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Sustainable Crawfish Farming in Louisiana: Strategies to Promote Crawfish Production

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Abstract
This study is used to describe sustainable crawfish farming in the state of Louisiana, and to also suggest some key strategies to help the state of Louisiana to promote crawfish production. It is an undeniable fact that the Louisiana Crawfish production over the years has been produced from wild habitats, mainly from the Atchafalaya River basin, which seems to be a factor of seasonality. Following the statistics of the total Crawfish production by Louisiana Crawfish Promotion and Research Board, it was underscored that more than 100 million pounds of crawfishes were produced. Out of the 100 million capacity of crawfishes produced annually, approximately 82 million pounds of crawfishes were obtained from regular crawfish farms and more than 18 million pounds of crawfishes were harvested from natural habitats by the activities of approximately 1,600 fishermen. Surprisingly, the crawfish industry employs about 7,000 people directly or indirectly and injects $300 million into the state's economy each year. Therefore, the sustainability of this industry will continue to generate sustainable employment, and reliable revenue to support the state's project. The study adopted a cross-sectional data collection procedure to sample 250 crawfish farmers in the State of Louisiana with the help of Cluster random sampling technique. The study was modeled after Ranganathan et al. (2017) and Robinson (2018) analysis and interpretation of Logistic regression model to estimate the strategic determinants of sustainable crawfish production in Louisiana. The study revealed that the engagement/involvement of crawfish farmers' in the productive and efficient system of production in the State of Louisiana (such as productive cage system) will remain an important driver of sustainable crawfish growth. The study further revealed the following fishing production strategies as sustainable for the crawfish growth based on the farmers perception and understanding: crawfish health management, genetically improved crawfish strains, more affordable quality feeds, human capacity development and extension services, as well as policy and public investment support for crawfish production. The study recommended that the Louisiana State government and the other key stakeholders should continuously invest in technology and transfers that will aid in sustainable crawfish production, and to also focus beyond the farm by strengthening the implementation of policy and public investment support for crawfish farming. These strategies will go a long way to generate more sustainable employment, and revenue to ensure growth in Louisiana.
Keywords: Sustainability, Strategies, Production, Natural and Wild-Habitats, Employment, Logistic Regression, Revenue, Crawfish, Seafood, Aquaculture, and Fishing
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INTRODUCTION

Sustainability of Crawfish farming is very crucial to the growth and development of the state of Louisiana. Crawfish farming is a major industry in Louisiana, with Louisiana commercial crawfish farmers providing 85% of domestically produced crawfish to Louisiana markets and across the nation (Louisiana Crawfish Promotion and Research Board, 2019). The Louisiana state's crawfish yield is estimated to hover around 100 million pounds of crawfish annually. Meanwhile, it is observed from the Crawfish and fish farming literature that Crawfish ponds and farming have no standard size, but most are between 10 and 40 acres, and most producers manage 150 or fewer acres across the state of Louisiana. In some instances, it was observed from the literature that most Crawfish farmers use the crawfish ponds for growing rice at other times of the year (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). Notwithstanding the importance of crawfish in the state of Louisiana, Crawfish as one of the innovative water-bodies products in the state of Louisiana has gone viral to the utility of both the internal and external sphere of influence. Domestically, crawfish has been widely used in the state of Louisiana, and highly celebrated as a crawfish festival. Crawfish production and utilization has also been seen across several states in the southern part of United States of America, particularly in Louisiana, Texas, Arkansas, Mississippi, Alabama, and South Carolina (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017).

In fact, Texas is the next most productive crawfish supplier after the state of Louisiana. There are seven large producers with 100-300 acres of capacity each, mostly in southeast Texas between Beaumont and Houston (Louisiana Crawfish Promotion and Research Board, 2019). Small-scale producers are entering the market as an

opportunity for supplemental income as crawfish demand grows. Crawfish also are cultivated for food in Arkansas, Mississippi, Alabama, South Carolina and North Carolina, and are consumed in these and many other states (Louisiana Crawfish Promotion and Research Board, 2019). According to the National Geographic Survey (2014), crawfish is referred to by several names including crawdads, crawfish, river crab, and mudbugs. Crawfish demand has increased domestically, nationally, and internationally but the production has not been able to match-up with the consumption of crawfish products globally. As a result of the global crawfish shortages, several states including Louisiana are trying to come up with several unique strategies, and production styles to help increase crawfish production to meet the global demand. The state has also devised several ways to package and brand their seafood products to be gorgeous and attractive for both the internal and external sphere of influence to help generate more revenue, and employment (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017).

Crawfish as one of the seafood is very unique in creating more employment, and generating more revenue to many states. This unique product needs a maximum attention to serve as a revenue generator for both the citizens and the state at large. In perusing the literature, it is observed that by its nature, it can be boiled, baked, or cooked into a delicious meal (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). In the state of Louisiana, crawfish is one of the most versatile foods available and also gain a lot of popularity outside its territory. However, a lot of people still look down on this tiny crustacean and mull over it to be a less important dish than their saltwater cousins.

Unlike, Lobsters, and other fishes which spend their lives in saltwater, including oceans and seas, crawfish set up shelter in fresh water, such as streams, rivers, and ponds (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). This implies that crawfish production can be expanded easily through artificial inventions, and some sustainable strategies, and procedures to guide the implementation of crawfish production (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). This system may comprise of a network of field stations throughout the nation that works with tribal, local, and state governments, other federal agencies, and foreign nations to conserve fisheries. Since the inception of the U.S. Fish and Wildlife Service in 1871, fisheries conservation has figured paramount to people and economies including crawfish as a product or an element of fisheries. Additionally, in 1965, the Fish & Wildlife Service established seven Fish Technology Centers nationwide to provide science and technology support and guidance to the National Fish Hatchery System and fish culture community (Oluwade & Adu-Frimpong, 2018; Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017).

In perusing several kinds of articles and publications, it was underscored that Louisiana's crawfish farming industry has grown to include more than 1,600 farms occupying more than 120,000 acres of land (Louisiana Crawfish Promotion and Research Board, 2019). Also, the production from wild habitats, mainly the Atchafalaya River basin, diverges from year to year. Again, the total production between 2004 and 2005 season was more than 82 million pounds, with almost 74 million pounds from farms and more than 8 million pounds harvested from natural habitats by approximately 1,100 fishermen (Louisiana Crawfish Production Manual, 2017). Meanwhile, it is an undeniable fact that the Louisiana Crawfish production over the years has been produced from wild habitats, mainly from the Atchafalaya River basin, which seems to be a factor of seasonality. Following the statistics of the total crawfish production estimation by Louisiana Crawfish Promotion and Research Board (2019), it was underscored that more than 100 million pounds of crawfishes were produced. Out of the 100 million capacity of crawfishes produced annually, approximately 82 million pounds of crawfishes were obtained from regular crawfish farms and more than 18 million pounds of crawfishes were harvested from natural habitats by the activities of approximately 1,600 fishermen. Surprisingly, the crawfish industry employs about 7,000 people directly or indirectly and also injects about $300 million into the state's economy each year (Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). Therefore, the sustainability of this industry will go a long way to continue to generate sustainable employment, and reliable revenue to support the state's project.

Nevertheless, many of the crawfish farmers rely on natural reproduction system by unharnessed crawfish from the previous year or on mature crawfish that are stocked to produce young naturally. In addition, it is a fact that crawfish aquaculture in the Louisiana State does not have some specific strategies to help sustain the growth of crawfish production to meet crawfish demand year-round. This has been a hindrance on the part of the crawfish farmers to sustain the growth and the populating capacities of their ponds with crawfishes now and in the near future. Therefore, this current study tends to model and investigate the sustainability of Louisiana crawfish production with a control variable of some key aquaculture strategies to ensure sustainability in the crawfish production by using logistic regression modelling technique.

LITERATURE REVIEW

Concept of Sustainability

According to Wurts (2016), the United States Farm Bill of 1990 defined sustainability as maintaining profitability, using non-renewable resources efficiently, supplying food and fiber needs, enhancing renewable resources and improving the quality of life in rural areas. Wurts (2016) further argued that the Food and Agriculture Organization of the United Nations described sustainable growth based on the management and conservation of the natural resource, and the orientation of technological and institutional change in such a manner as to ensure attainment and continued satisfaction of human needs for present and future generations (Wurts, 2016). It was further observed from the literature that such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable (Wurt, 2016).

Bardach in 1997 argued that obstacles to the future growth of aquaculture will be economical as much as social, and environmental as technical. A survey conducted by Caffey and co-workers in 1998 in the Southeastern United States defined indicators of sustainable aquaculture that could be measured. They fell into three categories: social, environmental, and economic. In 1999, Boyd further commented that environmental management was the issue that is central to sustainable aquaculture. Stickney stated in 2000, that sustainability involves the establishment of production systems that can exist, at least theoretically, in perpetuity. While, Costa-Pierce proffered a concept in 2002 termed ecological aquaculture. He suggested that the evolution and development of aquaculture must be in harmony with the environment and global ecosystems as well as human cultures and communities. Some have argued that the term sustainability should be discarded altogether. In 1995, Boyd and Tucker stated that aquaculture is not truly sustainable because it is dependent on external feed, chemical and energy inputs. In the year 2000, Wurts recommended that the sustainable aquaculture concept serve as a catalyst, embracing as many different perspectives as possible. Therefore, researchers can only defy entropy for a moment on the galactic time scale. Meanwhile, as described in the literature by Wurt (2016) the second law of thermodynamics tells us that the universal trend is from organization to randomness, order to chaos. Therefore, life on this planet can be sustained for a brief interlude, including the fishes in the aquatic-system.

History of Crawfish Production in Louisiana

Crawfish are small crustaceans that live in fresh water and are similar in flavor to shrimp and lobster (Covington, 2022). Approximately 95% of the crawfish consumed in the United States are harvested from Louisiana, but they're popular all over the world from Sweden to Spain to Nigeria (Covington, 2022). You can find this common crustacean crawling around in swamps, rivers, and lakes all over the planet. Crawfish is different from other saltwater fishes/bodies particularly Lobsters which spend their lives in saltwater, including oceans and seas, crawfish set up shelter in fresh water, such as streams, rivers, and ponds (Covington, 2022). Surprisingly, according to Covington (2022), crawfish, crayfish, mudbugs, yabbies' and crawdads are all the same freshwater crustacean, the name just depends on what region of the United States they're in. Crawfish look like very small lobsters (see Figure A for more details), and are eaten steamed or boiled.

Figure A: A Picture of Louisiana Crawfish

Source: https://www.oceanbox.com

Dating back to the native Americans and the early European settlers, the crawfish has been and inherent part of Louisiana culture. Abundant in the swamps and marshes across south Louisiana, crawfish were a favorite food of early residents. Centuries later, crawfish season in Louisiana is still exciting, with crawfish boils and

backyard parties a time-honored tradition. Commercial sales of crawfish in Louisiana began in the late 1800s (Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017). At that time, crawfish were harvested from natural waters through- out the southern region of the state. The first record of a commercial crawfish harvest in the United States was in 1880. That year, a harvest of 23,400 pounds was recorded, with a value of $2,140. By 1908, a U.S. Census report listed Louisiana's crawfish production at 88,000 pounds, with a value of $3,600 (Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017).

Technological advances have explained the growth of the Louisiana crawfish industry to include farming as well as fishing in the wild. In the 1960's, crawfish farming made its debut with the cultivation of crawfish in man-made ponds, using controlled water levels, forage management and water recalculation techniques to produce a highly marketable product. During the next 35 years, crawfish farming developed into the largest freshwater crustacean aquaculture industry in the United States. Louisiana leads the nation, producing more than 90% of the domestic crop. More than 1,600 farmers produce crawfish in some 111,000 acres of ponds. More than 800 commercial fishermen harvest crawfish from natural wetlands, primarily the Atchafalaya Basin. The combined annual yield ranges from 120 million to 150 million pounds. The total economic impact on the Louisiana economy exceeds $300 million annually, and more than 7,000 people depend directly or indirectly on the crawfish industry (Louisiana Crawfish Promotion and Research Board, 2019; Louisiana Crawfish Production Manual, 2017).

In fact, the Louisiana Crawfish Promotion and Research Board underscored that the technological advances have explained the growth of the Louisiana crawfish industry to include farming as well as fishing in the wild. In the 1960's, crawfish farming made its debut with the cultivation of crawfish in man-made ponds, using controlled water levels, forage management and water recalculation techniques to produce a highly marketable product.

According to Louisiana Crawfish Promotion and Research Board (LCPRB), during the next 35 years, crawfish farming developed into the largest freshwater crustacean aquaculture industry in the United States. As it stands now, it has been underscored in the literature that Louisiana leads the nation's crawfish production, that is producing more than 90% of the domestic harvest annually. Below is the map showing the major cities, and/or towns and neighboring states in the United States of America, of Louisiana State (see Figure B):

Figure B: A Political Map of Louisiana

Source: Map of Louisiana - Bing images

METHOD AND MATERIALS

This current study is modeled around the works of Ranganathan et al. (2017) and Robinson (2018) analysis and interpretation of logistic regression model to estimate the strategic determinants of sustainable crawfish

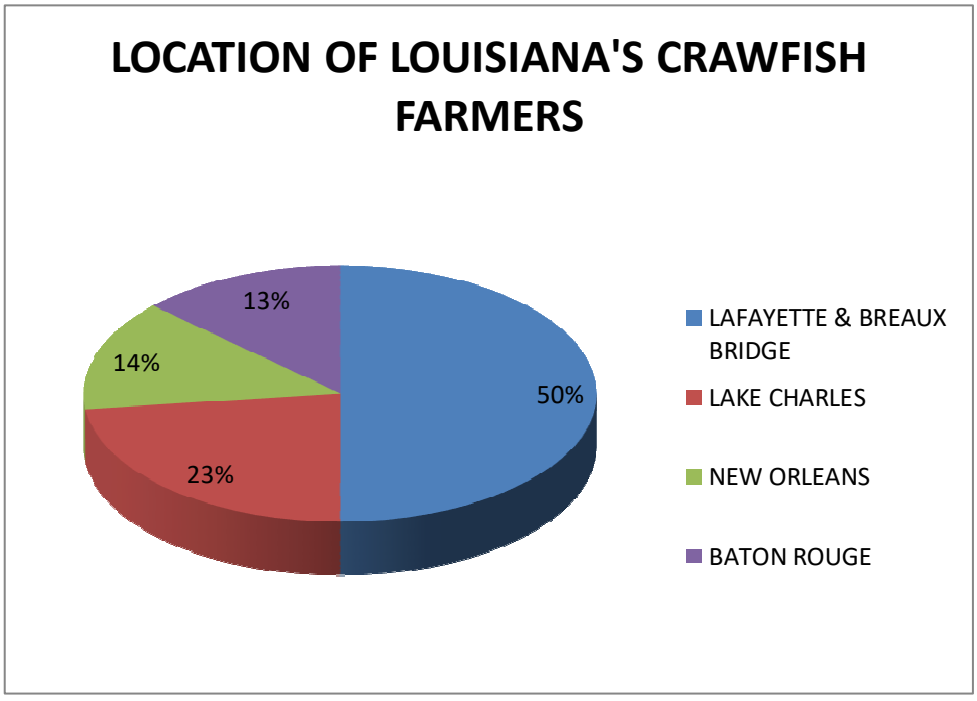
production in Louisiana. The variables that have been chosen were selected due to the fact that they adhere to the nominal measurement levels in this particular study. In order to reveal the determinants of crawfish production—the researcher used a logistic regression model to assess the perception of some crawfish farmers in Louisiana. The scope of the subject-matter looked into key sustainable strategies that are likely to influence growth and productivity in aquaculture such as general fishes, lobster, crawfish, etc. production in water-bodies. The study sampled 250 crawfish farmers across different parishes and cities in Louisiana. The estimation of the logistic model follows this equation:

$$\text{Logit } (Y) = a + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + E$$

For the purposes of this study, the dependent variable is measured as a dichotomous variable. That is "Y" =1, when the farmer is willing to participate in sustainable crawfish farming, otherwise=0. "a" represents the constant term in the model. "*Bs*" represents the coefficient of the explanatory variables and the X's represents the independent variables (strategies to aid in sustainable crawfish farming). X_1= Invest in technological innovation and transfer or invest in productive and efficient systems. {If farmers are willing to invest in technology and transfers (such as highly productive cage system, disease control, feeds and nutrition, etc.) =1; if not= 0}; X_2= Policy and public investment support or by focusing beyond the farm {Whether farmers are willing to follow spatial planning and zoning =1; if not= 0}; X_3= Shift incentives to reward sustainability {If favorable government intervention such as subsidies, etc. influence crawfish production =1; if not= 0}; X_4= Fish health management {If farmers practice crawfish health management =1; if not= 0}; X_5= Genetically improved fish strains {If farmer utilized genetically improved fish strains =1; if not= 0} and E= represents the term in the model. Logistic regression is useful to this study because it is an efficient model when dealing with large datasets with a large sample size. In addition, given that the dependent variable in the study is binary (Yes or No), logistic regression will allow for well-calibrated predictive possibilities (Ranganathan et al., 2017; Robinson, 2018). The study through SPSS 20.0 used p-values computed to determine the statistical significance of the variables estimated. The rejection of the null hypothesis was set at the 5%, significance levels of the Two-tailed test, with a p-critical value of 0.05.

DATA PRESENTATIONS AND DISCUSSIONS

Figure 1: Demographic Sample Locations of Crawfish Farmers

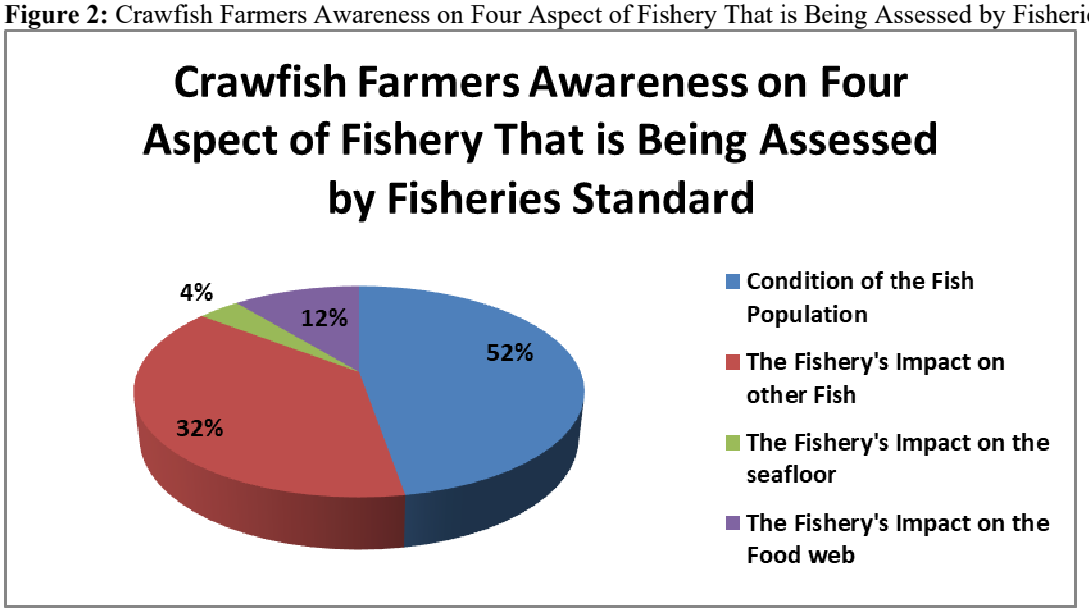


Source of Data: Field data, March 2022

Figure 1 shows the demographic sample of crawfish farmers in the state of Louisiana, who participated in the survey. Based on the March 2022 field, about 50% of the respondents were crawfish farmers sampled from the Lafayette community and surroundings (i.e. including Breaux Bridge), while 23% of the respondents were crawfish farmers sampled from the Lake Charles community and surroundings, 14% of the respondents were crawfish farmers sampled from the New Orleans community and surroundings, and 13% of the respondents were crawfish farmers sampled from the Baton Rouge community and surroundings. By inspection from the field data, it was observed that majority of crawfish production is seen more in Lafayette, Breaux Bridge, and Lake Charles

communities and surroundings.

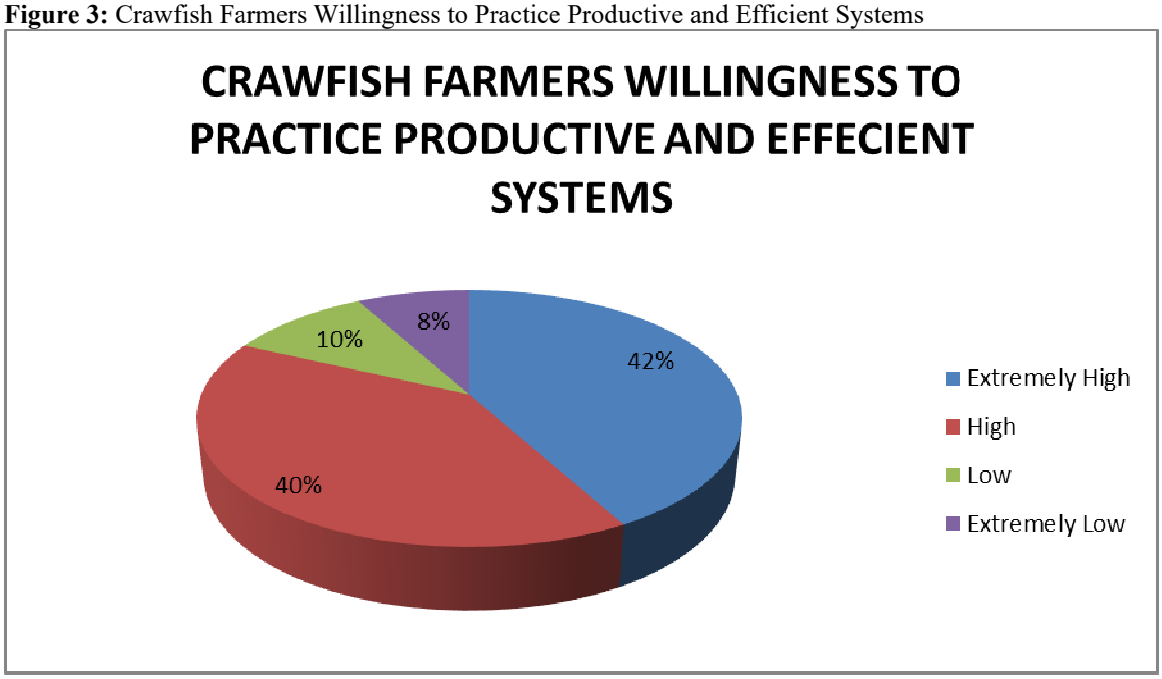
Figure 2: Crawfish Farmers Awareness on Four Aspect of Fishery That is Being Assessed by Fisheries Standard



Source of Data: Field data, March 2022

Figure 2 reveals the perception of Crawfish farmers on the four aspect of fishery that is being assessed by fisheries standard in the state of Louisiana. This survey is based on the farmers' perception, and awareness of the four aspect of fishery that is being assessed by fisheries standard. Based on the field data, 52% of the farmers from the various production units confirm that they are aware of the "conditions of the fish production" as one of the four aspects of fishery that is being assessed by fisheries standard, while 32% of the farmers also confirm that they are aware of "the fishery's impact on other fish" as one of the four aspects of fishery that is being assessed by fisheries standard. Additionally, it was observed from the field data that about 12% and 4% of farmers were aware of "the fishery's impact on the food web" and "the fishery's impact on the seafloor" respectively as part of the four aspects of fishery that are being assessed by fisheries standard. According to the Marine Stewardship Council, the Fisheries Standard assesses four aspects of a fishery, which must perform well in all four to be rated a Best Choice. They are: (1) the condition of the fish population, (2) the fishery's impact on other fish or animals that are caught or used as bait, (3) if the fishery is trying to understand and minimize its impact on the environment, and (4) the fishery's impact on the seafloor and food web.

Figure 3: Crawfish Farmers Willingness to Practice Productive and Efficient Systems

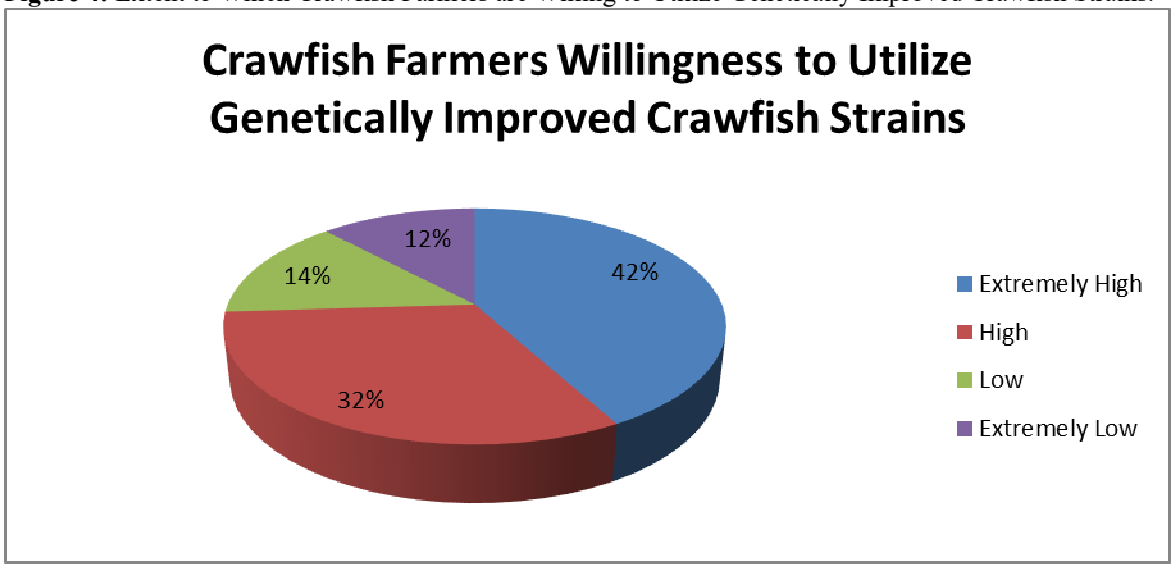


Source of Data: Field data, March 2022

Figure 3 reveals the extent to which crawfish farmers are willing to practice productive and efficient system

of production in Louisiana. Noticeably, about 42% of the farmers rated their willingness to practice productive and efficient system of production in Louisiana as extremely high, while 40% of the farmers rated their willingness to practice productive and efficient system of production in Louisiana as high. Nevertheless, about 10% and 8% of farmers also rated their willingness to practice productive and efficient system of production in Louisiana as low, and extremely low respectively. Among the many reasons that may be hindering the farmers to embark on productive and efficient system of fish farming include initial start-up capital, the cost of adopting new technology, lack of government support (i.e. incentives), cost of storage facility to keep the new young ones and the old ones (see Oluwade & Adu-Frimpong, 2018). With regards to the productive and efficient systems—it was observed from the literature that highly productive cage systems need to be expanded, for it to remain an important driver of sustainable aquaculture growth, including crawfish farming — provided that promotion and enforcement of biosecurity and environmental standards and zoning improve.

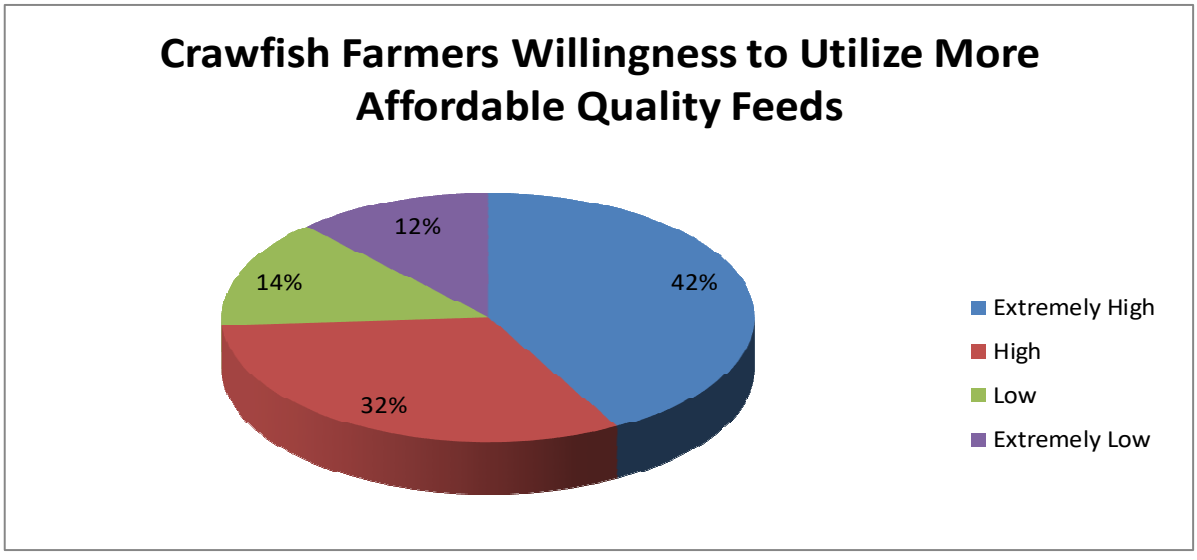
Figure 4: Extent to Which Crawfish Farmers are Willing to Utilize Genetically Improved Crawfish Strains.



Source of Data: Field data, March 2022

Figure 4 reveals the extent to which crawfish farmers are willing to use genetically improved crawfish to promote sustainable crawfish farming in Louisiana. Noticeably, about 42% of the farmers rated their willingness to use genetically improved crawfish to promote sustainable crawfish farming in Louisiana as extremely high, while 32% of the farmers rated their willingness to use genetically improved crawfish to promote sustainable crawfish farming in Louisiana as high. But, about 14% and 12% of farmers also rated their willingness to use genetically improved crawfish to promote sustainable crawfish farming in Louisiana as low, and extremely low respectively.

Figure 5: Extent to Which Crawfish Farmers are Willing to Utilize More Affordable Quality Feeds



Source of Data: Field data, March 2022

Figure 5 presents the discussion for the extent to which crawfish farmers are willing to use more affordable quality feeds to promote sustainable crawfish farming in Louisiana. By inspection, about 42% of the farmers rated their willingness to use more affordable quality feeds to promote sustainable crawfish farming in Louisiana as extremely high, while 32% of the farmers rated their willingness to use more affordable quality feeds to promote sustainable crawfish farming in Louisiana as high. But, about 14% and 12% of farmers also rated their willingness to use more affordable quality feeds to promote sustainable crawfish farming in Louisiana as low, and extremely low respectively.

Table 1: Regression Estimate of the Crawfish Sustainable Production Function

Variable	**Coefficient**	**Standard Error**
Investing in Productive and Efficient Systems (X1)	0.2345***	0.0226
Policy and Public Investment Supports (X2)	0.1362***	0.0019
Shifts incentives to Reward Sustainability (X3)	0.2042***	0.0629
Fish Health Management (X4)	0.5841***	0.5952
Genetically Improved Fish Strains (X5)	0.4432***	0.4851
Intercept	0.6584***	0.5952
R-Square		0.876
Sample (N)		250

Note: Standard errors are presented in parentheses. ****(**)* denotes significance at 1%, 5% and 10% significance level respectively.* **Source of Data:** Field data, March 2022

In all 250 crawfish farmers were surveyed across the state of Louisiana, with the help of stratified sampling technique. The study by SPSS 20.0 used p-values computed to determine the statistical significance of the variables estimated in the logistic regression analysis. The rejection of the null hypothesis was set at the 5%, significance levels of the Two-tailed test, with a p-critical value of 0.05. These results were obtained from SPSS 20.0.

Table 1 summarizes the regression estimations of sustainable crawfish farming in Louisiana. The coefficients of the independent variables (i.e. investing in productive and efficient systems, policy and public investment supports, shifts incentives to reward sustainability, fish health management, and genetically improved fish strains) are the values with the asterisked and their respective probability effect of the farmers willingness to participate in sustainable crawfish farming due to the various tested predictive variables is the sign the value possesses. By inspection from the regression results, it was observed that all the regressors implications on the farmers willingness to participate in sustainable crawfish farming are statistically significant at 1% and 5% significance levels. This implies that crawfish farmers willingness to participate in sustainable crawfish farming in the state of Louisiana are associated with the influence of the ability to invest in productive and efficient systems, policy and public investment supports, shifts incentives to reward sustainability, fish health management, and genetically improved fish strains. Lastly, about 88% variation in the crawfish farmers willingness to participate in sustainable crawfish farming in the state of Louisiana is explained by the ability to invest in productive and efficient systems, policy and public investment supports, shifts incentives to reward sustainability, fish health management, and genetically improved fish strains.

CONCLUSION AND POLICY RECOMMENDATION

Based on the discussion of the field data, the study recommended the following:

- It is highly recommended that the Louisiana government and other key stakeholders should invest more in technological innovation and transfer to promote sustainable crawfish farming across the state of Louisiana. It is important for policymakers to note that aquaculture is a young industry—decades behind that of livestock farming. Therefore, improvements in breeding technology, disease control, feeds and nutrition, and low-impact production systems are interlinked areas where science can complement traditional knowledge to improve efficiency. These sorts of innovations—whether led by farmers, research institutions, companies, or governments—have been behind productivity gains in every part of the world. For example, in Vietnam, a breakthrough in catfish breeding around the year 2000—complemented by widespread adoption of high-quality pelleted feed—that unlocked a boom in production growth and intensification. Vietnamese catfish production grew from 50,000 tons in 2000 to more than 1 million tons in 2010, even though the country's total catfish pond area only doubled during that time.
- Also, the policymakers should place a priority on research that develops solutions to potential problems and quantifies factors that will f**ocus beyond the farm.** This is because most aquaculture regulations and certification schemes focus at the individual farm level. But having many producers in the same area can lead to cumulative environmental impacts—such as water pollution or fish diseases—even if everyone is following the law. Meanwhile, spatial planning and zoning can ensure that aquaculture

operations stay within the surrounding ecosystem's by carrying capacity and can also lessen conflicts over resource use. For instance, Norway's zoning laws, for example, ensure that salmon producers are not overly concentrated in one area, reducing disease risk and helping mitigate environmental impacts. Also, in many countries, aquaculture is high on the political agenda for the promotion of food and nutrition security, and job creation. Although policies and strategies for aquaculture development are in place on paper, government funding has been low and implementation has been weak.

- Furthermore, the policymakers should design programs that will shift incentives to reward sustainability—this will go a long way to promote sustainable crawfish farming in the country. This is because, it has been observed from the literature that a variety of public and private policies can give farmers incentives to practice more sustainable aquaculture. For example, Thailand's government has provided shrimp farmers operating legally in aquaculture zones with access to free training, water supply, and wastewater treatment. The government has also provided low-interest loans and tax exemptions to small-scale farmers—helping them to adopt improved technology that increased productivity, and reducing pressure to clear new land.
- Lastly, the study recommends that the National Fish and Seafood Company should partner with crawfish farmers to leverage on the latest information technology. Advances in satellite and mapping technology, ecological modeling, open data, and connectivity mean that global-level monitoring and planning systems that encourage sustainable aquaculture development may now be possible. Therefore, a platform integrating these technologies could help governments improve spatial planning and monitoring, help the industry plan for and demonstrate sustainability, and help civil society report success stories and hold industry and government accountable for wrongdoing.

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