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The impact of the surrounding ecological factors influencing the collection and consumption of lake flies within the Lake Victoria region

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Abstract

The motivation of consuming edible insects, particularly lake flies, has the potential of improving the problem that results from the inability to sustainably meet the rising demand for animal-based protein as a result of increased population growth and urbanization. The aim of this study was to identify the impact of the surrounding ecological factors influencing the collection and consumption of lake flies within the Lake Victoria region. A sample size of 385 respondents was derived using purposive and multistage sampling method. The target population is a representative of 8 ministry of livestock staff in each county and 385 households from the area. The study was conducted in Siaya, Homabay, and Kisumu counties along the Kenyan Lake Victoria shores. A survey research design using structured questionnaires and key informant interview guides were used. The qualitative data collected was analyzed using thematic analysis focusing on examining themes or patterns of meaning within data whereas quantitative data was analyzed using inferential and descriptive statistics with the aid of SPSS computer software. Ecological factors were found to significantly drive the motivation to consume lake flies ($r=0.740$, $M=3.52$, $P=0.00$). The emergence of insects depends on moisture and temperature levels and biotic factors. Climate change increases or reduces the number of lake flies collected thus influencing consumption.

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Introduction

Developing countries are faced with increased population growth and urbanization resulting in high demand for food, especially animal-based protein (FAO, 2013). Kenya, being a developing nation, has a problem of how to sustainably meet the rising demand for animal-based protein in the face of climate change, environmental degradation as well as land and water scarcity (Lensvelt & Steenbekkers, 2014). The current protein from animal sources such as milk, meat, eggs and blood are insufficient, unsustainable and relatively expensive (GoK, 2013). Entomophagy, the collection and consumption of edible insects, has been a partial solution for developing economies like Kenya, with several advantages (Alemu *et al*., 2017a). Edible insects are nutritious, available and have a lesser ecological footprint (FAO, 2013). Lake flies are one of the edible insects commonly consumed in Western Kenya by the natives living around the peripherals of the lake (Ayieko, 2013) and the insects have contributed some rich culture and tradition in entomophagy before.

Insects are highly nutritious as they are a good source of protein, good fats, calcium, vitamins, and energy, and can be multiplied easily in small spaces in a short duration. They also have various beneficial attributes for the environment as compared to other sources of protein (Van Huis *et al*., 2013). A large number of edible insects are known and insects can be reared. Insects use significantly less water and are less land-dependent than conventional livestock. The use of insects as food can thus result in more energy-efficient food production and facilitate environmental conservation (Van Huis *et al*., 2013).

When crops fail due to adverse weather changes such as drought and flooding, most insects will survive the harsh conditions relative to other food sources such as plants because they tend to be hardy to such conditions (Skendžić *et al*., 2021). Thus, Polyphagous edible insects can be harvested sustainably for domestic consumption as sources of protein. Given the rapidity with which many edible insects are able to reproduce implies that most insects do not have any real problems or threat to extinction and hence edible insects are an ideal mini livestock. Lake flies are not likely to compete with other food production for space due to their natural habitat and choice of feeding habitat at the lake bottom. The lake flies nymphs inhabit the bottom of the lake (Abowei *et al*., 2012). The change in physicochemical properties that defines the chemistry and biology of the lake has significantly influenced the population of the lake flies at certain points (Clements *et al*., 2016; Sun *et al*., 2019).

Global climatic changes are expected to impact insect-plant interactions in several ways. They might affect insects directly, through changes in physiology, behavior and life history parameters, as well as indirectly, through changes experienced by host plants in their morphology (Karthik *et al.,* 2021, Giron *et al*., 2018), biochemistry (Karthik *et al.,* 2021)), physiology (Tonnang *et al*,. 2022; Bellard *et al*., 2012; Devi *et al*., 2019; Jones *et al*., 2012) and patterns of richness, diversity and abundance (Karthik *et al* 2021; Sharma *et al*., 2014; Skendžić *et al*., 2021; Pareek *et al*., 2017). Insects play important roles in ecosystem services, acting as herbivores, pollinators, predators and parasitoids, and changes in their abundance and diversity have the potential to alter the services they provide (Koltz *et al*., 2018; Gill *et al*., 2016; Grubisic *et al*., 2018). The number of studies reporting climate change effects on insects has rapidly increased during the past 20 years.

Several factors of climate change have been identified to influence the reproduction of insects. Khaliq *et al*. (2014), Ayieko *et al*. (2014), Selaledi *et al*. (2021) briefly outlined some of the factors that influence insect population. Weather conditions precipitated by climate change favour the increased emergence of insects. Moisture and temperature play a significant role in insect ecology. Climate change influences insect populations by influencing benthic fauna and its biodiversity that supports the insects.

In East Africa, particularly in Uganda, the long-horned grasshopper, Orthoptera Raspolia nitidula

Scopoli is a delicacy when in season. This insect is highly associated with forests that are not yet affected by the current climate change (Ayieko, 2014). However, its emergence and swarming are highly dependent on the onset of the rain season which is currently unpredictable due to climate change. Nevertheless, this could affect it indirectly because it feeds on the seasonal lash growth of forest trees (Wellington and Trimble, 1984; Martinat, 1987).

The unpredictable seasonal changes could affect the temporal distribution of the emergence and the number of edible insects. Insects are very sensitive to temperature increases and are known to be more active in higher temperatures (González *et al.*, 2020; Skendžić *et al.*, 2021; Denlinger *et al.*, 2019). It has been observed by several households of the Lake Victoria region that insect populations have increased due to increased harvests of insects for home consumption due to climate change. These households have collected lake flies and elated termites for a long period of time. (Ayieko, 2007; Ayieko & Oriaro, 2008).

Seasonal activity and lake fly abundance relates to temperature, rainfall, light conditions, and relative air humidity. All of the environmental variables had significant and mostly positive effect on lake fly abundance. The strongest and most positive effect on lake fly counts are temperature and rainfall five weeks prior to collecting session (Semelbauer, Mangová , and Kozánek, 2018).

This study was to identify the impact of the surrounding ecological factors influencing the collection and consumption of lake flies within the Lake Victoria region

Materials and methods

Location of the Study

This study was conducted in three counties namely: Siaya, Homabay and Kisumu counties. Only respondents bordering the lake shores, 0-3kms were surveyed because they experience the emergence of the lake flies. The lake flies, according to its biological characteristics, do not fly more than three kilometers away from the lake shores upon emergence from the lake. Siaya County is bordered by Busia County to the North, Kakamega County and Vihiga Counties to the North East and Kisumu County to the South East. It shares a water border with Homabay County which is located south of it. The total area of the county is approximately 2496.1 km^2 and has a population of 993,183(GoK, 2019) KNBS. The County lies between latitude 0°, 26' and 0° 18' north and longitude 33°58' east and 34°33' west. The County is subdivided into 6 sub-counties namely Alego Usonga, Ugenya, Ugunja, Gem, Bondo and Rarieda.

Homabay County lies between latitude 0°0.088' south and 0°5'15" south and between longitudes 34° East and 35° East. Homabay County has a population of 1,131,950 (GoK, 2019) KNBS and an area of 4267.1km^2 inclusive of water surface which on its own covers an area of 1227 km^2, and Lake Victoria is a major source of livelihood. The County is located in South Western Kenya along Lake Victoria where it borders Kisumu and Siaya counties to the North, Kisii and Nyamira Counties to the East, Migori County to the South and Lake Victoria and the Republic of Uganda to the West. The county is subdivided into 7 sub-counties namely Homabay town, Mbita, Ndhiwa, Rangwe, Karachuonyo, Kasipul and Kabondo.

Kisumu County lies between latitude 0°15' South and 0°52' South and between longitudes 34° East and 35° East. It has a population of 1,155,574 (GoK, 2019) KNBS and a land area of 2085.1 km^2.

Kisumu borders Siaya County to the West, Vihiga County to the North, and Nandi County to the North East, Kericho County to the East and Nyamira County and Homabay County to the South West. The county is subdivided into 7 sub-counties namely Kisumu East, Kisumu West, Kisumu Central, Mohoroni, Nyakach, Nyando and Seme.

Target Population

The target populations were 24 ministry of livestock staff and 10,187 households, who are residents of Siaya, Kisumu and Homabay Counties respectively, residing in the six wards namely Central Sakwa, West Uyoma, East Seme, West Seme, Kamreri East (Mbita) and Masara (Suba) which were purposively selected due to their proximity to Lake Victoria and history of lake flies consumption. The sampling frame was derived from the six Sub locations, one Sub location selected purposively from each of the six wards, with a total household count of 10,187, (GoK, 2019).

Sample Size Selection and Sample Size Calculation

The target population of this study was the residents of Siaya, Kisumu and Homabay Counties where a multistage sampling procedure was followed. In the first stage, the three Counties were purposively selected because consumption of lake flies was prevalent.

In the second stage, two Sub Counties were selected purposively per County depending on their proximity to Lake Victoria. In the third stage, two County Assembly Wards were purposively selected per each selected sub-county. A purposive and simple random sampling technique was used to select respondents.

Three wards were purposively selected due to their proximity to Lake Victoria shores and lake fly consumption history. Two sub-location per ward was purposely selected due to their history of lake fly collection and utilisation to represent a larger section of the region.

A simple random sampling using stratified sampling was used to select the respondents from the formulae as shown below to draw sample size.

The formula used for generating samples is by Israel, (2009). The sample size is calculated as follows:

$$n = \frac{N}{1 + N\,(e)^2} \quad \ldots\ldots (3.1)$$

Where;

- n = desired sample size
- N = Population size of the total households involved in the study
- e = Desired level of statistical precision. (±5 margin of error the precision level is 0.05)

Using this formula, the sample size is generated as below:

$$n = \frac{10187}{1 + 10187(0.05)^2} = 385 \ldots\ldots\ldots (3.2)$$

The sample size was 385 respondents

Sampling Strategy

Stratified sampling was used to select the 385 respondents from the sub-locations. A third of the respondents from each sub-location was purposively selected 1 kilometer, 2 kilometers and 3 kilometers respectively from the lake shores. Any one person found every one km was picked automatically till a radius of 3 kms. This random sampling technique was important in allowing the researcher to have confidence in a sample that was more likely to be representative of the total target population than non-random sampling methods. This was followed by simple random sampling using systematic sampling.

A systematic sampling interval of respondents was derived from;

$$\text{Sampling interval} = \frac{\text{Total sample frame}}{\text{Sample size}}$$

$$\text{Sample interval} = \frac{10187}{\text{Sample size}} = 26$$

Purposive sampling was used to select 8 key informants from each County due to their knowledge and involvement in entomophagy.

Table 1. Sample Size Distribution for Selected Sub Locations.

County	Sub County	Ward	Sub location	Target population (N=10,187)	Sample size (n= 385)
Siaya	Bondo	Central Sakwa	Uyawi	2501	95
	Rarieda	West Uyoma	Kokwiri	1653	62
Kisumu	Seme	East Seme	Kit Mikayi	1781	67
	Seme	West Seme	West Reru	1128	43
Homabay	Mbita	Gembe West	Kamreri East	1339	51
	Suba	Suba West	Masara	1785	67
Total				10, 187	385

Data Collection Procedures

Primary data was collected from the respondents by use of a semi-structured questionnaire which was segmented to meet each of the objectives of the study.

The questionnaire contains information on consumers' socioeconomic factors, ecological factors and current technologies used for the collection of lake flies. An interview guide was used to collect data from key informants who were sampled purposively from representative ministry of livestock, and key informants from the study area.

Validity of Instruments

A pre-test of instrument was done to assess the ease of understanding of the questions by respondents and their appropriateness under the study context, to establish whether the designed TPB-measures were valid for the extended TPB-constructs, and to minimize the differences in observed and real responses as suggested by (Verbeke, 2015) for verification purposes, the validated instruments were used for fieldwork. This was to ensure clarity in interpretation and assist in improving the instrument before the actual data collection. A selected team of peers and experts in agriculture extension was requested to review the questionnaire and its items. The guidelines for experts review focused on the representativeness of the objectives and variables coverage as well as the ability of the items based on their flows and ability to elicit the intended data and responses. Appropriate adjustments were made on the content item construction and order of the items in the questionnaire based on the suggestions/recommendations for the initial review, before administering it for the pilot study.

Data Analysis

According to Sekaran (2009), there are three objectives in data analysis; getting a feel for the data, testing the goodness of fit, and answering the research question. Data analysis consists of running various statistical procedures and tests on the data (Cooper & Schindler, 2006). The SPSS software was used to analyze the data. Quantitative data was analyzed using descriptive statistics tabulated in percentages, and frequencies to describe the categories formed from the data. The data was tabulated to permit interpretation. Qualitative data collected (through the open-ended section of the questionnaire) was coded, and repeated themes (responses) or concepts were recorded until saturation is achieved (Fusch & Ness, 2015; Hancock *et al.*, 2016). The study also performed descriptive analysis. Descriptive (frequencies and percentages) was used to portray the sets of categories formed from the data. Descriptive statistics enabled the researcher to meaningfully describe a distribution of measurements and summarize data (Leech *et al.*, 2013; Lang & Altman, 2015).

Variables in the Study

The ecological variables determined were: biotic factors, abiotic factors, and climate variability

Results

Response Rate

The study population was picked from the Ministry of Livestock staff. Out of 385 questionnaires administered, being the sample size of the study, a total of 270 questionnaires were filled and returned, this gave a response rate of 70.12%. According to Kothari (2008), a response rate of above 50 percent is adequate for a descriptive study.

Assessment of Reliability of Study Measures

The analysis of reliability was done using Cronbach's Alpha which evaluates internal consistency by establishing whether certain items within a scale measure the same construct validity. Since the scores were above 0.7, this infers that the research instrumentation was reliable.

Table 2. Reliability Analysis.

Determinant	No of items	Cronbanch's	Verdict
Ecological Factors	8	. 753	Reliable

Cronbach's alpha results indicate that the data collection instrument had consistency because all value is above the threshold value of 0.7. This result confirms that the instrument was reliable.

Demographical Profiles

This section presents the personal information of the respondents who participated in the research study.

Table 3. General Information of Respondents. These demographic variables should have been presented all by gender because gender influences the consumption of edible insects.

Category	Sub category	Frequency	Percentage
Gender	Male	60	22.2
	Female	210	77.8
Age Distribution	18-35 years	72	26.7
	36-45 years	72	26.7
	44-55 years	90	33.3
	above 56 years	36	13.3
Education level	No formal	72	26.7
	Formal	198	73.3
Distance from the Lake	0-1 km	99	36.7
	1-2 km	97	35.9
	2-3 km	74	27.4

Table 3 shows that male respondents were more than female respondents. The study sought to determine the age distribution of the respondents. The finding shows that a majority of the respondents were above 36 years. The study sought to determine the level of education of households. The findings shows that majority of the respondents had formal education. Table 3 indicates that there were more females than males and it was a fairly educated population.

The Study Variables Descriptive Statistics

This section presents a descriptive analysis of the independent variables (socio-economic factors, ecological factors, and harvesting technologies) and dependent variable (Consumption of Lake flies) of the study.

Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

The table below presents two different tests: the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's test of Sphericity.

Table 4. Kaiser-Meyer-Olkin (KMO) and Bartlett's Test Results.

Variable	Number of items	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
			Approx. Chi-Square	Degrees of freedom	p-value
Ecological factors	8	0.934	944.955	28	0.000

Source: Field Research, 2022

The results from table 4. above reveal that the items measuring each of the study variables were from a population with equal variance, given that their KMO Value was above the minimum threshold of 0.6 (Oluwatayo, 2012); hence it was concluded that the research tool was valid for further analysis.

Consumption of Lake flies

The study respondents were requested to show their level of agreement with the statements in relation to the consumption of lake flies. The constructs of consumption of lake flies have been analyzed using principal component factor analysis. The factor analysis shows variances in the differences in consumption of Lake flies of consumers. The eigenvalue represents the total amount of variance that can be explained by a given principal component. Component loadings represent the correlation of each item with the principal component were then computed and the results are shown in Table 5.

Factor Analysis for Consumption of Lake flies

Table 5. Factor Analysis for Consumption of Lake flies.

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.183	53.054	53.054	3.183	53.054	53.054
2	1.275	21.254	74.308	1.275	21.254	74.308
3	.614	10.233	84.541			
4	.385	6.419	90.960			
5	.288	4.802	95.762			
6	.254	4.238	100.000			

Extraction Method: Principal Component Analysis.

The eigenvalue is a measure of how much of the common variance of the observed variables a factor explains. Any factor with an eigenvalue ≥1 explains more variance than a single observed variable. Table 5. shows that the extracted factors given the Eigen values and that 74.3% of the total variation was explained by two components explain. While component 1 contributed the highest variation of 53.1%, the second component contributed 21.3% of the total variations.

Component Matrix for Consumption of Lake flies

Component matrix in table 6. revealed two statements with eigen values greater than 1 were extracted such that the statement developments of novel products that use insects as ingredients but avoid presenting the form of the insects to enhance lake fly consumption and that consumption of lake fly is a stable source of alternative protein with eigen values 1.152 and 1.144 respectively.

Table 6. Component Matrix for Consumption of Lake flies.

Component Matrix[a]	Raw Component		Rescaled Component	
	1	2	1	2
Consumption of lake flies has contributed to improved food security	.437	.374	.612	.524
Curious edible insects have continuous been attracted to consume lake flies	-.611	1.117	-.476	.869
Lake fly consumption is sustainable	.899	.224	.784	.195
Developments of novel products that use insects as ingredients but avoid presenting the form of the insects to enhance lake fly consumption.	1.152	.016	.885	.013
Consumption frequency of lake fly is on the rise	.307	.308	.469	.471
Consumption of lake fly is a stable source of alternative protein	1.144	.179	.902	.141

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Factor Analysis for Ecological Factors

Component matrix indicates that Nutritional characteristics, Consumer attitude, sufficient sensitization, household size and income level influence consumption of lake flies.

Table 7. Total Variance Explained in Ecological/Environmental Factors

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative%
1	6.787	84.835	84.835	6.787	84.835	84.835
2	.516	6.455	91.290			
3	.258	3.222	94.512			
4	.132	1.654	96.166			
5	.102	1.272	97.438			
6	.085	1.065	98.503			
7	.065	.807	99.311			
8	.055	.689	100.000			

Extraction Method: Principal Component Analysis.

Principle Component Analysis was used, which allows for the extraction of components that have an Eigen value greater than 1. The principal component analysis was used and one factors/components extracted. From Table 7, the one component explains 84.835% of the total variation. This therefore implies that Ecological factor component was explained by a single factor. Factors 2 to 8 had eigen values less 1and according to Kaiser Criterion, this factor was not retained and therefore only factor 1 was considered in determining the loadings on each of the constructs.

Component Matrix for Ecological Factors

Factor loadings on ecological factors was carried out and results revealed that factors 1 to 8 had positive loadings > 0.5, which is recommended loading for an item according to Hair *et al.*, (2014). The highest loading was 0.965 and lowest loadings being 0.852. The results of this analysis are as summarized in table 8.

Table 8. Component Matrix[a].

	Component
	1
Moisture and temperature play	.965
Biaotic factors	.951
Climate change influence insect population by influencing benthic fauna and its biodiversity	.949
Weather conditions	.942
Lake flies are abundant during rainy seasons	.939
Climate variability is a determinant of lake flies' availability	.907
Several factors of climate change have been identified to influence reproduction of Lake flies.	.856
Temperature levels influence availability of lake flies	.852

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component matrixes indicate that the eight factors play a significant role in insect ecology.

Collinearity Diagnostics

Collinearity diagnostics test was carried out to ensure that the variables were not having multicollinearity. The test is important in ensuring absence of multicollinearity that ultimately guarantee that the regression estimate not spurious or nonsensical. The results of this analysis are summarized in table 9.

Table 9. Collinearity Diagnostics[a].

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	SOCIO	ECO	TECH
1	1	3.910	1.000	.00	.00	.00	.00
	2	.056	8.340	.03	.06	.24	.19
	3	.025	12.525	.07	.38	.59	.14
	4	.009	20.742	.90	.55	.17	.66

Dependent Variable: Consumption of lake flies

Here for each regression coefficient its variance is distributed to the different eigen values (Hair, Black, Babin, &Anderson, 2013). According to Hair *et al.* (2013) for each row with a high Condition Index, you search for values above .90 in the Variance Proportions. If you find two or more values above .90 in one line you can assume that there is a collinearity problem between those predictors. If only one predictor in a line has a value of .90, this is not a sign for multicollinearity. The higher the collinearity, the greater the discrepancy between bivariate and multivariate contributions of variables.

Table 10. Factor Analysis for ecological factors based on a Principal Components' Analysis with Varimax Rotation for 8 items.

Statement	Factor Loading	Communalities	Decision
Ecological Factors			
Moisture and temperature play a significant role in insect ecology.	.998	.732	Significant
Biaotic factors influence availability of lake flies	.987	.705	Significant
Climate change influence insect population by influencing benthic fauna and its biodiversity that supports the insects.	.946	.700	Significant
Weather conditions precipitated by climate change favor the increased emergence of Lake flies.	.912	.587	Significant
Lake flies are abundant during rainy seasons	.901	.481	Significant
Climate variability is a determinant of lake flies availability	.376	.223	Insignificant
Several factors of climate change have been identified to influence reproduction of Lake flies.	.384	.132	Insignificant
Temperature levels influence availability of lake flies	.301	.026	Insignificant

Factor loading and communalities results indicate that five ecological factors are sufficient to measure the construct.

Model Summary

Siaya County Regression Prediction Model Summary for ecological and consumption of lake flies

A simple linear regression test was run to determine the predictive power of ecological on the consumption of lake flies as food within the Lake Victoria region in Siaya County results are shown in Table 11.

Table 11. Siaya County Regression Prediction Model Summary for *ecological factors* and consumption of lake flies.

Model Coefficient	Unstandardized coefficients		Standardized Coefficients	T	Sig.	Collinearity	
	B	Std Error	Beta			Tolerance	VIF
(Constant)	-.829	.524		-1.583	.118		
Ecological factors	.032	.016	.308	1.979	.052	.251	3.979

a. Dependent Variable: *Consumption of Lake flies as Food*

The findings reveals that ecological factors in table 11. were not significant p-value>0.05., establishing that taking ecological factors into account -.829 due to variation. ; a unit change in ecological factors while setting the coefficient of other independent variables zero would lead to an increase in consumption of lake flies by a factor of .032;

Using the bêta coefficient, the established regression model was as follows:

Y = -.829+.032X.

Where,

Y= Consumption of lake flies -.829= Constant term, .032X_2 ecological factors.

Siaya County Correlation Analyses

This section of the study presents findings on regression, analysis of variance and co-efficient of determination.

The findings in table 12 indicate that there is a positive correlation between ecological/technological factors and consumption of lake flies at a significant 0.05 level, the strength is average, at 72.0%.

Table 12. Relationship between Independent Variables.

Correlations					
		Consumption	Socioeconomic factors	Ecological factors	Collection
Consumption	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	108			
Ecological factors	Pearson Correlation	.720**	.847**	1	
	Sig. (2-tailed)	.000	.000		
	N	101	77	101	

**. Correlation is significant at the 0.05 level (2-tailed).

Kisumu County Regression Prediction Model Summary for determinants of consumption of lake flies

A simple linear regression test was run to determine the predictive power of ecological factors on the consumption of lake flies as food within the Lake Victoria region in Kisumu County results are shown in Table 13. The significance of the predictor variables was tested using a t-test. The findings reveal that ecological factors and were statistically significantly related to the consumption of lake flies p-value<0.05.

Table 13. Kisumu County Regression Prediction Model Summary for determinants of consumption of lake flies.

Model Coefficient	Unstandardized coefficients		Standardized Coefficients	T	Sig.	Collinearity	
	B	Std Error	Beta			Tolerance	VIF
(Constant)	-.808	.577		-1.402	.168		
Ecological factors	.357	.123	.478	2.897	.006	.305	3.274

a. Dependent Variable: Consumption of Lake flies as Food

The findings in table 14. established that taking all factors into account , ecological factors was -.808 due to variation. A unit change in ecological factors while setting the coefficient of other independent variables zero would lead to a lead to an increase in consumption of lake flies by a factor of .357.

Using the bêta (β) coefficient, the established regression model was as follows:

$Y = -.808+ ..357X_2$

Where,

Y= Consumption of lake flies **-.**808= Constant term, .357X_2 ecological factors,.

Kisumu County Correlation Analyses

This section of the study presents findings on regression, analysis of variance and co-efficient of determination.

The findings in Table 14. implies that There is a positive correlation between ecological factors and consumption of lake flies at significant 0.05 level, the strength is average, at 75.2%.

Table 14. Relationship between Independent Variables.

		Consumption	Ecological factors
Consumption	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	78	
	N	54	
Ecological factors	Pearson Correlation	.752**	1
	Sig. (2-tailed)	.000	
	N	69	69
	Sig. (2-tailed)	.002	.267
	N	73	69

** Correlation is significant at the 0.05 level (2-tailed).

Homabay County Regression Prediction Model Summary for determinants of consumption of lake flies

A simple Linear regression test was run to determine the predictive power of ecological factors on the consumption of lake flies as food within the Lake Victoria region in Homabay County results are shown in Table 15.

The Ecological factors significance of the predictor variables was tested using a t-test. The findings reveal that ecological factors was statistically significantly related to the consumption of lake flies p-value <0.05.

Table 15. Homabay County Regression Prediction Model Summary for determinants of consumption of lake flies.

Model Coefficient	Unstandardized coefficients		Standardized Coefficients	T	Sig.	Collinearity	
	B	Std Error	Beta			Tolerance	VIF
(Constant)	-.566	-.566		-.973	.335		
Socio economics	.297	.297	.303	1.892	.065	.293	3.413
Ecological factors	.354	.354	.517	3.286	.002	.306	3.264

a. Dependent Variable: Consumption of Lake flies as Food

The findings in table 16. established that taking all factors into account ecological factors constant factor was -.566 due to variation.; a unit change in ecological factors while setting the coefficient of other independent variables zero would lead to an increase in consumption of lake flies by a factor of .354;

Using the bêta (β) coefficient, the established regression model was as follows:

$Y = -.566+ ..354X_2$

Where,
Y= Consumption of lake flies -.566= Constant term,.354X_2 ecological factors.

Homabay County Correlation Analyses
This section of the study presents findings on regression, analysis of variance and coefficient of determination.

Table 16. Relationship between Independent Variables.

		Consumption	Ecological factors
Consumption	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	84	
	Sig. (2-tailed)	.000	
	N	59	
Ecological factors	Pearson Correlation	.757**	1
	Sig. (2-tailed)	.000	
	N	72	72
	Sig. (2-tailed)	.003	.207
	N	78	72

**. Correlation is significant at the 0.05 level (2-tailed).

The findings in Table 16 indicate that There is a positive correlation between ecological factors and consumption of lake flies at significant 0.05 level, the strength is average, at 75.7%.

Overall Results of Correlation Analyses
This section of the study presents findings on regression, analysis of variance and co-efficient of determination.

Table 17. Relationship between Independent Variables.

		Consumption	Ecological factors
Consumption	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	270	
	Sig. (2-tailed)	.000	
	N	189	
Ecological factors	Pearson Correlation	.740**	1
	Sig. (2-tailed)	.000	
	N	234	234
	Sig. (2-tailed)	.000	.060
	N	252	234

**. Correlation is significant at the 0.05 level (2-tailed).

The findings in table 17 indicate that There is a positive correlation between ecological/technological factors and consumption of lake flies at significant 0.05 level, the strength is average, at 74.0%.

Overall Results of Model Summary for determinants of consumption of lake flies
The probability value of $p<0.05$ indicates that the regression relationship was significant in predicting how socio-economic factors, ecological factors, harvesting technologies influence the consumption of lake flies.

Multiple regression analysis was the carried out to obtain regression coefficients. From table 18, it is revealed that, the tolerance values were <1 and the variance inflation factor (VIF) was <10 and hence there was no multi –collinearity. Due to absence of multi- collinearity, therefore the regression estimates were not spurious or nonsensical. This is as summarized in table 18.

Table 17. Overall Results of Model Summary for determinants of consumption of lake flies.

Coefficients[a]

Model Coefficient	Unstandardized coefficients		Standardized Coefficients	T	Sig.	Collinearity	
	B	Std Error	Beta			Tolerance	VIF
(Constant)	-.820	.190		-4.313	.118		
Ecological factors	.272	.033	.393	8.292	.050	.562	1.779

a. Dependent Variable: Consumption of Lake flies as Food

Discussion of regression results

The main objective of the study was to assess the determinants of lakefly consumption and its sustainability within the Lake Victoria region. The Specific objectives were to: identify and analyze the selected thematic socioeconomic factors how they individually and collectively influencing the consumption of lake flies within the Lake Victoria region, investigate the impact of the surrounding ecological factors influencing the collection and consumption of lake flies within the Lake Victoria region, identify and analyze the current technologies used for the collection of lake flies within the Lake Victoria region and how they influence collection and consumption.

Test of Research Hypotheses

The research hypothesis was stated as: H_{02} -Ecological factors do not significantly influence the consumption of Lake Flies within the Lake Victoria region. The result indicated that Ecological factors positively and significantly influence the consumption of Lake Flies within the Lake Victoria region with a β value of 0.272, standard error of 0.033; t value of 8.295 and p value 0.050. Hence, the null hypothesis was rejected.

From the results, it shown that ecological factors has a positive influence on the consumption of lake flies. The significance of the predictor variables was tested using a t-test. The findings reveal that ecological factors were statistically significantly related to consumption of lake flies p-value ≤ 0.05. The findings in table 17 established that taking all factors into account (socio-economic factors, ecological factors and ecological factors) constant factor was -.820 due to variation. a unit change in ecological factors while setting the coefficient of other independent variables zero would lead to an increase in consumption of lake flies by a factor of .272; Using the bêta coefficient, the aggregate predictive regression equation was summarized as follows:

$Y = -.820 + ..272X_2$.

Where,

Y= Consumption of lake flies, .820 = Constant term of multivariate (equation) regression, factors, $.272X_2$ ecological factors**.**

The findings reveal hat ecological factors were statistically significantly positively related to Consumption of lake flies, p-value ≤ 0.05. Hence, the hypotheses was rejected. The theoretical foundation of the study. Subjective Norms (SN) are the perceived approval or disapproval that people who are important to the individual (otherwise known as "salient referents" such as one's family members, peers, etc.) hold about a behavior (Ajzen & Fishbein, 1980).

In the study, perceived behavioral control was operationalized by sanity in the lake flies' Ecological factors as indicated by biotic factors, abiotic factors, and climate variability.

The major gap is that it is evident that the ecological factors determinants of lake flies' consumption as food and its sustainability is a concern to food security stakeholders and policymakers seeking to comprehend how to effectively ensure the sustainable alternative source of protein to Kenyans. Previous studies in this area seem to focus on food security only, failing to address salient issues on sustainability of lake flies consumption.

Ministerial Council Policy Guidelines on Novel Foods of Australia and New Zealand, (2016) came up with guidelines for novel food as follows; to ensure that priority is given to the protection and improvement of public health and safety in relation to food matters; to ensure that consumers have access to sufficient information to enable informed and healthy food choices, be consistent with and complement Australian and New Zealand national policies and legislation including those relating to nutrition and health promotion. Draw on the best elements of international regulatory systems (ie protocols, standards, guidelines, assessment processes) and be responsive to future trends and developments, provide a regulatory environment that is timely, cost effective, transparent and consistent with minimum effective regulation, and which encourages fair trade, industry growth, innovation and international trade.

On the African continent, Kenya (led by efforts from ICIPIE and JOOUST) has been developing as a local hub for research and development in this arena, it will be important to involve neighboring countries and partners in the efforts to strengthen the development. Insects have a long history as a part the diets of several ethnic groups in Kenya.

Traditionally, the consumption of insects has mainly taken place in western provinces of the country and has included primarily grasshoppers, termites, lake flies and crickets. These species are harvested and prepared solely for human consumption. The utilization of insects as food is strongly influenced by cultural perceptions of what is acceptable to be eaten in modern times. However, learning and understanding how a traditional practice can contribute to food security and sustainable development in Kenya is of equal importance (International Conference on Legislation and Policy, 2016).

An attempt to come up with policy and regulations on novel food like insects in Kenya concluded that Traditional harvesting of insects from the wild needs to be assessed species by species for sustainability and safety. The conference indicated that future legislation will be needed to regulate the harvest for sustainability and consumer safety. This would include: regulates and permits sustainable harvesting, stipulates flexible maximum quantities for each species, specifies areas for harvesting including possible closed seasons for harvest depending on the ecology of the insect, and regulates the amount sold and number of anticipated harvesters (International Conference on Legislation and Policy, 2016).

Regression Model Summary per County

The study sought to establish which County socio-economic factors, ecological factors and harvesting technologies influence the consumption of lake flies. Pearson's coefficient of determination was used. The results are as shown in table 17.

Independent Variables Coefficients Summary per County

The study sought to establish the influence of ecological factors influence consumption of lake flies most in the three Counties. Pearson's coefficient of determination was used. The results were as shown in table 18.

Table 18. Independent Variables Coefficients Summary per County.

County	Constant	Ecological factors
Siaya	-0.829	0.032
Kisumu	-0.808	0.357
Homabay	-0.566	0.354

The findings reveal that ecological factors Kisumu (0.357); Homabay (0.354); Siaya (0.032), influence the consumption of lake flies in all the three Counties of Kisumu County, Homabay County and Siaya County.

Findings from the Interviews

Consumption of Lake flies

The key informants were also requested to give recommendations that can ensure the sustainability of consuming lake flies. In response, firstly the respondents recommended that awareness be created among people living along the shores. Secondly, better preservation methods should also be put in place. Thirdly, awareness should be created among people living along the shores. Fourthly, re-afforestation along the lake shore and practicing non-pollutant fishing and agricultural practices.

The key informants were also requested to explain factors that can contribute to the frequency of lake flies' consumption. The interviewees suggested those good collection methods, knowledge on preparation (value addition) and proper timing on when it swarms. Additionally, they stated that the method of processing, storage conditions and ways/methods of preparing for consumption influence the frequency of lake flies' consumption.

Influence of Ecological Factors on Consumption of Lake Flies

The study was to investigate the ecological factors influencing the consumption of lake flies as food within the Lake Victoria region. This study sought to establish whether ecological factors such as biotic factors, moisture and temperature, and climate change have influenced the consumption of lake flies as food within the Lake Victoria region. The respondents were requested to show their level of agreement with the statements in relation to the influence of ecological factors on the consumption of lake flies as food within the Lake Victoria region.

Firstly, in the open-ended questions, the respondents were requested to indicate other ways in which climate change influences the consumption of lake flies. In response, the majority of the respondents were of the opinion that during dry period consumption is low, the climate change affects the number of flies hence consumption is affected, climate affects the number of flies collected hence consumption is affected, change in climate increases or reduces the number of flies hence consumption is affected. During cold seasons and rainy season, the swarming is low. During dry seasons, the consumption rate goes up. Windy seasons have abundance but irregular lake flies, swarming.

Secondly, the respondents were asked to explain their personal experiences concerning climate variability and consumption of lake flies. The study established that the consumption of flies varies with climate variability. The swarming volume decrease and hence cause the collections to reduce. When lake flies swarm during the rainy season, they are killed by rain drops. During windy periods, lake flies emerge hence can be trapped thus high consumption.

Furthermore, the respondents indicated that during the winter season, they appear in large numbers hence leading to its high collection, weather changes cause uncertain times when lake flies appear, the times that lake flies swarm are irregular, hot and windy seasons have more lake flies, during windy and hot seasons, more lake flies are seen and these seasons are just before the rainy seasons, consumption rate varies with climate.

Thirdly, the respondents were asked whether they think that lake fly is a sustainable source of protein. Respondents indicated that yes, if taken seriously in terms of preservation; I strongly agree that it is a source of protein but cannot sustain on its own if the technology of trapping and storage is improved. It is seasonal-Practicing of reforestation and healthy agricultural practices can make it sustainable if the environment is well conserved, making it available for harvesting.

Key informants of the study were asked to express their views on what they consider necessary for a suitable ecology of lake flies. The respondents indicated that improved vegetative cover, reduced pollution of the water bodies to protect breeding areas. Other respondents indicated that a natural environment that is preserved by limiting the use of chemicals protects lake flies' generational growth. Moreover, in an ecology whereby waves are calm, tree covers reduces erosion that provides the lake flies' habitat.

The key informants were also requested to explain whether the hotness or coldness of weather is considered when harvesting lake flies. In response, lake flies normally come out during hot weather but either in the morning or evening, coldness and darkness influence swarming and when to harvest. Wetness interferes with harvesting because the flies get stuck on the wet leaves and cannot be collected. When there is wind, you can harvest because the wind carries them away.

The key informants were also requested to explain which seasons of the year are lake flies abundant. The interviewees suggested that lake flies are abundant just prior to rainy seasons. Their appearance actually indicates the onset of rainy seasons. When land preparation is about to commence, their swarming is predictive of abundant rainfall. Specifically, lake flies are abundant in December–January-February and July-September pre rainy seasons. They are normally abundant during the rainy season. It indicates that it is going to rain soon.

Discussion

The response regression analysis R Square of 0.496 implies that ecological factors determine 49.6% variations in the consumption of lake flies as food within the Lake Victoria region. In the ANOVA, the probability value of $p<0.05$ indicates that the regression relationship was significant in predicting how ecological factors influence the consumption of lake flies as Food.

The level at which ecological factors influence consumption of lake flies as food within the Lake Victoria region is such that holding ecological factors to a constant zero, consumption of lake flies as food would be at .820. with β value of 0.272. Thus, a unit increase in ecological factors would lead to an increase in consumption of lake flies as food by factor .272 showing ecological factors is statistically significant in influencing the consumption of lake flies. Further, ecological factors had a positive influence on the consumption of lake flies ($t = 8.295$, $p <0.05$).

In the principal component factor analysis, the following ecological factors of lake fly consumption had a factor loading of > 0.5 ranging between 0.901 and 0.998: Moisture and temperature, Biotic, Climate change, Weather conditions precipitated by climate change and lake flies are abundant during rainy seasons, indicating the factors were significant in influencing consumption.

These findings suggest that the ecological factors had a positive significant influence on the consumption of lake flies as food within the Lake Victoria region. In terms of the analysis per county regarding ecological factors, the findings were as follows: Kisumu (r=0.757), Homabay (r=0.752), and Siaya (r=0.720). This implies that ecological factors influence the consumption of lake flies mostly in Kisumu County and least in Siaya County.

The respondents were requested to show their level of agreement with the statements in relation to the influence of ecological factors on the consumption of lake flies as food within the Lake Victoria region.

The Total Variance Explained table shows how the variance is divided among the 8 possible factors. Single factor had an eigenvalue (a measure of explained variance) greater than 1.0, which is a common criterion for a factor to be useful as postulated by (Shrestha, 2021). When the eigenvalue is less than 1.0, the factor explains less information than a single item would have explained (Razak *et al.*, 2016).

Ecological factors such as biotic factors, moisture and temperature, and climate change were analyzed to establish whether they influence the consumption of lake flies as food within the Lake Victoria region, so the fact that they all have strong loadings from the same factor provides some support for their being conceptualized as pertaining to the same construct. On the other hand, item 1 was intended to measure the role of moisture and temperature in insect ecology, it was established that it is highly related to this same component factor. In retrospect, one can see why this item could also be interpreted. The item reads, “Moisture and temperature play a significant role in insect ecology” this is in tandem with the findings of (Ayieko, 2014) which stated that lake flies are highly associated with forests that are not yet affected by the current climate change.

owever, its emergence and swarming are highly dependent on the onset of the rainy season which is currently unpredictable due to climate change.

In the open-ended questions, the respondents were requested to indicate other ways in which climate change influences the consumption of lake flies. In response, the majority of the respondents were of the opinion that during dry seasons, consumption is low and that climate change affects the number of lake flies hence consumption is affected. They also stated that climate affects the number of lake flies collected hence consumption is affected, and change in climate increases or reduces the number of lake flies hence consumption is affected. Also, it was reported that during cold and dry seasons, the consumption rates go up. During rainy seasons, the number of lake flies is abundant and this leads to high consumption. Windy seasons have a high quantity but irregular lake flies mostly due to disturbance. In addition, they reported that climate change affects collection hence consumption is affected.

The respondents were asked to explain their personal experiences concerning climate variability and consumption of lake flies. The study established that the consumption of lake flies varies with climate variability. The swarming volume decreases and hence causes the collections to reduce. When lake flies swarm during the rainy season, they are killed by raindrops. During windy periods, lake flies emerge and hence can be trapped thus high consumption, and this draws a parallel correlation to the postulation by (Jonsson *et al.*, 2015), who stated this observation when describing climate impact on the emergence of aquatic insects and delved in an instance of lake flies. This finding is in concurrence that climatic changes are expected to impact insect-plant interactions in several ways; climate change might affect insects directly, through changes in physiology, behavior and life history parameters, as well as indirectly, through changes experienced by host plants in their morphology (Karthik *et al* 2021, Giron *et al.*, 2018), biochemistry (Karthik *et al.,* 2021), physiology (Tonnang *et al.,* 2022; Bellard *et al.*, 2012; Devi *et al.*, 2019; Jones *et al.*, 2012) and patterns of richness, diversity and abundance (Karthik *et al* 2021; Sharma *et al.*, 2014; Skendžić *et al.*, 2021; Pareek *et al.*, 2017).

Key informants of the study were asked to express their views on what they consider necessary for a suitable ecology of lake flies. The respondents indicated improved vegetative cover, and reduced pollution of the water bodies to protect breeding areas. Other respondents indicated that a natural environment that is preserved by limiting the use of chemicals protects lake flies' generational growth. Moreover, ecology whereby waves are calm, tree covers reduces erosion that provides the lake flies with a suitable habitat this agrees with the findings in this in line with the finding of (Clements *et al.*, 2016; Sun *et al.*, 2019) indicating that change in physicochemical properties that defines the chemistry and biology of the lake flies habitat has significantly influenced the population of the lake flies.

The key informants were also requested to explain whether the hotness or coldness of weather is considered when harvesting lake flies. In response, they stated that lake flies normally come out during hot weather but either in the morning or evening, coldness and darkness influence swarming and when to harvest. They also responded that wetness interferes with harvesting because the lake flies get stuck on the wet leaves and cannot be collected. When there is wind, you can harvest because the wind carries them away.

In the open-ended questions, the majority of the respondents were of the opinion that during the dry period, consumption is low, climate change affects the number of flies hence consumption is affected, climate affects the number of flies collected hence consumption is affected, and change in climate increases or reduces the number of flies hence consumption is affected. During cold seasons and rainy seasons, the swarming is low. During dry seasons, the consumption rate goes up. Windy seasons have abundance but irregular lake flies, swarming. These findings are in agreement with the findings of Khaliq *et al.* (2014), Ayieko *et al.* (2014), Selaledi *et al.* (2021) which identified that several factors such as weather conditions precipitated by climate change favor the increased emergence of insects, and that moisture and temperature play a significant role in insect ecology.

Key informants of the study were asked to express their views on what they consider necessary for a suitable ecology of lake flies. The respondents indicated that they viewed improved vegetative cover, suitable temperatures, unpolluted environment and reduced pollution of the water bodies as necessary to protect breeding areas, this is in tandem with (González *et al.*, 2020; Skendžić *et al.*, 2021; Denlinger *et al.*, 2019) findings that Insects are very sensitive to temperature increases and are known to be more active in higher temperatures

Findings based on inferential statistics revealed that there is a positive correlation between ecological factors and consumption of lake flies at a significant 0.05 level, the strength is average, at 74.0%. The level at which ecological factors influence the consumption of lake flies as food within β value of .272**,** such that holding ecological factors to a constant zero and other factors constant, consumption of lake flies as food would be at .820. An increase in ecological factors would lead to an increase in consumption of lake flies as food by factor .272 showing ecological factors is statistically significant in influencing the consumption of lake flies. Further, ecological factors had a positive influence on the consumption of lake flies ($t = 8.292$, $p < 0.05$). This finding is in agreement with qualitative thematic findings from the key informants' responses.

The study findings are in agreement with the theoretical foundation of the study. Salient beliefs are the determinants of an individual's behavior and actions and can be categorized as behavioral beliefs, normative beliefs, or control beliefs (De Leeuw *et al.*, 2015). Behavioral beliefs are predictors of attitudes, normative beliefs of subjective norms, and control beliefs of perceived behavioral control. In order for beliefs to be predictive, they must be salient. Salience varies between individuals and also can vary based on situations that are present in an individual's life, as implied by Paluck & Shepherd, (2012).

The second research hypothesis was stated as: H_{02} - Ecological factors do not significantly influence the consumption of Lake Flies within the Lake Victoria region. The result indicated that Ecological factors positively and significantly influence the consumption of Lake Flies within the Lake Victoria region with a β value of 0.272 standard error of 0.033, t value of 8.295 and p value 0.050. a factor loading of > 0.5 ranging between 0.901 and 0.998 and in terms of the analysis per county regarding ecological factors, the findings were as follows: Kisumu (r=0.757), Homabay (r=0.752), and Siaya (r=0.720) Hence, the null hypothesis was rejected.

Conclusion

The second research hypothesis was stated as: H_{02} - Ecological factors do not significantly influence the consumption of Lake Flies within the Lake Victoria region. The result indicated that ecological factors positively and significantly influence the consumption of lake flies within the Lake Victoria region with a β value of 0.272 standard error of 0.033; t value of 8.295 and p value 0.050. a factor loading of > 0.5 ranging between 0.901 and 0.998 and in terms of the analysis per county regarding ecological factors, the findings were as follows: Kisumu (r=0.757), Homabay (r=0.752), and Siaya (r=0.720) Hence, the null hypothesis was rejected.

The amounts and pattern of emergence of insects during the onset of the rainy season have been influenced by the changes in the weather patterns. This study established how climate change is impacting edible insects. The periodicity of the emergence of the lake flies has been influenced by the unpredictability of the onset of the rain season and other weather activity on which the emergence of the flies depends on but these influences are yet to be explored. It is expected that climate change will have both positive and negative impacts on the collection and utilization of lake flies for human consumption. The status of abundance in the emergence of lake flies around Lake Victoria will depend on how researchers interpret and manage the climate change outcomes.

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