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Consumer willingness to pay for farmed seaweed with education on ecosystem services

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Abstract
Kelp aquaculture in the US is expected to grow significantly in the coming years. While the market potential is substantial, increasing demand is widely seen as a key step towards realizing this potential. Recent work on restorative aquaculture practices has led to increased study and valuation of ecosystem services of kelp aquaculture. This study demonstrates the efficacy of education on ecosystem services of kelp aquaculture as marketing material for kelp end products. Through an online willingness to pay survey, this study found a significant increase in consumer willingness to pay for end products after a brief education on ecosystem services. Price point of the product, income, gender, knowledge of ecosystem services, and frequency of kelp product consumption were found to be significant predictors of the magnitude of change in consumer willingness to pay. Of the four major categories of ecosystem services, supporting services were reported to be most important to consumers. These findings can guide private and public organizations in marketing efforts to drive consumer behavior and to actualize the large potential of kelp aquaculture in the USA.

Keywords Restorative aquaculture · Culture · Macroalgae · Kelp

Introduction

Seaweed farming is a rapidly emerging industry in the United States (Heidkamp et al. 2022). The industry has significant growth potential, primarily due to the large exclusive economic zone in the USA as compared to other nations (Kapetsky et al. 2013). Currently in the USA, there are two major areas of industry growth: Maine and Alaska (Kim et al. 2019). Though these areas have great potential for production, a lack of public knowledge and widely held misconceptions regarding seaweed aquaculture have stifled its growth and created apprehension among other ocean resource stakeholders. Commercial fishermen tend to fear how kelp farming may affect their ability to catch their desired species whereas coastal property owners operate with a "not in my backyard" mindset and worry about the possibility of aesthetic pollution (Kim et al. 2019). There is also distaste from local fisheries for the potential arrival of large corporations that may come with the expansion of the kelp and seaweed aquaculture industry (Greene et al. 2020). The permit and leasing processes across coastal communities in the United States presents an additional obstacle due to the disconnect between policy makers and potential growers (Duff et al. 2003; Knapp and Rubino 2016; Kim et al. 2019).

Lack of consumer understanding and familiarity of seaweed and kelp products likewise may hinder market growth in the USA and Europe. A recent study in Italy assessing the potential for seaweed in western diets identified a willingness of respondents to try seaweed food products but showed little respondent experience with such items (Palmieri and Forleo 2020). Likewise, recent studies on seaweed products consistently identify familiarity as a significant indicator of consumer acceptance and preference (Anusha Siddiqui et al. 2022; Embling et al. 2022). The disconnect between consumer familiarity with seaweed products and consumer willingness to try these products highlights the current gap in consumer education on seaweed products.

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Marketing product attributes, such as location of origin, product quality attributes, and environmental sustainability, is a common practice in aquaculture and wild harvest fisheries to stoke demand and increase consumer familiarity with products. A recent survey of industry professionals and managers identified these types of marketing as key next steps for the US farmed kelp industry to grow demand (Heidkamp et al. 2022), though this belief is based on theoretical expectation and adjacent products, as there is little existing research on kelp marketing to rely on for guidance. In this paper, we investigate how marketing the ecosystem service benefits of kelp aquaculture affects consumers' perception of products containing farmed kelp. The findings of this study are intended to help guide efforts to promote kelp aquaculture, and restorative aquaculture more broadly. We hypothesize that providing consumers with knowledge of ecosystem services would increase their willingness to pay for kelp products.

Ecosystem services

Of the many commercially grown aquaculture species in the United States, seaweeds are not among the most popular or profitable (FAO 2022). However, the recent interest in kelp aquaculture lies with their economic potential both through value added products like food and cosmetics, as well as with other non-traditional sources of value, most notably through ecosystem services, which are categorized into four (4) types (Fig. 1); provisioning, regulating, supporting, and cultural services (TEEB 2010).

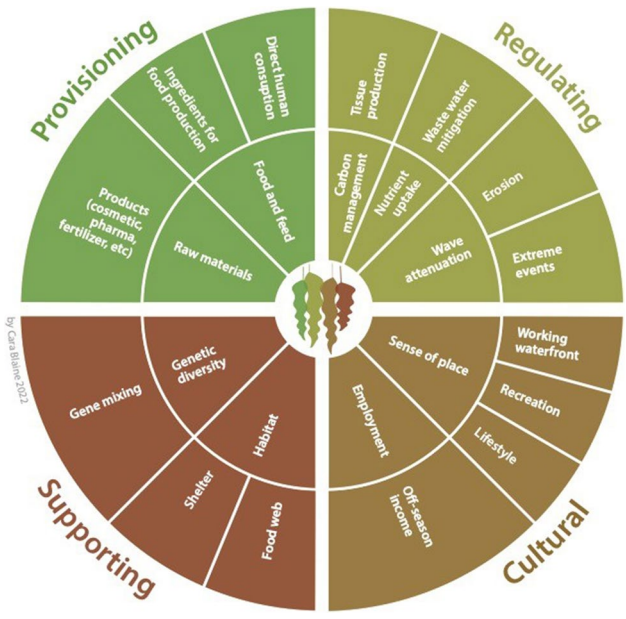

Fig. 1 Visual representation of the four categories of ecosystem services for farmed kelp in temperate regions. Figure created by Cara Blaine, adapted from (Alleway et al. 2019), courtesy of TNC

In the context of kelp aquaculture, provisioning services are those kelp end products obtained from ecosystems such as food, cosmetics, pharmaceuticals. These products can be food and feed material either for direct human consumption or as an ingredient for food production, or as raw material for products such as cosmetics, pharmaceuticals and nutraceuticals, or fertilizers (Marinho et al. 2016; Pechsiri et al. 2016; Mouritsen et al. 2019; Akomea-Frempong et al. 2021; Blikra et al. 2021; Figueroa et al. 2021; Samarathunga et al. 2022). Regulating services of temperate kelp aquaculture describe services such as carbon management through tissue production, wastewater filtration through nutrient uptake, and erosion and extreme event prevention through wave attenuation (Zhu et al. 2020; Grebe et al. 2021; Wu et al. 2022). Cultural services describe non-material benefits that contribute to the value-system and well-being of humans such as a recreational or spiritual connection to the ecosystem from temperate kelp aquaculture. These services can be categorized as sense of place such as working waterfronts, recreation or lifestyle as well as employment such as off-season income opportunities (Grebe et al. 2019). Supporting services sustain life and ecosystem structure through establishment of habitat or maintenance of species interactions. Supporting services are some of the least studied ES, and while further work is necessary, there is suggestion that temperate kelp aquaculture can assist in maintaining genetic diversity through gene mixing during nursery operations and provides habitat via shelter at farm structures and is therefore part of the local food web (Liu et al. 2012; Lucrezi 2021; Theuerkauf et al. 2022).

While ecosystem services are by definition anthropogenic, there is a growing body of work around the potential for aquaculture's ability to provide direct benefits to the local ecosystems (Barrett et al. 2022). These local impacts are the foundation of restorative aquaculture, defined by the Nature Conservancy as "commercial or subsistence aquaculture providing direct ecological benefits the environment, with the potential to generate net positive environmental outcomes" (TNC 2021).

Measuring the value of ecosystem services is a challenging task. One source of value is from the perspective of the consumer. Determining a consumer's willingness to pay for a service or product provides both a monetary value as well as insight into market dynamics. Similarly, willingness to pay has been used to measure perceived value of sustainability (vanOsch et al. 2017; Li et al. 2021).

Willingness To Pay

Willingness to pay (WTP) is the maximum amount a consumer is willing to pay for a product, and is the basis for measuring the change in social welfare (for consumers) for a change in product attributes. Safer cars, oceanview houses, and healthier food are all examples of product attributes that may be associated with greater consumer satisfaction

and higher willingness to pay. This concept has also been extended to measure consumer's value for sustainability. Recent studies have demonstrated a dramatic effect of sustainability on consumer WTP for food products and have concluded that consumers will in many cases pay a premium for sustainably produced food items (vanOsch et al. 2017; Li et al. 2021). Likewise, WTP studies have been used to demonstrate a substantial societal value associated with ecosystem services of kelp in Norway (Hynes et al. 2021).

There are two approaches to measuring WTP—revealed preferences and stated preferences (Breidert 2006). Revealed preferences are determined through market data or experiments using real world transactions. Experiments vary from laboratory experiments to field experiments. Both laboratory or field experiments can be conducted as auctions to either simulate or elicit real world purchase experiences. Stated preferences can be measured by survey, either direct or indirect. Indirect surveys are generally considered to be more robust than direct surveys and can take the form of conjoint analysis or discrete choice analysis (Kling et al. 2012). Direct surveys can take the form of expert judgements, where subject matter experts such as sales or marketing managers are surveyed. Direct surveys can also take the form of direct consumer surveys where end consumers are asked to indicate acceptable prices (Breidert 2006). Direct surveys, such as the Van Westendorp Price Sensitivity Meter, are commonly used by industry and academic analysis of new products or services (Arru et al. 2022).

Methods

The effect of education on ecosystem services on a participant's WTP for kelp products was measured through a single subject experimental design. Respondents were asked to provide a round of initial responses followed by a treatment, and then a final round of responses to attribute any measurable difference to the treatment.

Willingness to pay (WTP) of consumers was assessed using a Price Sensitivity Meter (PSM) survey. Study data were collected and managed using REDCap (Research Electronic Data Capture). REDCap is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources (Harris et al. 2009, 2019). The survey link was made available for two weeks in two ways. The link was made available in a weekly electronic newsletter for Lake Stewards of Maine, and via an Instagram post by the Maine Aquaculture Association. After two weeks, data collection was ended, and the link closed. Potential respondents were informed at the beginning of the survey that their responses would remain anonymous to avoid biasingresponses.

The survey was designed to measure WTP pre and post treatment with demographic, background, and perception questions collected at the end. The treatment consisted of a 90 s video providing a definition of ecosystem system services and provided examples specific to kelp aquaculture. It was considered a brief education on ecosystem services, allowing the study to attribute any change in willingness to pay from pre and post treatment to an education on ecosystem services. The video was designed to be simple and concise, consisting of a voice over slide presentation that relied on easily digestible definitions, images, and graphics from TEEB (The Economics of Ecosystems and Biodiversity) (TEEB 2010).

The initial WTP measurements were made directly after informed consent and attestation of age were collected to begin the survey, followed by the treatment video, and subsequently the second WTP measurements. The WTP PSM questions began with brief written descriptions of the product followed by four open ended price questions where the respondents were asked to identify the price at which the product would be (1) too expensive, (2) expensive but not out of the question, (3) considered a bargain, and (4) considered too low to assume the product would be of good quality. These price questions were asked in the same order for each of the five products; (1) Kelp Toothpaste, (2) Kelp Pinch, (3) Kelp Shampoo, (4) Kelp Supplement, and (5) Kelp Vodka (Table 1). The products were chosen as they are existing items easily accessed by most consumers either online or in store fronts. In addition, these products span a number of consumer sectors and range from luxury items to everyday use items.

The survey ended with demographic questions and perception and background questions. The demographic information collected included age, gender, income, level of education, location, and occupation. Perception and background questions were measured using a Likert scale or monthly count and covered expanding local aquaculture, importance of sustainability in purchasing decisions, knowledge of ecosystem services, likelihood of changing spending habits, frequency of seafood consumption, and frequency of kelp product consumption. In addition, respondents were asked to rank their perceived importance of the four types of ecosystem services: provisioning, regulating, supporting, and cultural.

For the purpose of this study, each difference in WTP was considered a single data point. As each respondent provided four price responses for each of the five products pre and post treatment, each respondent contributed forty data points. Where appropriate, demographic data was transformed into discrete categories in order to analyze the level

Table 1 Survey products and descriptions as they appeared in the online survey

	Product	Description
1	Kelp Toothpaste	"Kelp Fresh Toothpaste (6 oz): Helps brighten your smile and freshen your breath without the use of harsh abrasives and chemicals. Contains botanicals such as kelp, spearmint and parsley. Free of fluoride, gluten, saccharin, artificial sweeteners, parabens, propylene glycol and SLS"
2	Kelp Pinch	"Kelp Pinch (3.3 oz)—Flaked Bull Kelp bursts with salty, ocean flavor and savory richness. Use a pinch to make delicious broth. Top your next stir fry, ramen, rice bowl, or salmon with a healthy dose of ocean goodness."
3	Kelp Shampoo	"Kelp Deep Moisturizing Shampoo (8 oz)—Thickens hair shaft, dramatically improves moisture content, promotes fuller shinier hair naturally. Thick formula with loads of luxurious suds, promotes healthier hair in one wash. Improves shine and manageability, with organic Iceland Kelp, Rosemary, Ancient Amber extracts. Boosted with Vitamin C, E, B3, B5, B6, and Iceland Geothermal Kelp a rich source of healing Calcium Alginate. Gentle natural cleansing, provides improves scalp health with Witch Hazel extract, thicker shinier hair after first wash."
4	Kelp Supplement	"Sea Kelp Dietary Supplement (90 capsules): Get a daily boost of natural vitamins, minerals, and antioxidants. This product combines three potent algae superfoods only found in pristine waters. Sea kelp is one of the best natural sources of iodine, which is essential for healthy thyroid function and balanced hormones."
5	Kelp Vodka	"Sugar Kelp Vodka (750 mL)—created in partnership with locally harvested sugar kelp to produce a delicious and unique flavored vodka. The brininess is a delicious base for a Martini or Bloody Mary. Distilled in small batches."

of significance of demographic and perception-based questions on any measured change in WTP.

The hypothesis was evaluated by two sample t-test to determine if a significant difference in WTP was observed post treatment. Through backwards selection, a linear multivariate regression model was constructed from a series of ANOVA tests used to evaluate levels of significance for demographic, product attributes, and perception variables. This study used a calculated variable, ΔWTP *(Price 2 – Price 1),* to determine the effect of these variables on a change in respondent WTP. Variables were considered significant at $p < 0.05$. Lastly, averages of ΔWTP were used to assess potential trends of significant variables on ΔWTP.

Results

Willingness To Pay (WTP)

The results of this study show a statistically significant increase in consumer willingness to pay for kelp end products after an education on ecosystem services ($t(819) = 10.303$, $p < 0.0001$).

Additionally, five of the collected variables were found to significantly ($p < 0.05$) influence ΔWTP. Gender (G) ($F(1,234) = 11.56$, $p = 0.0007$) and knowledge of ecosystem services (KES) ($F(6,700) = 5.76$, $p < 0.00001$) were found to have the most significant effects of the identified variables. Price point (PP) ($F(3,313) = 5.15$, $p = 0.0016$) and frequency of kelp product consumption (FKP) ($F(5,385) = 3.797$, $p = 0.0021$) were moderately significant followed by income (I) ($F(8,390) = 2.29$, $p = 0.02$), the least statistically significant of the identified variables. In addition, two sets of interactions were additionally found to be significant: FKP and KES ($F(10,451) = 2.22$, $p = 0.015$), as well as well as KES and I ($F(5,257) = 2.54$, $p = 0.027$). The resulting model determined via backwards selection of variables and their interactions; $\Delta WTP = PP + KES + FKP + G + I + KES{:}\ FKP + KES{:}\ I$.

To understand consumers perceptions of ecosystem services of kelp aquaculture, this study had respondents rank the four major categories of ecosystem services in order of importance directly after treatment. Supporting services was ranked most important, followed by regulating services, culture services, and finally provisioning services.

Respondent Perceptions and Background

Perception questions were collected using a Likert scale (1 – 7), while background questions were collected as a monthly count. Likert responses were converted to a perception where a reported value of 1 was equivalent to 0%, a 4 equivalent to 50%, and a 7 equivalent to 100%. Monthly count was converted to a monthly percent average. Respondents felt positively about expanding local aquaculture (EAQ) (Fig. 2). Likewise, respondents reported that importance of sustainability (IS) was high in everyday purchasing practices. Notably, neither of these questions had a response on the negative, or "not important" half of the reporting scale. Most respondents agreed that they were likely to change their spending habits (CSH) if it were to have an impact on local marine ecosystems, although outliers indicated they were not very likely to change their spending behavior.

Respondents reported a wide range of KES. Most respondents had little to no previous KES, with an average response of minimal knowledge, a 3 out of 1–7 scale, of knowledge. This was the only perception and background question that included responses at both extremes of the self-reporting scale.

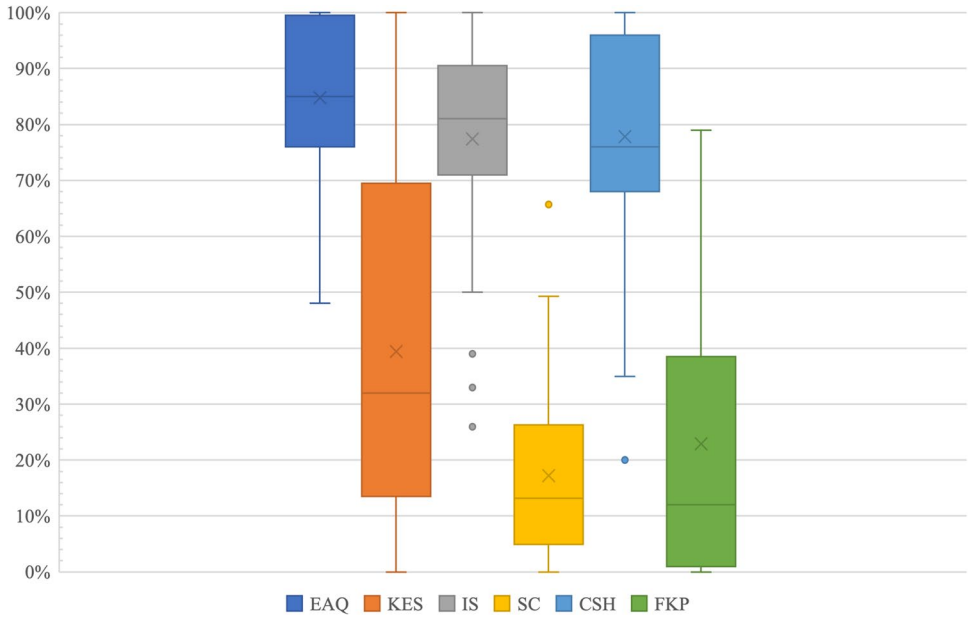

Fig. 2 Respondent perception and background responses by question, reflecting respondent variation by mean, quartiles, and outliers where EAQ is perception of expanding local aquaculture, KES is knowledge of ecosystem services, IS is importance of sustainability, SC is monthly seafood consumption, CSH is likelihood of changing spending habits, and FKP is frequency of kelp product consumption

Consumption of kelp products (FKP) was second only to KES in terms of range of responses. While most respondents reported little to no consumption of kelp products, some respondents reported moderate consumption. Seafood consumption (SC) was reported within a smaller range indicating respondents only occasionally consumed seafood on a monthly basis.

Respondent Demographics

The survey collected 41 complete responses. All responses in each survey were checked for logical congruency and incomplete surveys were discarded as a protection against bots. Respondents varied widely in reported demographics. Reported gender was split 63% to 37% female to male, respectively. Respondent age varied substantially with an average age of 31 (std. dev. ± 12). For the purposes of this study, age was broken out into just two major categories; older and younger. While a majority of respondents were from the ages of 23–31, there were a number of respondents above the age of 47 with no respondents in between. The older and younger bucketing allow for an approximation of generational impact in our analysis.

Location information was compiled at the state level. Maine was the most commonly reported location with 32% of responses. New York was the second most reported location with 22% of responses followed by Massachusetts with 12% of responses. The remaining respondents reported a wide range of locations, with 2 respondents each from Tennessee, Pennsylvania, New Hampshire, Georgia, and 1 respondent each from Vermont, North Carolina, Florida, Washington D.C., California, and Australia.

Reported individual income of respondents varied significantly with a minimum of no reported income and a maximum of US$220,000 annual income. The median reported salary of respondents was US$65,000 annual income with an average reported annual income of US$71,448.97 (std. dev. ± 51,655.39). For analysis, income was bucketed by US$25,000 intervals (Fig. 3).

Level of education was reported across five categories. A majority of respondents reported a bachelor's degree. The second most common level of reported education was a master's degree with the two accounting for 88% of all respondents (Fig. 4).

Discussion

Willingness To Pay

Consumers were willing to pay more for kelp products after a brief education on ecosystem services. This result demonstrates that ecosystem services can serve as a valuable marketing tool both for public and private organizations. Further understanding how best to educate consumers on ecosystem services is an important next step.

Though this study was designed to evaluate WTP of kelp as a provisional ecosystem service, surprisingly, respondents ranked provisioning services of kelp as least important among all four categories of ecosystem services. While regulating services were found to be the second most important category of ecosystem services, this result contradicts what we have observed as the messaging on kelp aquaculture and reflected in the literature (TNC 2021). Generally, messaging on ecosystem services of kelp aquaculture and mariculture

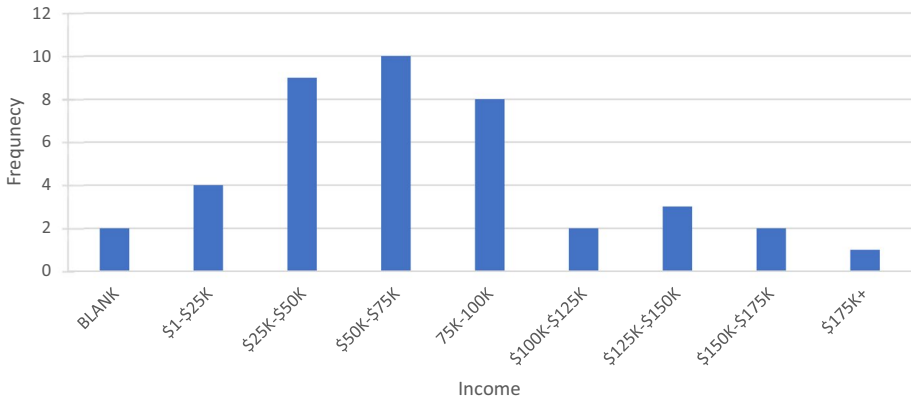

Fig. 3 Histogram of reported respondent income by 25K category

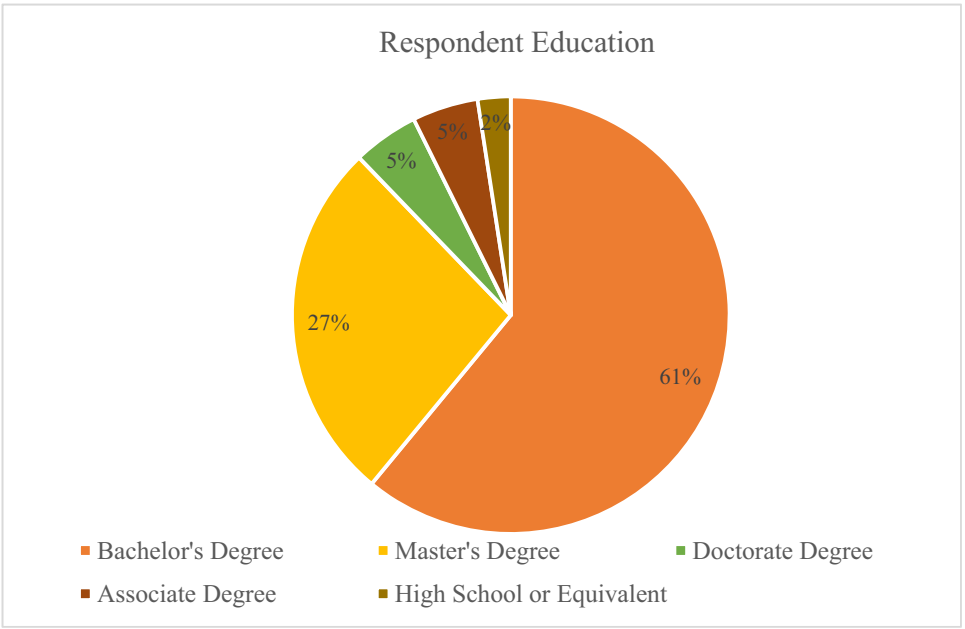

Fig. 4 Reported highest level of education received per respondent

more broadly have focused on regulating services such as carbon sequestration and nutrient uptake, and until 2018 over half of all published work on ecosystem services of mariculture has been focused on regulating services (Weitzman 2019; Gentry et al. 2020). Further study of supporting services and cultural services is needed, and the results of this study highlight the potential importance of supporting services for marketing material to change consumer behavior.

Product Attributes

Of the two product attributes, product, and price point, only price point was found to have a significant effect on change in willingness to pay (WTP). This study found that as price point increased from low to high, so does change in WTP (ΔWTP) across products. This result is encouraging as it shows that products ranging from inexpensive everyday items to more expensive luxury items experience a near proportional, positive ΔWTP after an education on ecosystem services. In addition, this study did not find that product type was a significant variable in (ΔWTP). This lack of product effect emphasizes the far reaching and potentially equitable benefit of education on ecosystem services on WTP across a variety of kelp end products. This affirms that education on ecosystem services is a leverage point to change consumer behavior and bolster the US kelp industry as a whole.

Perceptions and Background

Two perception and background variables were included in the final model: KES and FKP. For the purposes of this study, KES was meant to capture previous knowledge. However, given the necessity to order the treatment first

and perception questions second, it is thought that some respondents may have been reporting perceived KES due to treatment. The wide range of responses is most likely a result of respondents answering these two separate questions. The effect of such confusion would be an artificially high level of *previous* KES. Thus, as the calculated average of all respondents still indicates a minimal KES, it is thought that most respondents had little to no previous knowledge on ecosystem services.

The highest ΔWTP of the possible responses on KES were found at the extremes, either expert knowledge or no knowledge of ecosystem services. This result is encouraging, while somewhat surprising. For those respondents who reported little KES, we expected to see a large change in WTP. We did not expect those respondents who reported substantial knowledge of KES to have an equivalently large change in reported WTP to low reported KES respondents. It is likely these high KES respondents may not often equate ES with their everyday purchasing behavior. As such, the brief education on ecosystem services may have served to simply put ES in mind when providing a price response. Further study on how existing KES influences consumer behavior will be necessary to further understand how an education on ecosystem services may be used to change consumer behavior.

A majority of respondents reported little to no FKP, which was to be expected given current market size and popularity in the USA. This study found that consumers who were least frequent consumers of kelp products had a larger reported ΔWTP when compared to the few respondents who reported high consumption of kelp end products. This affirms the major result and underlying assumption of the study that there is a large opportunity to affect consumer behavior in the current early stages of the kelp industry in the USA via an education of ecosystem services.

Demographics

Gender (G) and I were the demographic variables included in the final model. This study collected gender identity in an open-ended format, but only received either male or female responses. On average, female respondents reported a nearly double ΔWTP over men. This result is consistent with recent studies that found gender to have a substantial affect in their assessments of ΔWTP for sustainably produced food products (Li et al. 2021). While this study did include food products, the five kelp products presented to respondents represented a variety of markets from ranging from cosmetics to health supplements indicating gender effects are likely true across market sectors and a variety of product types.

The least significant of the five identified variables was income. Notably the interaction of income and KES was found to be significant. Interestingly, this study found that on average, low reported income accounted for the largest ΔWTP of respondents. It is important to note that most respondents reported an income of 100 K or below, which may be responsible for this finding. Of the reported incomes up to 100 K, there is a clear increase in ΔWTP with increased income, while reported incomes above 100 K were varied. Given the concentration of respondents below 100 K reported income, for most respondents we see an increase in ΔWTP after an education on ecosystem services as income increased. While this this finding is unsupported for reported income levels in this study above 100 K, the finding is consistent with recent studies showing a positive relationship between income and WTP for plant-based food products (Anusha Siddiqui et al. 2022). A logical next step in a future study might examine each factor of the model and apply the model to different situations (consumers, geographies, industries) to examine the robustness of the model.

Relevance to Industry

Given the expected growth of kelp aquaculture and end-product markets here in the US, there is a growing focus on promoting and marketing both kelp production as well as kelp products (Markets and Markets 2020). This growing focus on marketing and education is spearheaded by two parties, private companies marketing specific products, and public entities, non-profits and NGOs, promoting kelp aquaculture practices. This study puts forth education on ecosystem services as a valuable tool to be used by either public or private entities.

We have demonstrated there to be considerable change in stated consumer preferences after a brief education on the ecosystem services of kelp aquaculture. This study was able to demonstrate this change with a generalized and basic video. We would assume that targeted marketing material produced by public and private organizations would have a greater effect than demonstrated in this study. Furthermore, this study assists in addressing some basic question on how best to target such marketing techniques and has shown this effect to be significant across a variety of end product sectors and across price points.

Participants

This study aimed to hear from participants thought most likely to be impacted by an education on ecosystem services. The 41 respondents of the survey were a majority young people who are not averse to aquaculture, who value sustainability, have little prior knowledge of ecosystem services and do not consume much seafood or kelp products. This study has shown that for this sample, ecosystem services can serve as a valuable marketing tool both for public and private organizations, however, further study of this effect

is necessary to validate these findings for broader populations. While the results of this study do reflect Maine and in part of the northeast of the USA, a larger geographical and demographic sample will be needed to confirm the efficacy of education of ES on consumer WTP across the USA and Europe.

Conclusion

This study, the first of its kind to our knowledge, demonstrates the value of consumer education on ecosystem services. While not directly assigning values to ecosystem services of kelp aquaculture, this study clearly demonstrates perceived value of these services by consumers and the public. We hope this work assists private and public efforts to promote sustainable kelp aquaculture and the growth of this industry in the USA.

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Author Contribution C.J.B. secured funding and worked with W.B. to conceive and design the project. R.M.G. provided discipline specific advice on experimental design and analysis. W.B. led the data collection, analysis, and wrote the first draft of the manuscript, with advice from R.M.G. and C.J.B. All authors made significant contributions and edits to the preparation of the manuscript. All authors reviewed the final manuscript.

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Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors have no competing interests to declare.

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