal or logistic probability function, π_i. Such zeros apply to the genuine non-purchasers. The second step models the count data following a Poisson distribution conditional on the excess zeroes, assuming some zero observations are due to sampling and allocate a probability to observe zero counts (1- π_i). Lambert (1992) also describes the ZIP model in the form of modeling two states - the probability of a perfect-state of complete zeros, and the probability of an imperfect-state of zeros and non-zeros because of uncertainty. Assuming separate sets of covariates, $\boldsymbol{x}$ and $\boldsymbol{z}$, the ZIP is then expressed as:

$$P(Y_i = y_i|x,z) = \begin{cases} \pi_i + (1-\pi_i)exp(-\lambda_i)\ y_i = 0 \\ (1-\pi_i)\dfrac{exp(-\lambda_i)\lambda_i^{y_i}}{y_i!}\ y_i > 0 \end{cases} \quad 0 \le \pi_i \le 1 \tag{1}$$

where $Y_i \sim Poisson\ (\lambda_i)$, the parameter λ_i is the conditional mean and an exponential function of the $\boldsymbol{x}$, $\lambda_i = \exp.(\boldsymbol{\beta}'x_i)$ and π_i is the probability of zero outcome, $\pi_i = g(\boldsymbol{\theta}'z_i)$; β and θ are unknown parameters. In eq. (1), the probability of observing a zero, $P(y_i = 0)$ is the sum of observing an excess zero not subject to the Poisson process and the probability of observing a zero in the Poisson model with mean $\lambda_i = 0$. Note that exp.$(-\lambda_i)\ \lambda_i^0\ /\ 0! = \exp.\ (-\lambda_i)$. The ZIP model accounts for the probability of observing a zero using a mix of distributions.

The mean and variance of the ZIP are expressed respectively as $E(y_i) = (1-\pi_i)\ \lambda_i$ and $Var(y_i) = \lambda_i\ (1-\pi_i)\ (1+\lambda_i\ \pi_i)$. When $\pi_i = 0$, the ZIP model becomes the basic Poisson model while as $\pi \rightarrow 1$, the variance increases and there is over-dispersion from the excess zeros. The estimation is accomplished by maximizing the log-likelihood, *LL*:

$$\begin{aligned} LL = &\sum_{y_i=0} log\left[exp(\pi_i) + exp\left(-exp(\lambda_i)\right)\right] + \sum_{y_i>0}(y_i\lambda_i - exp(\lambda_i)) \\ &- \sum_{i=1}^{n} log[1+exp(\pi_i)] \ - \sum_{y_i>0} log(y_i!) \end{aligned} \tag{2}$$

This study modeled a dependent variable Y_i equal to the purchased count of select species in the basket. The vector of covariates $\boldsymbol{x}$ is associated with the imperfect state and include the binary variables of importance of locally sourced, freshness, price, produced in the USA, sustainably produced, 3rd party certified / verified, product is farmed, product is wild-caught, and no added hormones; purchases of finfish, shellfish and mollusks; and demographic variables. The set of $\boldsymbol{z}$ covariates is associated with the perfect state and include the importance of locally sourced, freshness, price, produced in the USA, sustainably produced, 3rd party certified / verified, product is farmed, product is wild-caught, and no added hormones as well as location of respondents. Variable description and summary statistics of the variables are presented in Table 1. All covariates are binary dummies, and effects coded demographics are used in the models. The NLogit 5.0 software was used to estimate the four models.

Table 1
Summary statistics and description of variables.

Variable	Description	Mean	Std. Dev.
Dependent			
Purchase count	Number of species purchased from the 10 species basket	1.148	1.501
Purchase count	Number of Aquaculture species purchased	0.872	1.029
Purchase count	Number of Wild caught species purchased	0.276	0.670
Purchase	Salmon species	0.669	0.752
Explanatory			
Purchased finfish	Proportion who purchased finfish in 2019	0.867	0.339
Purchased shellfish	Proportion who purchased shellfish in 2019	0.662	0.473
Purchased mollusks	Purchased mollusks in 2019	0.326	0.469
Local (Yes/No)	Local source is important when choosing seafood	0.592	0.492
Fresh (Yes/No)	Freshness is important when choosing seafood	0.846	0.361
Prices (Yes/No)	Price is important when choosing seafood	0.852	0.355
USA (Yes/No)	Produced in USA is important when choosing seafood	0.708	0.455
Sustainability (Yes/No)	Sustainability is important when choosing seafood	0.720	0.449
Certified (Yes/No)	3rd party certification is important when choosing seafood	0.579	0.494
Farmed (Yes/No)	Farmed product is important when choosing seafood	0.463	0.499
Wild (Yes/No)	Wild-caught product is important when choosing seafood	0.581	0.494
Hormone-free (Yes/No)	Hormone-free is important when choosing seafood	0.732	0.443
Male	Male respondent	0.447	0.497
Female	Female respondent	0.549	0.498
Age 18–34	Age 18 to 34 years	0.409	0.492
Age 35–54	Age 35 to 54 years	0.403	0.491
Age 55–64	Age 55 to 64 years	0.110	0.313
Age ≥ 65	Age 65 and above	0.078	0.269
Income <25 K	Household income is less than $25,000	0.221	0.415
Income 25-74 K	Household income is $25,000–74,000	0.455	0.498
Income 75-149 K	Household income is $75,000–149,000	0.245	0.430
Income ≥150 K	Household income is $150,000 and above	0.079	0.270
Asian	Race is Asian	0.052	0.223
Black	Race is Black	0.097	0.297
Hispanic	Race is Hispanic	0.097	0.297
White	Race is White	0.730	0.444
Other race	Other race indicated	0.023	0.151
South	Respondent is located in the South region	0.386	0.487
West	Respondent is located in the West region	0.191	0.393
N. East	Respondent is located in the North East region	0.201	0.401
N. Central	Respondent is located in the North Central region	0.203	0.402

Note: Reference variables in the various categories are female, age 65 and over, income below $25,000, other race and N. Central.

3. Results and discussion

3.1. Summary statistics

The response and socio-demographic information of respondents in this study are presented in Table 1. From Table 1, most respondents were white (73%), female (55%), within the age range of 25–44 years (54%), and with household income of below $75,000 (78%). Among the factors consumers considered important to their seafood choices, freshness, price, produced in the USA, sustainability, and hormone-free were the most indicated by consumers, 72%–85%. Besides the economic factor of price, the importance of freshness and some green attributes (sustainability, 3rd party certification, wild capture and hormone-free) on consumer fish choice is consistent with other reported survey results in the U.S. (Davidson et al., 2012; Hall and Amberg, 2013; Quagrainie et al., 2008; Roheim et al., 2012; Yip et al., 2017).

The factors of local, farmed, and wild-caught were also considered important by 50%–60% of consumers, which is relatively lower than the importance of green attributes. From Tables 1, 58% of consumers preferred wild caught compared to 46% preferring farmed fish. In addition to the importance of select factors to fish choice, respondents were asked about seafood types purchased. A high number of consumers indicated buying finfish (87%) and about 66% and 33% respectively purchased shellfish and mollusks. From the perspective of the species considered in this study, the 87% purchasing finfish is very logical and the variable accounts for information about the species, therefore it is used as a surrogate constant in the estimations.

3.2. Model selection

The model diagnostics are provided in Table 2. The appropriateness of the ZIP model is assessed with Vuong (1989) statistics. The Vuong statistic is specified as:

$$V = \frac{\overline{m}\sqrt{n}}{S_m} \tag{3}$$

where

$$m_i = ln\left[\frac{\widehat{P_1}(Y_i|X_i)}{\widehat{P_S}(Y_i|X_i)}\right] \tag{4}$$

m_i is the log of the fitted probabilities for the i^{th} observation and has a mean $\overline{m}$ and a standard deviation S_m; P_S is the standard Poisson and P_1 is the zero-inflated model. The Vuong statistic asymptotically follows a standard normal distribution (0,1) and if $V > 1.96$, then the model favors the zero-inflated model and if $V < -1.96$ it favors the standard model. From Table 2, the ZIP is more appropriate to use than the Poisson in all models, which is very plausible because given the study objectives, ZIP aligns with inferences from the study design.

3.3. Parameter estimates

Table 3 presents the estimated partial effects calculated at the means, which shows estimates of the effects in the count probability portion (imperfect state) and the effects in the zero inflated portion (perfect state) in all models. The results for finfish, shellfish and mollusks purchased were consistent across the models (Table 3). These factors lead to a higher probability of demand for the select fish species in the basket whether a basket of all 10 species, aquaculture species, wild-caught species or salmon. For all species, aquaculture species and salmon, the associated estimate for the finfish variable showed the strongest effect, 100%, 71% and 44% probability respectively on fish count purchased among all other variables assessed in the models (Table 3). All the species are finfish therefore, the finding should be expected. In addition, the positive probability of consumers who purchased shellfish and mollusks in the various models reinforces the assumption that seafood consumers do purchase different fish species or a combination of them from time to time. It also suggests consumers buy from a wider basket of seafood. These factors lead to a higher probability of demand for the select fish species in the basket whether the basket contains all 10 species, aquaculture species, wild-caught species or salmon.

Table 2
Model diagnostics.

	All 10 Species	**Aquaculture Species**	**Wild Capture Species**	**Salmon**
Vuong statistic	4.34[a]	4.74[a]	6.45[a]	4.39[a]
Pr(y = 0)	33%	41%	82%	49%
Pr(y > 0)	67%	59%	18%	51%

[a] Estimated parameter is significant at 0.01 level.

Table 3
Estimated partial effects from the models.

Variable	All 10 species Coef.	Aquaculture species Coef.	Wild Capture species Coef.	Salmon Coef.
Poisson Regression Part				
Purchased finfish	1.018***	0.712***	0.131	0.438***
Purchased shellfish	0.187**	0.131*	0.041	0.041
Purchased mollusks	0.643***	0.448***	0.204***	0.260***
Importance of				
Local	0.098	0.071	−0.115**	−0.084
Fresh	−0.445***	−0.416***	−0.197***	−0.192*
Prices	−0.637***	−0.455***	−0.139**	−0.244***
USA	0.115	0.030	−0.087	−0.132*
Sustainability	−0.073	−0.048	0.034	0.033
Certified	−0.070	−0.090	−0.023	−0.026
Farmed	0.221***	0.083	0.075	−0.008
Wild	0.104	0.085	0.074	0.052
Hormone-free	−0.223***	−0.167**	0.005	−0.152*
Demographics				
Male	0.124***	0.077**	0.047**	−0.025
Age 18–34	0.066	−0.009	0.058**	0.013
Age 35–54	0.129***	0.101**	0.036	−0.049
Age 55–64	−0.094	−0.032	−0.035	0.058
Income 25-74 K	−0.181***	−0.099**	−0.074***	−0.060
Income 75-149 K	0.081**	0.040	0.057**	0.059
Income 150 K & above	0.285***	0.171**	0.090**	0.098
Asian	0.198**	0.212**	−0.009	0.086
Black	−0.001	−0.048	0.012	−0.204**
Hispanic	−0.146	−0.073	−0.116	0.094
White	−0.161**	−0.155**	−0.070	−0.087
Zero Inflated part				
Local	0.050	0.04	0.137***	0.056*
Fresh	0.065*	0.073***	0.078*	0.093***
Prices	0.121***	0.076***	−0.029	0.031
USA	0.035	0.012	0.149***	−0.049
Sustainability	0.052	0.003	−0.001	−0.002
Certified	0.081*	0.155**	0.030	0.028
Farmed	−0.106**	−0.031	0.010	−0.170***
Wild	0.034	0.023	−0.008	0.151***
Hormone-free	0.112***	0.073**	−0.033	0.136***
Location				
South	0.069*	0.056**	−0.050	−0.023
N. East	0.048	−0.003	−0.061	−0.045
West	0.016	−0.024	−0.036	0.007

***,** and * respectively, indicate estimated coefficient is significant 0.01, 0.05, and 0.10 level.

The importance of freshness and price, were significant in both parts of the models; negative in imperfect state of fish purchase and positive in perfect state of no purchase, i.e., both factors decrease the probability of fish purchase (Table 3). Although the importance of price was not assessed as a numerical composite value, the indication by consumers of its importance to seafood choice is consistent with theory. It decreases the purchase of fish species through a decrease in the probability of purchase and an increase in no fish purchase. The results for the importance of freshness appear unexpected and contrast results from previous studies that have reported the importance of freshness in seafood demand (Claret et al., 2012; Davidson et al., 2012; Hall and Amberg, 2013; Mitra et al., 2021). However, Americans are generally reported to consume seafood more when dining out than at-home therefore freshness may not be an important attribute (Love et al., 2020; Surathkal et al., 2017). National Marine Fisheries Service – NMFS (2021, 2022) reports a general decline in the consumption of fresh finfish and Surathkal et al. (2017) suggests that healthy diet and leisure-cooking could be attributes that impact non-value added seafood purchases from retail stores.

Regarding the importance of hormone-free on purchase of all species, aquaculture species and salmon, the factor had significant effect on non-purchase with decreasing probability of 22%, 17% and 15% respectively in the imperfect state of fish purchase, with corresponding increasing probability of 11%, 7% and 14% in the perfect state of non-purchase. In the salmon model, those who found hormone-free claims important were no more or less likely to buy more wild capture species than those who did not. Localness was found to be significant to consumers who did not purchase wild capture fish. There is a decreased probability of buying wild capture fish in an imperfect state of 12%, while there is a 14% probability of not purchasing wild capture fish in a perfect state of no purchase. In the salmon model, there is a 6% probability of non-purchase if local was considered important. Similarly, there is a reduced probability of 13% that consumers will not buy salmon if sourcing from USA was important.

The importance of 3rd party certification had significant effect in the perfect state of non-purchase with an increasing probability of about 8% for all species and 16% for aquaculture species. The findings generally contrast what many studies have reported about the increasing influence of green attributes to seafood purchases (Brécard et al., 2009; Hallstein and Villas-Boas, 2013; Hilger et al., 2019; Risius et al., 2019; Uchida et al., 2014; Vitale et al., 2020; Xu et al., 2012; Yip et al., 2017; Zander and Feucht, 2018).

Clearly, consumers' *ex ante* claims on the importance of green attributes to their seafood purchases do not match their demand for the fish species from these baskets. There could be three reasons for the conflicting results on green attributes obtained in this study. First, it could be that consumers value 'green attributes' but perceived the fish species of interest as unsustainable and thus do not purchase them. The U.S. imports 70–85% of its seafood needs, with salmon among the top seafood products consumed (National Marine Fisheries Service – NMFS, 2022). Shamshak et al. (2019) observe that the large U.S. seafood import together with limited ability to increase capture harvest, have in many ways defined U.S. seafood market trends and consumers may have cautious confidence in green attributes. Second, the increasing environmental concerns in the seafood sector gave rise to diverse market-based green schemes by governments, non-governmental organizations, trade associations, and private sector companies including food retail chains. The diversity, relevance and lack of clarity of many of these schemes may have created confusion and mistrust among consumers (Alfnes, 2017; Brécard, 2014; Hallstein and Villas-Boas, 2013; Prag et al., 2016). For example, Hallstein and Villas-Boas (2013) reported evidence that a green, yellow and red color-coded sustainability advisory scheme on seafood products led to overall decline in yellow-coded seafood sales by 15.3%, and no difference in seafood sales of green or red coded products. It suggests that the utility of green characteristics to seafood choices could be declining as consumers pay little attention to credence attributes when buying seafood. Third, previous studies largely focused on single seafood species and the effects of various ecological, environmental and sustainable attributes on demand. These credence attributes provide some quality cues to consumers for particular individual species and probably not a collection or representative group of seafood (Nguyen et al., 2015).

The importance of farmed fish contributed to increased purchase of the basket of all 10 fish species with an increase in fish purchase by 22% probability and a probability of no purchase by 11%. For salmon, the importance of farmed fish decreased non-purchase by 17%. A higher percentage of consumers preferred wild fish (Table 1) and the literature commonly report of consumer preference for wild fish over farmed fish (Davidson et al., 2012; López-Mas et al., 2020; Rickertsen et al., 2017; Roheim et al., 2012; Uchida et al., 2014). However, farmed seafood is commonly available in markets and seafood supply from the wild and aquaculture are about the same (FAO, 2020). López-Mas et al. (2020) reported that European consumers favored wild fish over farmed fish but they consumed higher amounts of farmed fish because of control in the production process, price, and availability. It suggests that having higher perceptions of wild-caught seafood compared to farmed fish may not necessarily translate into higher demand for the former. Six of the species in the basket found on the U.S. market are mainly farmed and so is salmon. Therefore, the results from the salmon model are consistent with the market. About 78% of salmonids come from aquaculture (National Marine Fisheries Service – NMFS, 2021).

Focusing on the demographic characteristics, males were more likely than females to purchase the species in all models except salmon (Table 3). Age is also among the major predictors of fish demand. The model results show positive relationships for fish purchase with younger millennials (ages of 25 and 34) for wild capture species and older millennials (ages of 35 and 44) for all species and aquaculture species. Regarding income, consumers earning less than $75,000 household income were less likely to purchase any of the fish while those earning $75,000 and above were more likely to purchase fish. Higher income households have been reported to have higher preferences for quality proteins such as fish (Chidmi et al., 2012; Tonsor and Marsh, 2007). The race and ethnicity variables have different results for Asians versus Whites. While Asians have a probability of 20% relative to 'Other race' purchasing all fish species and 21% probability purchasing aquaculture species, Whites have a 16% less probability each relative to 'Other race' purchasing all fish species and aquaculture species respectively. Seafood is generally a traditional ethnic diet of Asian consumers compared to other race and ethnic groups so the results are in order.

The results in Table 3 also show some spatial effects of seafood purchase. Relative to consumers in the North Central region, consumers in the South region are 7% and 6% less likely to purchase all fish species (Model I) and aquaculture (Model II) species respectively. These results suggest potential unfamiliarity of southern consumers relative to North Central region consumers of bluegill, walleye, yellow perch, Great lakes whitefish, and lake trout. Also, these fish species are not commonly available in the southern region; catfish is the predominately produced fish in the south (Roheim et al., 2012; Singh et al., 2014).

4. Conclusion

The study examined fish demand for a selected number of fish species supplied from the North Central region of the U.S. The study focused on demand in the form of species count purchased from a representative fish basket of 10 species, aquaculture species and wild-capture species and compared that with salmon. This is important because the marketplace offers a wide variety of seafood, and consumers purchase different fish species or a combination of them from time to time.

The results from the study showed that between 72% and 85% of consumers indicated that freshness, price, produced in the USA, sustainability and hormone-free were important to their fish choices. Estimates from the econometric models confirm that consumers do purchase different fish species or a combination of them from time to time. The results also showed the importance of some green factors (sustainability, 3rd party certification, wild capture and hormone-free) conflict with previous studies. This study focused on a collective or a basket of fish and it appears the effects of credence attributes may not apply generically to a collective group of fish or that the utility of green characteristics to seafood choices may be declining because consumers pay little attention to them when buying seafood.

Regarding method of production, even though a higher percentage of consumers preferred wild seafood, the importance of farmed was found to increase fish purchased. Farmed fish is commonly available in the marketplace and for species with both wild caught and farmed products, the later are relatively cheaper. Farmed fish is very acceptable to seafood consumers and policy makers, producer groups, and aquaculture advocates should continue supporting the development of both marine and land-based aquaculture to supplement the stagnant supply from wild-capture fisheries. Such efforts should be collaborative to harness the benefits of farmed fish from the consumers' perspectives.

Overall, the results from this study are informative regarding farmed fish and adoption of different green schemes, and implications for fisheries and aquaculture stakeholders seeking to grow the sector as a whole. The use of green credence attributes needs further examination as to their value to consumers relative to price.

CRediT authorship contribution statement

Kwamena Quagrainie: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Simone Valle de Souza:** Conceptualization, Supervision, Project administration, Funding acquisition. **April Athnos:** Software, Validation, Investigation. **Chinonso Etumnu:** Writing – review & editing. **William Knudson:** Writing – review & editing. **Ronald Kinnunen:** Writing – review & editing. **Paul Hitchens:** Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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