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Defining U.S. consumers' (mis)perceptions of pollinator friendly labels: an exploratory study

RESEARCH ARTICLE

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Abstract

Declining pollinator insect populations is an important global concern due to potential negative environmental and economic consequences. However, research on consumer *perceptions* of pollinator friendly traits is limited. Understanding consumer perceptions is important because they impact behavior and product selection. In turn, this affects the effectiveness of relevant policies and pollinator insects' access to beneficial plants. This manuscript quantifies consumers' perceptions of plant traits that aid pollinators. U.S. consumers (n=1,243) were surveyed to identify their perceptions of pollinator friendly traits. Binary logit models and marginal effects were estimated using 22 plant traits and consumers' purchasing interest, existing knowledge, and demographic variables. Results imply consumers interested in purchasing pollinator friendly plants selected positive traits regardless of accuracy. Furthermore, consumers selected traits that aligned with their knowledge. Older participants had more accurate perceptions of pollinator friendly traits. Results highlight the challenges facing regulatory efforts geared towards promoting pollinator friendly products/practices.

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1. Introduction

Recently, pollinator insects have become an important environmental topic due to decreasing populations and their global significance (Hanley *et al.*, 2015; Klein *et al.,* 2007; Wratten *et al.*, 2012). Estimates indicate 70% of the world's food crops rely on insect pollination (Klein *et al.*, 2007) worth a total value of €153 billion (~$194.7 billion; Gallai *et al.*, 2009). Additionally, pollinators contribute to biodiversity, wildlife food availability, and prevention of soil erosion and water runoff (Hanley *et al.*, 2015; Wratten *et al.*, 2012). Thus, declining pollinator populations has potential to harm global markets, food availability, and the environment. Contrary to recent trends, in 2017, the U.S. Department of Agriculture's National Agricultural Statistics Service reported that honeybee populations were increasing; however, there are many questions that have yet to be addressed (National Agricultural Statistics Service, 2017).[1] To date, pollinator-related research has focused on causes of declining populations (Fairbrother *et al.*, 2014) and overall economic and production impacts (Figueiredo Jr *et al.*, 2016; Gallai *et al.*, 2009; Klein *et al.*, 2007) but relatively few studies address consumer perceptions of 'pollinator friendly' products (Rihn and Khachatryan, 2016; Wollaeger *et al.,* 2015).

Consumer perceptions are important because they influence behavior, purchasing intentions (Costanigro *et al.,* 2015; Stranieri and Banterle, 2015), and (in this case) pollinator insects' access to habitat and nutrient sources (Breeze *et al.,* 2015; Fairbrother *et al.*, 2014; McIntyre and Hostetler, 2001). Evidence suggests consumers are confused about pollinator-related claims which can influence behavior (Wollaeger *et al.,* 2015). For example, consumer perceptions and their intrinsic definitions influence their purchasing choices for eco-friendly foods (Campbell *et al.*, 2015; Stranieri and Banterle, 2015). This may be problematic since consumer perceptions may not align with the actual product characteristics which can impact marketing efforts, labeling strategies, promotional message clarity, and policy effectiveness (Campbell *et al.,* 2013, 2015; Stranieri and Banterle, 2015). This issue is amplified by 'pollinator friendly' being a credence attribute, which is not searchable unless in-store promotions (e.g. labels) are used. But, with the wide variety of pollinator-related labels (Rihn and Khachatryan, 2016), how do consumers perceive and define 'pollinator friendly' plants? We do not know.

The present study's objective is to better understand consumers' definitions of 'pollinator friendly' products by investigating the relationship between consumer factors (i.e. purchase interest, knowledge, demographics) and perceptions of pollinator friendly product attributes. Section 2 provides a brief review of relevant literature summarizing pollinator friendly product attributes, policy implications, and the existing pollinator-related consumer behavior research. Section 3 outlines the research methodology while Section 4 presents the results. Lastly, Section 5 provides a brief discussion and concluding remarks.

2. Background: definitions, policy, and consumer behavior research

Several definitions of practices that aid pollinators are available; however, very few definitions exist that clearly identify product characteristics that aid pollinators. The U.S. Forest Service (2015) and Xerces Society (2015) indicate that providing habitat and/or nutrients to pollinators constitutes 'pollinator friendly' products. Several studies have identified product-specific (plant) traits related to aesthetics (Kendal *et al.,* 2012), production practices (Gabriel and Tscharntke, 2007; Kiester *et al.,*1984), and physiological characteristics (Kiester *et al.,* 1984), including: integrated pest management (IPM) strategies, organic production, natural production, environmentally friendly production, native origins, fragrant flowers, reduced/no pesticide use, and (often) the production of fruit, nectar, flowers, and/or pollen. Thus, a 'pollinator friendly' label can imply many different traits which may result in consumer confusion and reduce the label's effectiveness.

Policy implications associated with defining and labeling pollinator friendly products are related to mandatory labeling or restrictions on use. Currently, a relevant debate is the mandatory labeling of neonicotinoid

[1] Honeybees are a frequently studied pollinator insect, partially because they are very economically important due to commercial use in many operations producing crops that require insect pollination (Klein *et al.*, 2007; Mwebaze *et al.*, 2010).

(neonic) pesticides. Neonic pesticides are systemic pesticides used to protect crops from insect predation. The systemic nature of the pesticide means it is present within the entire plant including parts utilized by pollinators (pollen, nectar). This means neonics may affect pollinator insects' health and behavior (Blacquiére *et al.*, 2012). Currently, the UK government and several U.S. retailers (e.g. Home Depot) have restricted the use of neonic pesticides (Environmental Protection Agency, 2013). However, existing scientific research of the risks of neonic pesticides to pollinators is inconclusive (Barbosa *et al.,* 2015; Blacquiére *et al.*, 2012; Fairbrother *et al.,* 2014; Hanley *et al.*, 2015). For instance, Pilling *et al.* (2013) studied the affect of neonics in pollen over 4 years and found no differences between neonic-treated and control hives' health. Blacquiére *et al.* (2012) determined that the lethal and sublethal effects of neonics on pollinator insects only occurred in lab experiments but not in field experiments. Another study (Fairbrother *et al.*, 2014) reported that Varroa mites and disease are the primary cause of worldwide bee loss. This finding is supported by the USDA's report on honeybee health (National Agricultural Statistics Service, 2017). Regarding consumer behavior research, research shows that not many consumers are aware of neonic pesticides and many are confused about what 'neonic-free' labeling means (Rihn and Khachatryan, 2016; Wollaeger *et al.,* 2015). This is problematic since in order for a policy to be effective, consumers must understand the key message being communicated to them (Brécard, 2014). Without a clear understanding of consumers' perceptions of products that aid pollinators the marketing potential and policy effectiveness relative to using pollinator-related labels is limited.

The effectiveness of pollinator-related labels is especially important because evidence suggests consumers are interested in pollinator-benefiting policies and products. In 2008, UK consumers were willing to pay £1.77 billion/year (~$3.52 billion) to support bee protection policies (Mwebaze *et al.,* 2010). Breeze *et al.* (2015) determined UK tax payers were willing to pay £13.4 per year (~$21.61/year) to conserve wildflowers for pollinators. In 2012, U.S. consumers were willing to pay $4.78-6.64 billion to purchase beneficial plants or donate to butterfly conservation programs (Diffendorfer *et al.*, 2014). While these studies emphasize broad consumer awareness of the importance of conserving pollinators, consumer perception studies are needed to understand the motives behind this behavior. Currently, there are two relevant consumer perception studies. Wollaeger *et al.* (2015) demonstrate consumers are more likely to purchase plants produced using 'bee friendly' production methods when compared to traditional insect management practices. Consumers' purchasing frequency positively affected their awareness and knowledge of 'bee friendly' production methods. Similarly, Rihn and Khachatryan (2016) found consumer knowledge affects purchasing behavior and that broad pollinator labels (e.g. 'pollinator friendly') are preferred to species-specific labels (e.g. 'bee friendly'). However, neither of the studies delved into consumers' underlying perceptions and their accuracy. In this study we address this gap.

3. Methodology

3.1 Survey design

An online survey was used to assess consumer perceptions of 'pollinator friendly' traits. In the survey, participants indicated from a pre-determined list which traits they considered to be beneficial to pollinator insects. Ornamental plants (in general) were selected as the product because they are key nutrient and habitat sources for pollinator insects (U.S. Forest Service, 2015; Xerces Society, 2015). In order to capture participants' overall perceptions of 'pollinator friendly' traits, specific ornamental plant examples were not included. The 22 listed traits were developed from consultations with green industry professionals and existing literature. The list also included an 'other, please list' option to insure all potential traits were covered. Product traits were randomized to eliminate any order effect and participants were asked to 'select all that apply.' Likert scales were used to measure participants' purchase interest for products that aid pollinators (1=not at all interested; 7=very interested) and knowledge of pollinator-related topics (1=not at all knowledgeable; 7=very knowledgeable; similar to Campbell *et al.* (2013) and Wollaeger *et al.* (2015)). Lastly, participants completed a standard set of socio-demographic questions.

3.2 Sample summary

A sample of 1,243 U.S. participants was collected during January 2015 using an online survey conducted by Qualtrics, LLC. Participants were recruited from Qualtrics' online panel. Online surveys have previously been used to collect data from a wide variety of participants in consumer perception studies (Campbell *et al.*, 2014, 2015; Wollaeger *et al.*, 2015). The average age of participants was 52 years old (Table 1). Males comprised 42% of the sample. Most (54%) of participants had less than a 4 year college degree. Participants' 2014 household income was in the $51,000-60,000 range and the average household size was 2.6 people. 86% of the sample classified themselves as Caucasian/white. U.S. population statistics are provided for comparison purposes (U.S. Census Bureau, 2014). Overall, the sample over-represented older consumers, females, higher education levels, higher income households, and Caucasian/white consumers. Some of these results may be attributed to the study product (plants) where older women are the core consumers (Mason *et al.*, 2008).

3.3 Econometric model

The empirical model focused on the following themes: (1) understanding consumers' perceptions of traits that aid pollinators; (2) how their interest in purchasing products to aid pollinators affected those perceptions; and (3) how their existing knowledge of pollinators/related topics and their socio-demographics influenced those perceptions. Following Campbell *et al.* (2013), a set of binary logit models and marginal effect estimates were used to determine the impact of the explanatory variables (i.e. knowledge, purchase interest, and socio-demographic characteristics) on their perceptions of 'pollinator friendly' traits.

Table 1. Summary statistics of U.S. respondents in an online survey exploring consumer perceptions of 'pollinator friendly' plant traits (n=1,243).

	Description	Sample mean (std. err.)	U.S.[1] mean
Age	Age (in years) of participant	51.605 (30.670)***	37.6***
Gender	1=male; 0=female	0.421 (0.494)***	0.490***
Education1	1= less than 4 year degree; 0=otherwise	0.540 (0.499)***	0.707***
Education2	1= Bachelor's degree and/or some graduate courses; 0=otherwise	0.298 (0.458)***	0.189***
Education3	1= Graduate degree; 0=otherwise	0.162 (0.368)***	0.104***
Income	2014 gross household income	5.397 (3.070)***	$51,939***
	1≤$20k		
	2=$21k-30k		
	3=$31k-40k		
	4=$41k-50k		
	5=$51k-60k		
	6=$61k-70k		
	7=$71k-80k		
	8=$81k-90k		
	9=$91k-100k		
	10≥$100k		
Household	Number of people in household	2.599 (1.345)	2.54
Ethnicity/race	1=Caucasian/white; 0=otherwise	0.859 (0.349)***	0.781***

[1] Adapted from U.S. Census Bureau (2014).

***, **, and * indicate significance at P-values ≤0.001, 0.010, and 0.050, respectively. Significance was determined using single-sample t-tests.

To accommodate the binary logit model, the traits were coded to equal 1 if selected and 0 if they were not selected.[2] A binary logit model was analyzed for each trait. Specifically, the probability (P_i) of the i^{th} participant selecting each trait can be represented by

$$P_i = \frac{1}{1+e^{-x_i'\beta}} \quad (1)$$

where x_i represents participant i's purchasing likelihood, knowledge, and socio-demographic variables and β indicates the estimated coefficients. Marginal effects were then estimated.[3] The marginal effects indicate 'the percent change given a one-unit increase from the mean' for continuous variables while the dummy explanatory variables specify 'the percent change for a move from the base attribute level to the level of interest' (Campbell *et al.*, 2015). Alternative models were also ran to test for heterogeneity but the results were similar and available from the corresponding author upon request.

4. Results

4.1 Exploratory analysis of perceptions

Participants' perceptions of different 'pollinator friendly' traits varied (Table 2). Most participants selected traits associated with flowers (i.e. pollen producing, flower producing, nectar producing, bright colored flowers, fragrant, and produces fruit) as being beneficial. This is likely due to consumers realizing that flowers are a main source of nutrients for adult pollinator insects (Kiester *et al.,* 1984). However, bright colored flowers were not always beneficial to pollinators since plant breeding efforts emphasizing aesthetic characteristics can reduce nutrient availability (Landry, 2010). The aesthetic results may also reflect that consumers associate bright colors with aiding pollinators since 31.9% selected bright colored foliage. Additionally, 35.9% of participants selected native as a beneficial trait. This is not surprising since native plants have coevolved to aid native pollinators and are often preferred by pollinator insects over exotic plant species (Frankie *et al.*, 2005). Production methods were also frequently selected (including environmentally friendly, pesticide free, grown using natural practices, organic, and grown using IPM strategies). A small percentage (1.9%) of consumers viewed aiding pollinators as a marketing gimmick.

Many of these findings are consistent with previous literature on products that aid pollinators. However, there were some inconsistencies as well. 30% of consumers associated locally grown with aiding pollinators and 22% indicated that a product classified as 'pollinator friendly' meant it was safer for humans (Table 2). To date, neither of these traits has been shown to positively affect pollinators. Increasing consumer interest and demand for local and sustainable products is likely responsible for these misperceptions. Local production is popular due to product acclimation to the local environment and consumers' perceptions of local community benefits (i.e. economy, jobs, etc.) (Campbell *et al.*, 2014; Wehry *et al.*, 2007). Interest in sustainably produced plants (i.e. ones perceived as 'safer for humans') is often due to human and environmental health concerns (Campbell *et al.*, 2014). If consumers perceive 'pollinator friendly' positively, they may project additional positive traits (such as local and safe for humans) onto those products to enhance their benefits and attractiveness. Alternatively, consumers may not be knowledgeable about pollinator friendly products and therefore used their personal preferences and past experiences to shape their perceptions (Campbell *et al.*, 2015; Wollaeger *et al.,* 2015).

These results provide an overview of consumer perceptions of product traits that aid pollinators; however, additional quantitative results need to be considered in order to make inferences from the data. In the next section, the influence of purchase interest, knowledge, and socio-demographic variables on consumer

[2] For instance, if a participant indicated 'fragrant' was a trait that aids pollinators then fragrant equals 1, conversely, if s/he did not select fragrant it equals 0.

[3] Due to limited space, only the marginal effect estimates are provided in the manuscript. The binary logit estimates are available upon request from the corresponding author.

Table 2. Percentage of respondents who selected accurate and inaccurate 'pollinator friendly' plant traits (n=1,243).

Trait definition	Percent selected[1]	Accurate trait[2]
Grown using integrated pest management strategies	12.0	Yes
Organic	25.0	Yes
Grown using natural practices	33.6	Yes
Native	35.9	Yes
Fragrant	39.7	Yes
Pesticide free	40.9	Yes
Environmentally friendly	40.9	Yes
Nectar producing	57.1	Yes
Flower producing	59.6	Yes
Pollen producing	61.5	Yes
Produces fruit	32.4	Varies[3]
Other	1.1	–
Genetically modified	2.1	No
Safer for humans	22.2	No
Marketing gimmick	1.9	No
More expensive	7.1	No
Greenhouse grown	8.2	No
Locally grown	30.2	No
Bright colored foliage	31.9	No
Pesticides were used	2.3	No
Bright colored flowers	48.9	Varies[4]
None of the above	5.1	No

[1] Respondents were instructed to 'select all that apply'; hence, the percentages do not sum to 100%.

[2] A definition of product and/or traits that aid pollinator insects was not available. Therefore, green industry professionals and existing literature were used to identify beneficial traits. Traits that improve pollinator health include: integrated pest management strategies (Kiester *et al.,* 1984), natives (Frankie *et al.*, 2005), organic systems (Gabriel and Tscharntke, 2007; Morandin and Winston, 2005), environmentally friendly, and natural practices (Frankie *et al.*, 2005). Additionally, plants have coevolved with pollinator species to attract specific pollinators through fragrance, flower morphology, and nutrient sources (i.e. pollen and nectar) (Kiester *et al.,* 1984). Conversely, pesticides have been shown to negatively influence pollinator health (Fairbrother *et al.,* 2014; Hanley *et al.*, 2015; Pimentel, 2005).

[3] Not all fruit producing crops require insect pollination; however, several fruit producing crops rely on insect pollination (Gallai *et al.*, 2009; Klein *et al.*, 2007) and 23% of fruits are highly economically vulnerable to pollinator population loss (Potts *et al.*, 2010). Therefore, the 'fruit producing' trait is listed as 'varies'.

[4] Although flowers are beneficial to pollinator insects (Kiester *et al.,* 1984), bright colored, long-lasting flowers are often bred at the expense of the plant's reproductive organs (including pollen and nectar) which can be detrimental to pollinators (Landry, 2010). Therefore the 'bright colored flowers' trait is listed as 'varies' since it can vary between species and cultivars.

perceptions of products that aid pollinators using the marginal effect estimates from the binary logit models are discussed.

4.2 Marginal effects for accurate traits

Marginal effect estimates provide insights on why consumers perceive certain traits as beneficial and not others. For ease of interpretation, accurate traits were divided into production method traits (Table 3) and product traits (Table 4). Consumers who were interested in purchasing products to aid pollinators had an increased probability of correctly identifying beneficial production methods (Table 3). Consumers who were knowledgeable about neonic pesticides were 9.7% more likely to select organic production methods as being

Table 3. Marginal Effect estimates from binary logit models exploring consumer perceptions of accurate 'pollinator friendly' production method traits (n=1,243).

	Integrated pest management	**Organic**	**Natural practices**	**Pesticide free**	**Environmentally friendly**
Purchase interest[1]					
Pollinator friendly plants	0.013 (0.008)	0.044 (0.011)***	0.063 (0.012)***	0.063 (0.013)***	0.070 (0.013)***
Knowledge					
Neonicotinoid pesticides	0.021 (0.021)	0.097 (0.031)***	0.024 (0.037)	0.032 (0.040)	0.073 (0.040)
Landscape, garden, plants	0.014 (0.009)	0.022 (0.012)	-0.000 (0.013)	-0.002 (0.014)	-0.008 (0.014)
Environmental stewardship	0.009 (0.007)	0.017 (0.010)	0.009 (0.012)	0.028 (0.012)**	0.015 (0.013)
Pollinators (in general)	0.011 (0.010)	-0.021 (0.015)	-0.001 (0.017)	0.025 (0.017)	-0.027 (0.018)
Pollinator health	0.006 (0.011)	0.017 (0.016)	0.001 (0.018)	0.009 (0.020)	0.020 (0.020)
Bee keeping	0.006 (0.007)	0.007 (0.010)	0.018 (0.012)	0.008 (0.013)	-0.013 (0.013)
Plants that improve pollinator health	0.013 (0.010)	0.015 (0.015)	-0.006 (0.017)	0.002 (0.018)	0.026 (0.018)
Pollinator friendly features	-0.020 (0.010)*	-0.016 (0.015)	-0.012 (0.018)	-0.029 (0.019)	-0.006 (0.019)
Entomology	-0.003 (0.007)	-0.013 (0.011)	-0.011 (0.013)	-0.026 (0.013)	-0.004 (0.013)
Agriculture	-0.009 (0.008)	0.003 (0.011)	-0.003 (0.012)	-0.008 (0.013)	0.006 (0.013)
Socio-demographics					
Age	0.000 (0.000)	-0.001 (0.001)	0.000 (0.000)	0.000 (0.000)	0.002 (0.001)*
Gender	0.026 (0.017)	-0.050 (0.026)	-0.043 (0.029)	-0.014 (0.030)	-0.070 (0.031)*
Income	-0.000 (0.003)	-0.003 (0.005)	-0.013 (0.005)**	-0.006 (0.005)	-0.018 (0.006)**
Household	-0.010 (0.007)	-0.016 (0.010)	-0.012 (0.011)	-0.010 (0.012)	0.005 (0.012)
Education	0.006 (0.006)	0.018 (0.008)**	0.008 (0.009)	-0.005 (0.010)	0.024 (0.010)*
Ethnicity	0.036 (0.028)	-0.114 (0.034)***	-0.053 (0.040)	-0.040 (0.043)	-0.027 (0.044)
Log likelihood	-422.835	-635.419	-748.108	-797.831	-783.438
LR chi^2	58.30	113.03	74.27	66.67	95.45
Prob>chi^2	<0.001	<0.001	<0.001	<0.001	<0.001
Pseudo R^2	0.0645	0.0817	0.0473	0.0401	0.0574

***, **, and * indicate significance at *P*-values ≤0.001, 0.010, and 0.050, respectively; standard errors are presented in the parentheses.

[1] Base categories include: not interested in purchasing products(s) to aid pollinators, not knowledgeable about neonicotinoid pesticides, not knowledgeable about landscape/garden/plants, not knowledgeable about environmental stewardship, not knowledgeable about pollinators (in general), not knowledgeable about pollinator health, not knowledgeable about bee keeping, not knowledgeable about plants that improve pollinator health, not knowledgeable about pollinator friendly features, not knowledgeable about entomology, not knowledgeable about agriculture, female, graduate degree, and other ethnicity.

Table 4. Marginal effect estimates from binary logit models exploring consumer perceptions of accurate 'pollinator friendly' plant traits (n=1,243).

	Nectar producing	**Flower producing**	**Pollen producing**	**Fragrant**	**Native**	**Fruit producing**[2]
Purchase interest[1]						
Pollinator friendly plants	0.081 (0.013)***	0.078 (0.013)***	0.068 (0.012)***	0.043 (0.013)***	0.065 (0.013)***	0.073 (0.012)***
Knowledge						
Neonicotinoid pesticides	-0.079 (0.041)	-0.059 (0.041)	-0.066 (0.041)	0.013 (0.039)	-0.018 (0.038)	0.038 (0.037)
Landscape, garden, plants	-0.010 (0.014)	0.047 (0.014)***	0.002 (0.014)	0.010 (0.014)	-0.003 (0.014)	-0.002 (0.013)
Environmental stewardship	0.026 (0.013)*	0.016 (0.013)	0.027 (0.013)*	0.012 (0.012)	0.025 (0.012)*	-0.012 (0.012)
Pollinators (in general)	0.003 (0.018)	0.028 (0.018)	0.031 (0.018)	0.011 (0.017)	0.013 (0.017)	0.09 (0.016)
Pollinator health	-0.008 (0.020)	-0.014 (0.020)	0.000 (0.020)	0.002 (0.019)	0.003 (0.019)	0.017 (0.018)
Bee keeping	0.009 (0.013)	-0.007 (0.013)	0.006 (0.013)	-0.006 (0.012)	-0.018 (0.012)	0.003 (0.012)
Plants that improve pollinator health	-0.007 (0.019)	0.003 (0.019)	-0.006 (0.018)	0.013 (0.018)	0.008 (0.017)	0.002 (0.017)
Pollinator friendly features	-0.019 (0.019)	-0.021 (0.019)	-0.020 (0.019)	-0.021 (0.018)	-0.013 (0.018)	-0.002 (0.017)
Entomology	-0.006 (0.014)	-0.025 (0.014)	-0.017 (0.014)	-0.017 (0.013)	0.013 (0.013)	-0.040 (0.013)**
Agriculture	0.024 (0.013)	-0.008 (0.013)	0.020 (0.013)*	0.020 (0.013)	-0.008 (0.013)	0.027 (0.012)*
Socio-demographics						
Age	0.000 (0.001)	0.001 (0.001)	0.004 (0.001)***	-0.000 (0.001)	0.000 (0.000)	0.001 (0.001)
Gender	-0.017 (0.031)	-0.022 (0.031)	-0.020 (0.031)	-0.019 (0.030)	-0.050 (0.029)	0.006 (0.029)
Income	-0.006 (0.006)	-0.010 (0.006)	-0.000 (0.005)	0.003 (0.005)	-0.002 (0.005)	-0.010 (0.005)*
Household	-0.017 (0.012)	-0.003 (0.012)	0.007 (0.012)	-0.019 (0.012)	-0.019 (0.011)	-0.000 (0.011)
Education	0.012 (0.010)	0.008 (0.010)	0.005 (0.010)	0.009 (0.010)	0.019 (0.009)*	0.015 (0.009)
Ethnicity	0.091 (0.043)*	0.134 (0.043)**	0.072 (0.042)	0.076 (0.044)	0.016 (0.042)	-0.072 (0.039)
Log likelihood	-792.311	-767.045	-752.198	-798.698	-761.096	-728.389
LR chi^2	93.55	123.68	129.80	54.74	83.40	92.57
Prob>chi^2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pseudo R^2	0.0557	0.0746	0.0794	0.0331	0.0519	0.0597

***, **, and * indicate significance at P-values ≤0.001, 0.010, and 0.050, respectively; standard errors are presented in the parentheses.

[1] Base categories include: not interested in purchasing product(s) to aid pollinators, not knowledgeable about neonicotinoid pesticides, not knowledgeable about landscape/garden/plants, not knowledgeable about environmental stewardship, not knowledgeable about pollinators (in general), not knowledgeable about pollinator health, not knowledgeable about bee keeping, not knowledgeable about plants that improve pollinator health, not knowledgeable about pollinator friendly features, not knowledgeable about entomology, not knowledgeable about agriculture, female, graduate degree, and other ethnicity.

[2] In this table, the 'fruit producing' trait is presented with the accurate traits due to the importance of honeybees in the production of economically important fruit crops (e.g. blueberries, citrus, strawberries, etc.; Gallai *et al.*, 2009; Klein *et al.*, 2007).

'pollinator friendly'. Additionally, consumers who were knowledgeable about environmental stewardship were 2.8% more likely to indicate pesticide free as a production practice that aids pollinators. Interestingly, being knowledgeable about pollinator friendly features reduced the likelihood of selecting IPM by 2.0%. This may reflect low consumer knowledge about what constitutes IPM strategies. Regarding the influence of socio-demographic variables, older participants were 0.23% more likely to select environmentally friendly as a beneficial trait, while males and consumers with higher incomes were 7.0% and 1.8% less likely to select environmentally friendly. Higher income individuals were 1.3% less likely to select natural practices. More educated respondents were 1.8% and 2.4% more likely to select organic and environmentally friendly production methods. Caucasian/white consumers were 11.4% less likely to indicate organic practices.

Consumers' purchase interest also increased their probability of selecting accurate product traits (Table 4). Consumers who were knowledgeable about landscapes, gardens, and plants were 4.7% more likely to select flower producing as a beneficial trait. Plant aesthetics were a primary attribute when making purchasing decisions (Kelley *et al.*, 2001; Kendal *et al.,* 2012). As a result, this group of consumers may have an increased interested in aesthetic characteristics. Consumers knowledgeable in environmental stewardship were 2.7% more likely to select pollen producing and 2.5% more likely to select native. Entomology knowledgeable consumers were 4.0% less likely to select fruit producing. Consumers knowledgeable in agriculture were more likely to select pollen (2.0%) and fruit producing (2.7%) traits as beneficial. Older participants were also more likely to select pollen producing (0.4%). Individuals with higher incomes were less likely to select fruit producing (-1.0%). Individuals who had obtained a higher education level were 1.9% more likely to select native as a beneficial trait. Caucasian/white consumers had a higher probability of selecting the nectar (9.1%) and flower producing (13.4%) traits.

4.3 Marginal effects for inaccurate traits

Regarding inaccurate traits, consumers who were interested in purchasing pollinator friendly products did not perceive 'pollinator friendly' as a marketing gimmick (Table 5). This is intuitive because if consumers are interested in purchasing products that aid pollinators, they are more likely to actively seek out those products rather than discount the information as a marketing gimmick. Neonic pesticide knowledgeable consumers were 0.8% more likely to inaccurately select genetically modified. Consumers who were knowledgeable about pollinators were 3.0% less likely to inaccurately select safer for humans. Consumers knowledgeable about bee keeping were 1.2% more likely to select expensive. Consumers interested in purchasing pollinator friendly products were more likely to select bright colored foliage (4.3%) and flowers (7.2%) as traits that aid pollinators. Consumers knowledgeable about neonicotinoid pesticides were 9.2% less likely to select 'bright colored flowers'. For socio-demographics, age negatively influenced the probability of selecting genetically modified and marketing gimmick. Males were less likely to select bright colored foliage (-7.7%) and flowers (-8.8%). Caucasian/white consumers were 8.6% less likely to select safer for humans but 8.7% more likely to select bright colored foliage and 9.4% more likely to select bright colored flowers.

Consumers' increased purchase interest improves the probability of inaccurately selecting locally grown by 5.0% (Table 6). Knowledge about pollinator friendly features or agriculture increased consumers' likelihood of selecting greenhouse grown by 2.9 and 1.4%, respectively. Purchase interest negatively impacted the probability of selecting 'none of the above'. Age negatively affected the likelihood of selecting 'pesticides were used'.

5. Discussion: emerging consumer perception patterns

Cumulatively, when examining consumers' accurate and inaccurate perceptions and how purchase interest, knowledge, and socio-demographics influence these perceptions, several interesting patterns emerge (Tables 3-6). First, increased interest in purchasing products to aid pollinators results in the consumer selecting more positive traits even if they are not accurate (e.g. locally grown). A potential explanation for this result is that if consumers perceive pollinator beneficial products positively (as indicated by increased purchase interest)

Table 5. Marginal effect estimates from binary logit models exploring consumer perceptions of inaccurate 'pollinator friendly' plant traits (n=1,243).

	Genetically modified	**Safer for humans**	**Marketing gimmick**	**Expensive**	**Bright colored foliage**	**Bright colored flowers**
Purchase interest[1]						
Pollinator friendly plants	-0.002 (0.001)	0.015 (0.010)	-0.005 (0.002)**	-0.002 (0.006)	0.043 (0.012)***	0.072 (0.013)***
Knowledge						
Neonicotinoid pesticides	0.008 (0.004)*	0.054 (0.031)	0.006 (0.005)	0.031 (0.018)	-0.006 (0.037)	-0.092 (0.042)*
Landscape, garden, plants	0.001 (0.002)	-0.019 (0.011)	0.002 (0.002)	0.003 (0.007)	0.015 (0.013)	0.013 (0.014)
Environmental stewardship	-0.000 (0.001)	0.001 (0.010)	-0.000 (0.002)	-0.001 (0.006)	-0.001 (0.011)	0.003 (0.013)
Pollinators (in general)	0.001 (0.002)	-0.030 (0.015)*	-0.002 (0.003)	-0.012 (0.008)	0.005 (0.016)	0.034 (0.018)
Pollinator health	0.003 (0.002)	0.004 (0.016)	0.002 (0.003)	0.005 (0.009)	0.002 (0.018)	-0.008 (0.020)
Bee keeping	0.001 (0.001)	0.010 (0.010)	0.002 (0.002)	0.012 (0.006)*	0.010 (0.012)	-0.011 (0.013)
Plants that improve pollinator health	-0.001 (0.001)	0.026 (0.015)	-0.002 (0.002)	-0.014 (0.008)	-0.005 (0.017)	0.005 (0.019)
Pollinator friendly features	-0.002 (0.002)	0.017 (0.015)	0.002 (0.003)	0.012 (0.008)	-0.006 (0.017)	-0.005 (0.019)
Entomology	0.000 (0.001)	-0.019 (0.011)	0.001 (0.002)	-0.005 (0.006)	-0.013 (0.012)	-0.008 (0.014)
Agriculture	0.001 (0.001)	0.015 (0.011)	-0.002 (0.002)	0.001 (0.006)	0.020 (0.012)	0.001 (0.013)
Socio-demographics						
Age	-0.000 (0.000)**	0.000 (0.000)	-0.000 (0.000)*	0.000 (0.000)	0.000 (0.000)	0.001 (0.001)
Gender	0.004 (0.003)	-0.004 (0.025)	0.000 (0.004)	-0.001 (0.014)	-0.077 (0.028)**	-0.088 (0.031)**
Income	0.001 (0.001)	-0.006 (0.005)	0.001 (0.001)	0.001 (0.003)	-0.001 (0.005)	0.005 (0.006)
Household	-0.001 (0.001)	0.007 (0.009)	0.001 (0.002)	0.008 (0.005)	-0.005 (0.011)	-0.008 (0.012)
Education	-0.001 (0.001)	-0.002 (0.008)	0.000 (0.001)	0.003 (0.005)	-0.006 (0.009)	0.006 (0.010)
Ethnicity	-0.002 (0.003)	-0.086 (0.032)**	0.010 (0.007)	0.025 (0.022)	0.087 (0.042)*	0.094 (0.045)*
Log likelihood	-92.005	-629.953	-99.110	-304.100	-741.059	-801.910
LR chi^2	59.94	41.83	30.36	20.25	58.30	99.58
Prob>chi^2	<0.001	<0.001	0.0239	0.262	<0.001	<0.001
Pseudo R^2	0.2379	0.0321	0.1328	0.0322	0.0378	0.0585

***, **, and * indicate significance at *P*-values ≤0.001, 0.010, and 0.050, respectively; standard errors are presented in the parentheses.

[1]Base categories include: not interested in purchasing product(s) to aid pollinators, not knowledgeable about neonicotinoid pesticides, not knowledgeable about landscape/garden/plants, not knowledgeable about environmental stewardship, not knowledgeable about pollinators (in general), not knowledgeable about pollinator health, not knowledgeable about bee keeping, not knowledgeable about plants that improve pollinator health, not knowledgeable about pollinator friendly features, not knowledgeable about entomology, not knowledgeable about agriculture, female, graduate degree, and other ethnicity.

Table 6. Marginal effect estimates from binary logit models exploring consumer perceptions of inaccurate 'pollinator friendly' production method and plant traits (n=1,243).

	Greenhouse grown	Locally grown	Pesticides were used	Other[2]	None of the above
Purchase interest[1]					
Pollinator friendly plants	0.005 (0.006)	0.050 (0.012)***	-0.001 (0.002)	-0.002 (0.001)	-0.008 (0.002)***
Knowledge					
Neonicotinoid pesticides	0.014 (0.019)	-0.018 (0.036)	0.003 (0.005)	-0.004 (0.006)	-0.000 (0.011)
Landscape, garden, plants	0.002 (0.007)	-0.008 (0.013)	0.003 (0.002)	0.001 (0.002)	-0.001 (0.002)
Environmental stewardship	-0.004 (0.006)	0.015 (0.011)	0.003 (0.002)	0.001 (0.002)	-0.005 (0.003)
Pollinators (in general)	-0.016 (0.009)	0.009 (0.016)	-0.004 (0.003)	0.001 (0.002)	-0.006 (0.004)
Pollinator health	-0.001 (0.009)	-0.014 (0.018)	0.001 (0.003)	0.003 (0.002)	0.001 (0.005)
Bee keeping	0.004 (0.006)	-0.013 (0.012)	0.001 (0.002)	0.000 (0.002)	0.003 (0.003)
Plants that improve pollinator health	-0.013 (0.009)	0.018 (0.016)	-0.000 (0.002)	-0.002 (0.002)	-0.002 (0.004)
Pollinator friendly features	0.029 (0.009)***	0.015 (0.017)	0.003 (0.003)	-0.001 (0.002)	-0.003 (0.004)
Entomology	-0.003 (0.006)	-0.003 (0.012)	0.001 (0.002)	0.001 (0.002)	0.002 (0.003)
Agriculture	0.014 (0.006)*	-0.003 (0.012)	-0.000 (0.002)	0.000 (0.002)	-0.001 (0.003)
Socio-demographics					
Age	-0.000 (0.001)	0.000 (0.000)	-0.000 (0.000)*	0.000 (0.000)	-0.000 (0.000)
Gender	0.000 (0.015)	-0.035 (0.028)	-0.002 (0.004)	0.005 (0.004)	-0.000 (0.006)
Income	-0.001 (0.003)	-0.005 (0.005)	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)
Household	0.002 (0.006)	-0.021 (0.011)	0.000 (0.001)	0.002 (0.001)	0.001 (0.002)
Education	-0.002 (0.005)	0.006 (0.009)	0.004 (0.006)	0.002 (0.001)	-0.000 (0.002)
Ethnicity	-0.021 (0.019)	-0.018 (0.039)	0.003 (0.007)	0.007 (0.008)	-0.001 (0.008)
Log likelihood	-331.988	-723.742	-113.680	-69.943	-186.773
LR chi^2	34.25	59.57	39.77	13.25	111.75
Prob>chi^2	0.0078	<0.001	0.001	0.719	<0.001
Pseudo R^2	0.0491	0.0395	0.1489	0.0865	0.2303

***, **, and * indicate significance at *P*-values ≤0.001, 0.010, and 0.050, respectively; standard errors are presented in the parentheses.

[1] Base categories include: not interested in purchasing product(s) to aid pollinators, not knowledgeable about neonicotinoid pesticides, not knowledgeable about landscape/garden/plants, not knowledgeable about environmental stewardship, not knowledgeable about pollinators (in general), not knowledgeable about pollinator health, not knowledgeable about bee keeping, not knowledgeable about plants that improve pollinator health, not knowledgeable about pollinator friendly features, not knowledgeable about entomology, not knowledgeable about agriculture, female, graduate degree, and other ethnicity.

[2] The 'other' trait allowed participants to note traits that were not included in the provided list. Other traits were inconsistent with being solely in the accurate or inaccurate categories. Participants' other list included: do not know (n=6), pet safe (n=1), larvae food plants (i.e. herbs; n=1), or blank (n=6).

they associate it with other positive traits (much like the 'halo effect' discussed by Wu and Petroshuis (1987)). Thus they are more likely to have positive opinions regardless of accuracy, which sequentially influences their product choices.

There are advantages and disadvantages to this phenomenon. Advantages include the opportunity to promote products that aid pollinators which increases product availability and can be leveraged to generate consumer interest in those products. In turn, this may lead to increased profits and greater abundance of pollinator friendly products in the environment which may have substantial long-term impacts on pollinator insect populations (Frankie *et al.*, 2005; Hanley *et al.*, 2015). However, if consumers' obtain greater satisfaction from bright colored foliage and flowers (depending on species/cultivar) than from pollinator friendly traits, the non-beneficial traits may outweigh the beneficial traits. This may be problematic since plant aesthetics are a primary purchase driver but do not always benefit pollinators (Kelley *et al.*, 2001; Kendal *et al.,* 2012; Landry, 2010). Pollinator-related labels may be able to overcome this issue; however, to what extent is unknown and outside the scope of this study.

Consumers' existing knowledge also influences their perceptions of what constitutes a product that aids pollinators. Results imply that existing knowledge and interests strongly affect consumer perceptions which, in turn, influence their choices (Campbell *et al.,* 2013; Wollaeger *et al.,* 2015). For instance, consumers knowledgeable in landscaping, gardens, and plants select flower producing (an important aesthetic trait). Environmental stewardship knowledgeable consumers primarily select environment friendly attributes (pesticide free, pollen producing). Similarly, neonic pesticide knowledgeable consumers avoid selecting pesticide containing options an (as reflected through the selection of organic) which is consistent with Wollaeger *et al.* (2015). These patterns provide insights into how consumers' existing knowledge influences their perceptions which can be used to increase awareness of traits that positively affect pollinator health.

Regarding socio-demographic variables, age appeared to have the most impact with older participants having a more accurate perception of traits that aid pollinators. This is not surprising considering older consumers are the core consumers of plants (Mason *et al.*, 2008), meaning they are likely more familiar with the products and their impact on pollinators. Education also appeared to increase the accuracy of participants' selection of traits that benefit pollinators.

In conclusion, research has shown consumers are interested in pollinator conservation measures but, to date, very few studies investigate consumer perceptions of products that aid pollinators. We found consumers' interest in purchasing pollinator friendly products, existing knowledge, and socio-demographics all contribute to their perceptions of beneficial traits. Overall, findings indicate some confusion exists about what traits are actually beneficial to pollinator insects. However, results should be interpreted cautiously since there are unobserved individual/consumer characteristics that (due to data limitations) were not included in the analyses. Though the study results are consist with previous studies addressing the impact of consumer knowledge on behavior (Campbell *et al.,* 2013; Rihn and Khachatryan, 2016) and consumer behavior toward traits that benefit pollinators (Wollaeger *et al.,* 2015) indicating robustness of the present results. Future studies incorporating additional variables and experimental methods (e.g. incorporation of live plants, exposure to pollinator-related news in mass media, treatment groups, etc.) could further test the robustness of results.

There is an opportunity for researchers to further quantify how difference consumer characteristics influences their definitions of 'pollinator friendly' products. Furthermore, policy makers and industry stakeholders could benefit from educating consumers about pollinator beneficial traits and use in-store promotions to influence consumer behavior toward those items. Ultimately, this could positively influence demand for pollinator beneficial products and improve pollinator health through increased availability of beneficial products.

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