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Characterization of Artisanal Fishing Harvest with Hook and Line in the Artificial Reefs Located in Isla del Tigre and Zacate Grande, Honduras

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Abstract

Commercial fisheries play a crucial role in food production and employment globally. However, overfishing has led to a decline in fish stocks, negatively affecting catch yields in open waters. This overfishing is not restricted to commercial fisheries but also applies to artisanal fisheries in the Gulf of Fonseca, Honduras. To support fisher communities, artificial reefs were stablished in the gulf area 4 years ago. Artisanal hook and line fishing on artificial reefs in Isla del Tigre and Zacate Grande were surveyed to assess the impacts of these reefs. In parallel, 40 fishermen were interviewed to evaluate their perception. The installation of artificial reefs has been positively received by anglers, after leading to an initial doubling in catch per unit effort. However, over time, there has been a decline in fish yield, with current yield well below pre reef catches. Three quarters of Fishermen however still overwhelmingly perceive reefs as positive and advocate creating more. It is recommended that conservation measures including no fish zones, minimum size restrictions, and seasonal closures be implemented before stocks are completely wiped out. Additionally, periodic monitoring of stocks and compliance is recommended.

Keywords: Catch yield, fish stocks, fishery sustainability

Resumen

La pesca comercial es vital para la producción de alimentos y el empleo en todo el mundo, pero la sobrepesca ha llevado a la disminución de poblaciones de peces, afectando negativamente las capturas en aguas abiertas. Esta problemática no solo afecta la pesca comercial, sino también la pesca artesanal en el Golfo de Fonseca, Honduras. Tomando en consideración la problemática recurrente del recurso pesquero se estableció el siguiente estudio. Se evaluó la pesca artesanal con anzuelo y línea en arrecifes artificiales ubicados en la Isla del Tigre y Zacate Grande para entender la situación pesquera de la zona. Paralelamente se realizaron 40 encuestas para conocer la percepción de los pescadores. La instalación de arrecifes artificiales fue bien recibida por los pescadores encuestados, inicialmente duplicando las capturas por esfuerzo. Sin embargo, con el tiempo, el rendimiento pesquero ha disminuido siendo mucho menor que antes de la instalación de los arrecifes. Aun así, la mayoría de los pescadores siguen considerando los arrecifes artificiales como algo positivo y abogan por más instalaciones. Se recomienda implementar medidas de conservación, como zonas de pesca prohibida, restricciones de tamaño y vedas estacionales, para evitar la desaparición total de las poblaciones. Además, se sugiere un monitoreo periódico de las poblaciones y el cumplimiento de las regulaciones.

Palabras clave: Comunidades de peces, rendimiento de captura, sostenibilidad de la pesca

Introduction

Commercial fishing is one of the most influential activities around the world, generating jobs and food globally. Over the years, catches in the open sea have declined due to the scarcity of fish stocks caused by over-fishing two influential sectors. The State of World Fisheries assessed by the Food and Agriculture Organization (FAO) compiled the tons per year of aquaculture and fishing activities worldwide. It showed how commercial fishing had a peak in the 1960s and then in the following years, the harvests of tons per year stabilized. At the beginning of the 80s and has been increasing ever since. Today aquaculture production has reached 180 million tons per year in inland and marine waters, matching tonnage harvested through commercial fishing (Food and Agriculture Organization of the United Nations [FAO], 2022). Currently due to the changes implemented by those organizations focused on creating a turn towards sustainable alternatives such as the United Nations, determined that unregulated commercial fishing degrades and causes a loss in habitat structure affecting the development of healthy fish populations. Over the past decade, the wider effects of overfishing on marine ecosystems have become a concern to scientists, fisheries managers, and the fishing industry with fish stocks in decline worldwide (Twibell et al., 2009).

Overfishing is not only affecting big commercial fisheries around the world, but it also affects other far more sustainable artisanal fisheries. The definition established by FAO decrees “traditional fisheries involving fishing households (as opposed to commercial companies), use of a relatively small amount of capital and energy, relatively small vessels, making short fishing trips close to shore, mainly for local consumption” (FAO, 2015). The classification between the different fishing scales takes into consideration the boat size (tonnes) and the technological investment, and the crew. A fisherman can be classified between artisanal, modern artisanal or semi-industrial, and industrial based on the technological investment on board and its capacity of harvest may vary between small-scale, intermediate, and large scales.

The negative effects of extensive fishing have left ecosystems essential for the proliferation of populations of many fish species vulnerable. Reefs are widely known to be diverse ecosystems filled with life and serve as a shelter for many marine species. New methodologies like artificial reefs have emerged to supplement natural available spaces. Artificial Reefs originated in Japan, while their use in the United States began in 1830 and subsequently spread to other parts of the world (Santamaría et al., 2019). The main use of Artificial Reefs includes the generation of new substrates for species settlement, feeding, breeding, and predator refuge (Becker et al., 2018).

Artificial reefs create new habitats to use biomass, boosting the abundance of biological resources (Leitão, 2013). The implementation of artificial reefs has two purposes, one being to create habitats that simulate optimal conditions for the reproduction and feeding of fish. These conservation methodologies such as artificial reefs are promoted to counteract the effects of extensive fishing or anthropogenic activities. The second purpose is to maintain a localized place where it is accessible for the fishermen to harvest and a place suitable for the fish to coexist (Carr & Hixon, 1995). The effects of artificial reefs may vary depending on the purpose for which it is desired to work. The artificial reef can either work with a conservation approach as mentioned above or it can work to maintain an optimal stock population of fish for the communities in the area. In addition to the help of the proliferation of fish for harvesting, the structures placed serve to avoid trawling with nets, protecting the ecosystems on the ocean floor. The site chosen for the artificial reefs must simulate the natural reefs to guarantee the adaptation of the fish to the structures (Bohnsack et al., 1994).

Agriculture and fishing, comprise 30.5% of the Honduran workforce (Ham. A, 2020). Honduras has 820 km of coastline between the Gulf of Fonseca (133 km) and the north coast conforming to the rest. Honduras estimates that some 21,250 artisanal fishermen live from this activity. Fishermen are distributed through inland waters (22%), waters in the Caribbean (26%), and the Gulf of Fonseca (52%) (Herrera et al., 2015). Fishing has a significant impact on the economy and development of the surrounding communities in Honduras. Nearly 50% of artisanal fisheries in Honduras are concentrated

in the Gulf of Fonseca (Rivero Rodríguez, 2021). The General Law of Fisheries and Aquaculture dictates that artisanal fishermen of basic classification must carry out their fishing activities three nautical miles away from a continental maritime beach or populated island, imposing a limitation on the area where fishing activities are allowed to be conducted.

According to Herrera et al. (2015), the total contribution of fishing to the food industry contributes 8,500 tons per year. Honduras, unlike its surrounding countries Nicaragua and El Salvador, does not have an industrial fleet in the Pacific for fishing activities due to unfavorable conditions for trawling and industrial fishing activities. Nicaragua, Honduras, and El Salvador share a 2,000 km^2 Gulf of Fonseca, (Medina, 2013). The Gulf serves as an important focal point for food security, encompassing 43 communities. The communities surrounding the golf harvest 4,090 metric tons of fish, crustaceans, and bivalves per year (Carranza, 2018). In addition, the south side of Honduras contains approximately 60 different species of fish that are of economic value (Carranza, 2018). It is important to mention that the communities that live surrounding the gulf depend solely on the services provided by the bay ecosystem (Carranza, 2018). These species are locally classified as white fish and red fish, with white fish comprising (33%) of the catch, which has relatively low commercial value for artisanal fishermen, currently 85 cents per kilo, and red fish fetching three times its value.

The following study focuses on the Gulf of Fonseca´s fishing management techniques, particularly in Honduras, El Salvador, and Nicaragua. Implementing viable solutions like artificial reefs was considered to be a potential solution to boost commercial fish populations. Taking in considerations this problematic in Isla del Tigre and Zacate Grande the following objectives were determined for this study: assess the perceptions of hook and line fishermen towards artificial reefs, characterize artisanal fishing harvest with hook and line in the artificial reefs, and assess the sustainability of artificial reef fisheries.

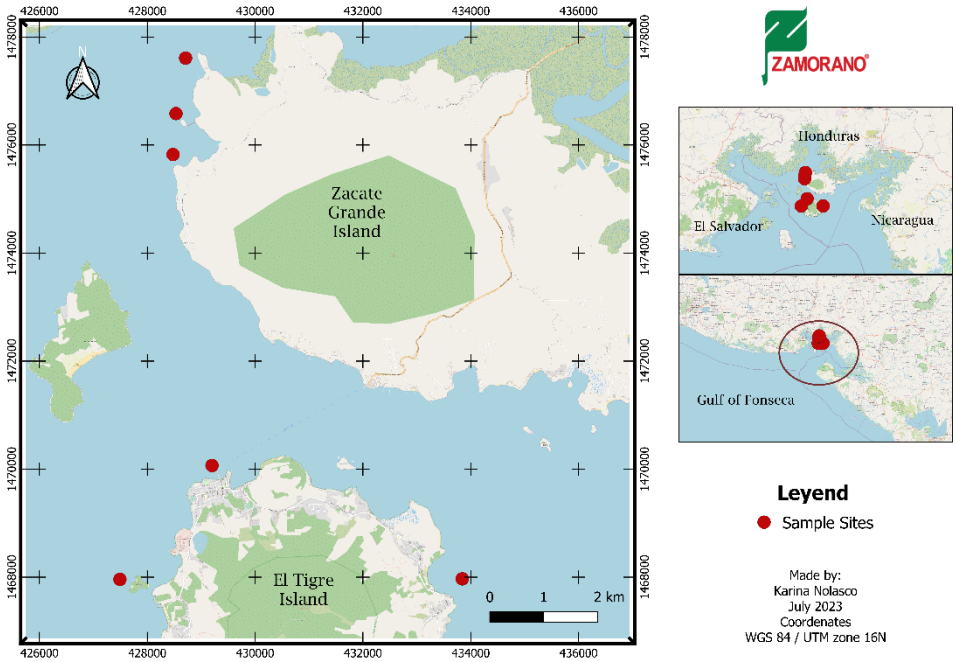
Methodology

Location of the Study

The study was carried out in the fishing communities around Isla del Tigre, located in the department of Valle, Honduras where artisanal fishing is one of the main subsistence activities. The Amapala region spans approximately 80 km^2 and consists of 13 villages and 64 hamlets, which are further divided between two islands: Isla del Tigre and Zacate Grande. The total population of the area is 13,586, with men accounting for 51.4% and women comprising 48.6% of the population (Instituto Nacional de Estadísticas [INE], 2023). The average annual temperature in these regions is 30 °C with maximum temperatures reaching around 34 – 35 °C and minimum temperatures ranging from 25 - 26 °C. The average annual humidity stands at 65% (World Bank Organization, 2021). The study focused on four fishing communities of a sector of the Isla del Tigre (Figure 1): Remolino, Punta Honda, La Flor, and Amapala. The communities selected were considered primarily engaged in fishing by the locals of the island, thus making them points of interest for the investigation.

Figure 1

Sampling points in El Tigre and Zacate Grande Island

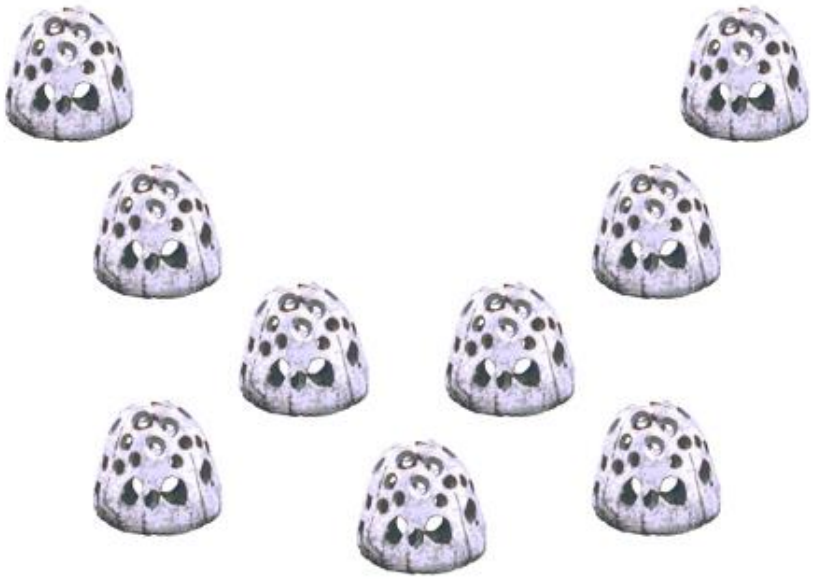


Reef Dome Installation

The study was carried out in partnership between CODDEFFAGOLF (“Comité para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca”), DIGEPESCA (“Dirección General de Pesca y Acuicultura”), “Fundación Chito y Nena Kafie”, and MiAmbiente, government entity responsible for uniting public and private efforts to care for the environment and natural resources. It's in charge of creating environmental policies and laws and ensures their proper implementation was also involved in the installation of 180 domes (artificial reefs) across 12 sites located around the Gulf of Fonseca. The artificial structures constructed for this purpose consist of concrete domes with multiple orifices. Designed to provide refuges. CODDEFFAGOLF established specific criteria for submerging the artificial reefs, including a recommended depth range of 5 - 15 m, a composition of 70% sand and 30% clay for the seabed, distance from the cost ranging between 100 - 300 m, and the presence of gentle currents (Figure 2). These criteria were considered during the installation process to ensure optimal conditions for the artificial reefs in Isla del Tigre.

Figure 2

Artificial reef design stated by CODDEFFAGOLF



Data Collection

When anchoring next to the canoes, a brief explanation was given to the anglers on what the study consisted of and how their participation was important to carry out the study. A survey was then conducted to all the fishermen present in the boat (Annex A). In most cases, there were one or two passengers engaged in fishing activities, assisting in the collection of both survey and harvest data. Participation was voluntary and a small percentage, approximately ten percent, declined to participate. It is important to note that during the second data collection trip, unfavorable tides hindered the completion of some *in-situ* surveys at the fishing sites. Consequently, alternative approaches were employed including interviewing anglers arriving at the beach or heading home where the anglers who frequent the artificial points were interviewed.

Perceptions of Artificial Reefs

The use of semi-structured surveys on Kobo Toolbsox to gather insight regarding the installation and functioning of artificial reef (Annex B). It allows the user to collect data through several options such as surveys applied in the field using mobile devices without the requirement of Wi-Fi. The primary interest behind commencing the application of the surveys was to ensure that the anglers were actively engaging in fishing within the Artificial Reef. The study population consisted of thirty-nine interviews with fishermen 33 men and six women. The surveys applied consisted of a series of closed answers where the possible answers of the respondents adapted to the answers presented in the survey. The questions are divided into two sections: The demographic section and the perception of the implementation of Artificial Reefs. There was a total of 40 surveys applied.

The data collection process for assessing the perspective on the installation of artificial reefs consisted of various variables. These variables included gender, the number of children the interviewee had, utilization of reefs for fishing activities, agreement regarding the installation of artificial reefs, the number of individuals per household, awareness of changes in harvesting in fishing sites, awareness of changes after the installation of artificial reefs, fishing trips per week, hours

dedicated to fishing activities per week, perception of the yield following the integration of artificial reefs, and economic activities.

Characterization of the Harvest in Artificial Reefs

Sampling was carried out *in situ* where the harvest was characterized by the following variables: time spent fishing to the nearest half hour, presence of artificial reefs, location, species, quantity of the species harvested, total catch rate per hour, maximum weight, minimum weight, value of the product, catch yield in lempiras. Data was recorded on a preprinted table. The data collection was conducted simultaneously with the application of the interviews, asking the fishermen about their harvest acquired in the period from the beginning of their workday until the moment they were being interviewed. Once the general data was recorded, such as the species that had been harvested, the time the fisherman had spent in the activity, the site where they were currently fishing, and their perception towards the use of artificial reefs; the entire harvest was then quantified to determine the pounds per hour that were being caught per angler. In most cases, the catch in a boat was shared and an equal portion was attributed to each fisher. Additionally, the data collected in the field, data of recent historical catch per unit effort by the installation of reefs and just after reefs were installed was provided by the organization with which we collaborated to carry out this research, CODEFAGOLF. The data collection was done by replicating the sample size and variables collected in the previous study.

Sustainability of Artificial Reefs

To assess the sustainability of artisanal fishing practices at the artificial reef installation the use of tables containing the variables of the study were utilized to arrange the data. The catch information provided by CODDEFFAGOLF, dated December 2019, and data provided for the year 2017, the harvest of various reef sites that were taken just before and after the installation of the reefs. Two of the sites evaluated by CODDEFFAGOLF previously were Caracol and Amapala, this data serves as a baseline for assessing changes in the resource.

Statistical Analysis

The study population involved the participation of 39 fishermen. Analyzing the study´s data, descriptive statistics were employed to calculate the mean values obtained from both the harvest data and the interview responses with a confidence level of 95%. Furthermore, a chi-square analysis was conducted to examine the relations between variables, including the utilization of artificial reefs, changes in fishing, artificial reef installation, artificial reef installation sites, and time spent fishing.

Results and Discussion

Perceptions of Artificial Reefs

The participants engaged in artisanal fishing activities spanned an age range of 40 years old with a minimum age of 20. Remarkably, one individual, at the age of 93, continued practicing artisanal fishing to sustain his family´s livelihood. Furthermore, out of the interviewees, 29 individuals revealed that they were parents, with an average of three children per participant. Additionally, it was observed that, on average, two members of the fisher's families were actively involved in artisanal fishing. Based on the data collected, it can be inferred the extent to which fishermen rely on fishing activities as their primary source of income. In the survey conducted, approximately 70% of the respondents indicated that they derived financial support for purchasing, school supplies, groceries, and additional household necessities through the earnings of the fish sales. Furthermore, this reliance on fishing for subsistence extended to the family members of the surveyed fishermen, who also depended on fishing to sustain their households.

Regarding gender, out of the 38 participants, six of the participants were women who were accompanying their partner in daily fishing activities. This significant participation of women is unusual among fishing communities. The remaining 32 participants were men who had been involved in fishing since the ages of 6 - 7. During informal conversation it was noted that most of the communities worked in fishing activities and even involved the company of children during fishing trips. Women played a role of company as well during long fishing trips.

Respondents were asked about the number of people living in their households to analyze the dependency on artisanal fishing for their livelihood. It was observed that 94.7% of the respondents lived with more than two people in their homes, while the remaining 5.3% reported having fewer than two people residing with them. During the survey administration, in an informal conversation with the fishermen, it was frequently mentioned that it is common to encounter young families with parents

under 20 years of age, who begin their families with three members and rely on fishing as their primary means of economic support.

The utilization of artificial reefs was considered a crucial variable in the study. Out of the 38 respondents, 92% actively utilized these integrated artificial reef points. Conversely, 7.9% of the interviewed population did not make use of artificial reefs. Fishermen who frequented the artificial reef sites expressed that visiting these locations was more advantageous and practical for them compared to undertaking long journeys in search of fishing spots. In the studies conducted by CODDEFFAGOLF in 2017, it was noted during informal conversations between fishermen and surveyors that visiting the artificial reef points was perceived as advantageous by the fishermen. This preference stemmed from the convenient proximity of the artificial reef installations to their communities.

Agreement on Artificial Reef Installation

Furthermore, to determine whether respondents utilized artificial reefs, understanding their agreement with the installation of these technologies was also crucial for the study. It was observed that 34 (89.5%) of the interviewees agreed with the installation of the reefs. Conversely, four 10.5% of the respondents did not agree with the implementation of artificial reefs. The inclination towards utilizing artificial reefs among artisanal fishermen can be attributed to their recognition of these structures as focal points for fish aggregation. However, during informal conversation accompanying the surveys, three respondents 7.9% who mentioned not using artificial reefs expressed their reluctance to frequent these areas due to overcrowding, which hampers their ability to effectively harvest the resource. There exists perceived competition between artisanal fishermen and those utilizing alternative fishing technologies such as gillnet fishing.

Duration of Fishing Trips

In response to the high demand and necessity of fishery resources in the region, quantifying the number of weekly fishing trips was crucial for generating a panorama to ensure sustainable

extraction within the area of artificial reefs. It was observed that 97.4% of the participants engaged in fishing activities at the artificial reefs. The majority of fishermen mentioned that it was customary for them to spend seven days a week, securing sustenance for their families for personal consumption or selling purposes. The responses obtained through the surveys and informal conversations consistently revealed that the fishermen´s capture hours, as mentioned before, typically lasted for shifts of 4 hours or more. This finding aligns with the data presented in CODDEFFAGOLF´s previous reports, which indicate that the fishermen´s daily fishing hours have remained unchanged for the past 6 years. The remaining 2.6% went fishing twice a week in the location of the artificial reefs.

Additionally, to the fishing trips per week, it was deemed necessary to inquire about the duration of fishing trips per day (Table 1). It was noted that 81.6% of the fishermen spent more than 4 hours per day engaged in fishing activities. Conversely, 13.2% of the surveyed population mention dedicating approximately 3 hours per day to fishing. It is worth noting, during this segment of data collection, approximately 60% of the respondents highlighted their experience of spending hours waiting for a significant catch on days when harvest productivity was low. This waiting period aimed to accumulate a substantial quantity of fish for commercial purposes or subsistence.

Table 1

Duration of fishing trips

Allocated hours on fishing (hr)	Frequency	Percentage (%)
2	1	2.6
3	5	13.2
4	1	2.6
More than 4	31	81.6

Economic Implications (Debts and Loans) Related to Fishing Activities

Gaining insight into the overall structure of fishermen´s lives provided a perspective on the significance of the fishing resource for these families, as it serves as their primary source of subsistence and income. As part of the harvest characterization, inquiries were made regarding how fishing productivity impacted the fishermen´s way of living. In terms of loans or debts associated with fishing

activities, 86% of the participants reported having neither debts nor loans. Conversely, 5.3% of the fishermen stated that they had loans or debts linked to fishing activities.

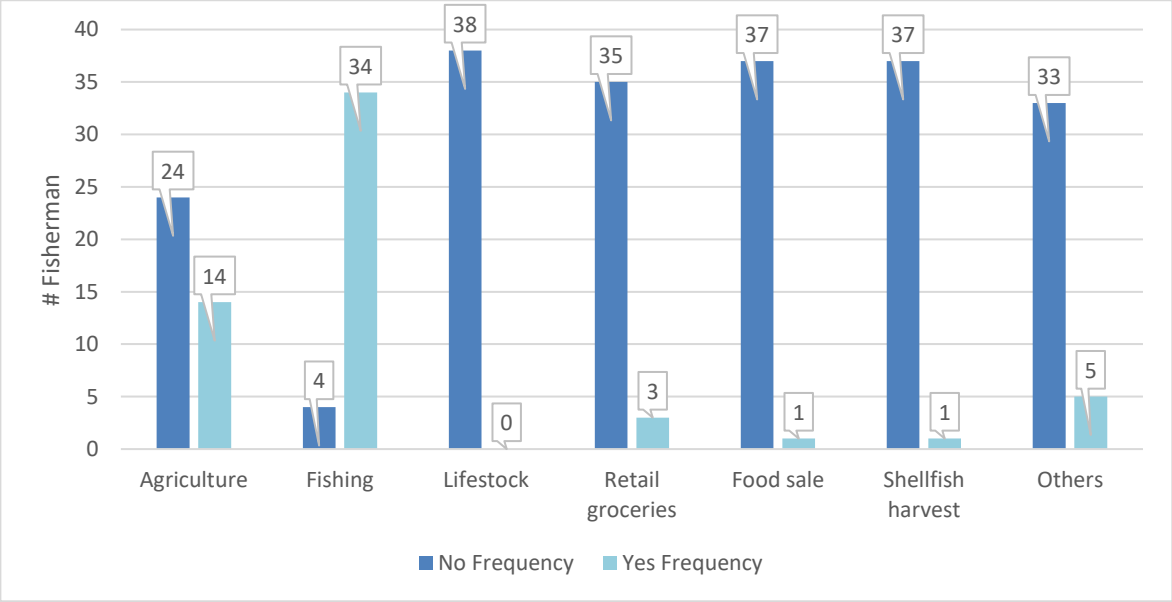
As for the availability of fishing funds among the surveyed fishermen, it was observed that 52.6% of the participants had such funds. The fishermen highlighted how these funds were utilized to cover various expenses, including canoe maintenance, bait, fishing line, and other necessary supplies. On the other hand, 39.5% of the fishermen stated that they did not have any funds specifically utilized for fishing activities.

Economic Activities

To gain insight into the fishermen´s environment and their daily lives it is crucial to understand the various economic activities they are engaged in and if they are significant alongside the fishery resource. Hence, an analysis of additional economic activities in which the respondents are involved was conducted. These activities included agriculture, fishing, livestock, and retail of groceries (pulperias) (Figure 3**Error! Reference source not found.**). Fishing emerged as the primary economic activity 89.47%. Agriculture came in a distant second with 36.84%. It is noteworthy that fishermen who relied on agriculture as a secondary source of income mentioned challenges associated with engaging in agriculture in the region., including water shortages, prolonged droughts, and the maintenance required for crops. Other economic activities, such as food sales, livestock, and shellfish harvest, had lower participation rates ranging from 2.63% to 7.89%. Additionally, 13.16% of the surveyed population partook in unlisted activities, including construction work in the surrounding areas.

Figure 3

Economic activities conducted by the fishermen



Perception of Changes in Harvest Quantity Following the Integration of Artificial Reefs

Regarding the assessment of harvest changes following the installation of artificial reefs, the fishermen were asked whether they observed an increase, whether the harvest has remained the same, or a decrease in their harvest after the integration of this technology in the fishing grounds. The result revealed that 73.7% of the participants reported an increase in their harvest (Table 2). Conversely, 15.8% stated that their harvest remained the same. However, 10.2% of the surveyed population mentioned a decrease in their harvest. Based on the collected CPUE data (Catch per Unit Effort), it is shown that the harvests increased after the installation of the reefs, aligning with the fishermen´s perception.

Table 2

Perception of changes in harvest quantity following the integration of artificial reefs

Quantity of the harvest	Frequency	Percentage (%)
Increased	28	73.7
Decreased	4	10.5
Stayed the same	6	15.8

Relation Between Variables Regarding Reef Perception

In addition to the descriptive analysis of the qualitative variables conducted using survey responses, the relationship between the perception variables was analyzed by a chi-square analysis. The statistical method aimed to investigate the relationship between certain variables within the study. When relating the variables of the utilization of artificial reefs and changes in fishing since the integration of artificial reefs, a significant relationship was observed ($P < 0.05$). Similarly, the variables of artificial reef utilization and changes over the quantity and frequency of capture through the years showed a significant relationship ($P < 0.05$).

Likewise, a significant relationship ($P < 0.05$) was observed between the change in the harvest with the use of fishing points with artificial reed integrated and the utilization of artificial reefs. However, no significant relationship ($P > 0.05$) was found between the variable of utilization of artificial reefs and the time spent per day on fishing activities. The analysis of the variables reveals a clear relation between the utilization of artificial reefs and changes in fishing activity. Despite the perception of fishermen indicating abundance in the reef areas, the collected data reveals consistently low weights for harvested catches, ranging from 1 pound to a maximum of 2.13 pounds on the recent data collected. These findings suggest that the resource in the area is severely depleted, and fishing in the artificial reef zone creates a misleading perception of resource stability. This statement can be further supported by the average catch per hour recorded by CODDEFFAGOLF´s sampling in 2017 and 2019 before and after the installation of the artificial reefs.

A relationship was identified between the utilization of artificial reef sites and changes in the harvest at the reef. By considering the harvest data collected y CODDEFFAGOLF before the reef installations, it can provide insight into the pre-existing harvest conditions in the area. It was observed that the average catch was 2.8 pounds per hour. With the introduction of artificial reefs, fishermen have reported and experienced an initial doubling in their harvest.

Disputes Concerning Fishing Resources

Based on the survey's responses and informal conversations with hook fishermen, it has been noted that older members of the artisanal fishing community identify that the harvest have changed throughout the years. They saw how the artificial reefs have gathered the fishing resource in the fishing spots but the weight and quantity that is being extracted doesn't compare with the individuals they were capturing 10 - 15 years ago. They also recognize that the quantity and quality of their harvests do not compare to the early years following the installation of artificial reefs. One explanation provided by the hook fishermen is the presence of net fishermen. Artisanal fishermen who utilize hook extraction methods state that they have been adversely affected by the overexploitation caused by net fishermen. Additionally, hook and line fishermen state that nets often become entangled in the structures of the artificial reefs, which may be resulting in the destruction of organic matter that attract fish to the reefs.

While the hook fishermen acknowledge that using nets enables collective extraction and may potentially increase fish yield, the varying weights in the harvests at different artificial reef sites they state that this could be one of the factors contributing to overexploitation. The combinations of factors, such as harvesting techniques and the quantities being extracted, along with the inappropriate use of the structures, can lead to the overexploitation and depletion of fish stocks. When fishing pressure on the artificial structures fails to effectively generate biomass and only concentrates it in a point, it can lead to the rapid overexploitation of the resource (Delgadillo-Garzón & García, 2009). The harvested individuals weighed between 0.25 to 2 pounds, indicating that they are juveniles and are not reaching maturity cutting off the reproduction cycle of the future populations of fish in the area.

Overexploitation in Artificial Reef Sites

The fishing resource on Isla del Tigre plays a vital role in the socioeconomic development of the neighboring communities. The data gathered throughout this study has provided a broader

understanding of the current state of the fishery resource. The collected data presents compelling evidence of overexploitation at the artificial reef sites. Two key indicators support this claim: the decline in weights and sizes of the harvested species, with juveniles weighing around 1.2 pounds being caught, and the CPUE data demonstrates that fishermen have consistently engaged in 4 - 5 hours of fishing per day through the years 2017, 2019, and 2023 while harvesting fewer fish.

Additionally, these reduced weights are unfavorable for a community that depends on the quality of the harvest. Overexploitation of juvenile fish can affect in the future fishing stocks in the near future. Similarly, the study of Lapinski et al. (2014) examined the impact of artificial reefs deployment on biomass enhancement. Their findings revealed a noteworthy potential for increased extraction of juveniles from specific areas within the area of artificial reefs, compared to non-reef reference sites.

Artificial reefs appear to function as a gathering area for various species within the gulf, benefiting anglers but potentially disturbing population equilibrium. Bohnsack et al. (1994) stated that the increase in biomass in artificial reef sites could be an attribution to fish aggregation rather than enhanced production.

Characterization of Fish Harvested in Areas within the Reef Area

Data collection was carried out with a total of 23 fishermen, 21 of 23 fishermen were interviewed within the sites of artificial reefs. Apart from two individuals targeted areas outside the reef area. Fishermen shared the perception that the artificial reef zones harbor a greater fish population. Furthermore, the artisanal fishermen who use hook and line in collaboration with CODDEFFAGOLF, agree that the artificial reef structures are specifically intended for handlines.

Regarding fishing days in artificial reefs, the majority of fishermen 65.2% fish once daily. The remaining is divided into seven fishermen 30.4% who conduct two expeditions per day, and one went out five times a day. It is worth noting that the fishermen gave an estimation of the number of fishing trips they would undertake in a day under favorable fishing conditions, such as good tides, lunar phase

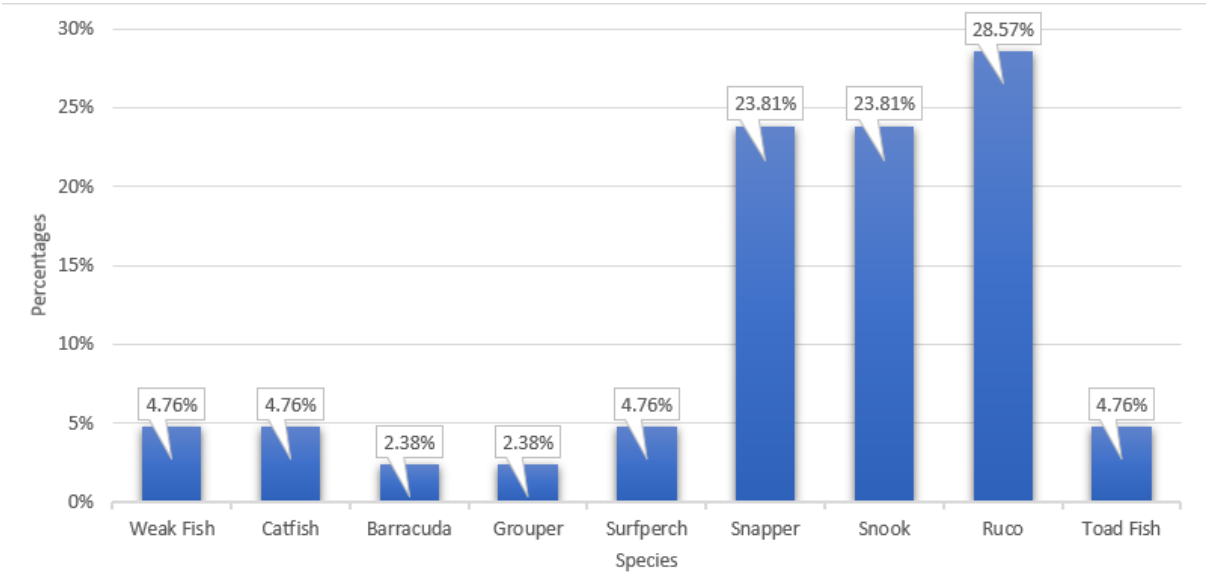
and weather. Informal conversations with the respondents emphasized that most of the fishermen engaged in fishing activities once a day due to various factors such as household responsibilities, other employment commitments, or the need to distribute their products to sale points.

Within the fishing points, the objective was to identify the presence of different commercially valuable species. These includes, “Weak Fish” (*Cynoscion phoxocephalus*), (Annex C),“Catfish” *(Ariopsis spp.*), “Barracuda” (S*phyraen*a *ensis*), “Grouper” (*Epinephelus spp.*), “Surfperch” (*Eugerres axillaris*), “Snapper” (*Lutjanus argentiventris*) (Annex D), “Snook” (*Centropomus spp.*) (Annex E), “Grunt” (*Pomadasys macracanthus*) and “Toad fish” were found (**Error! Reference source not found.**4).

Snapper, Snook, and Grunt were the most caught species. Snapper accounted for 23.8%, while Snook (Annex D) accounted for 23.8%. Likewise, Grunt were common across the different fishing points, conforming a 28.8%. The frequency of Grunts is also demonstrated in the studies conducted by CODDEFFAGOLF since the characterization of the harvest done previously demonstrates a significant number of individuals compared to the other species captured in the sites. The other species identified such as Weak Fish, Catfish, Barracuda, Grouper, Surfperch, and Toad Fish, reflected a lower percentage ranging from 2.4 to 4.8%, reflecting a reduced occurrence during the data collection.

Figure 4

Frequency of species throughout the harvests



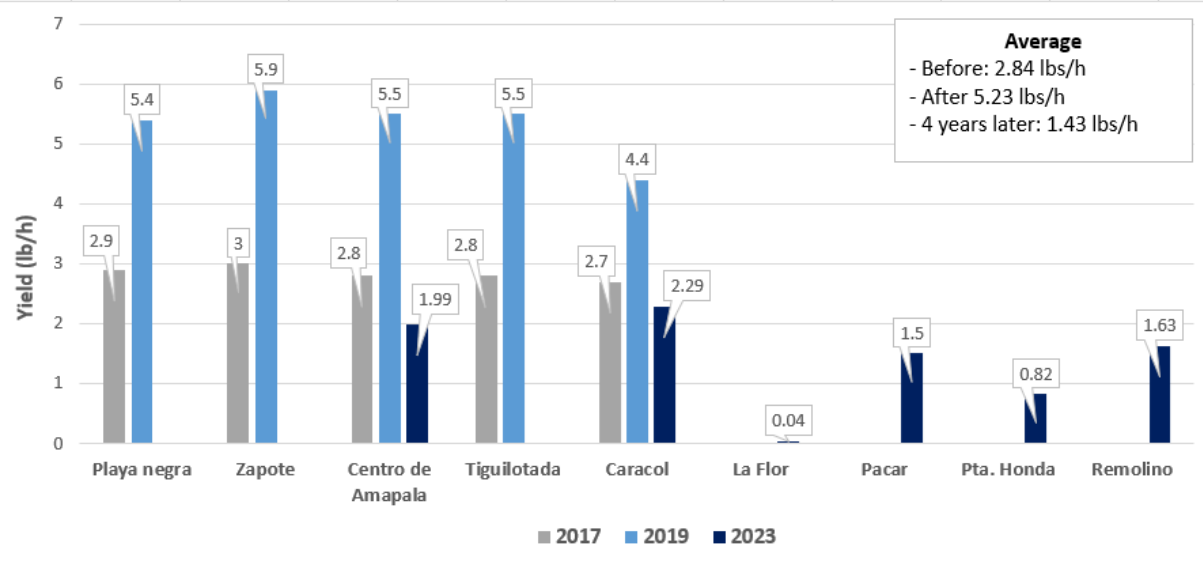
The following variables: catch hour, total weight (lbs), total hourly catch yield (lbs/hr), maximum weight, and minimum weight, were determined to estimate the catch per unit effort within the dome placement zones. The anglers conducted their fishing activity for an average of 4.39 hours of fishing per trip. Additionally, the total weight (lbs) harvested per fishermen averaged 5.6 lbs. Furthermore, the total catch yield per hour was calculated by relating the weight of the catch to the fishermen´s hour of work, obtaining an average of 1.43 lbs/hr. In relation to the information above, it was observed that the individuals characterized from the different harvests had a mean regarding the maximum and minimum catch weight of 2.14 and 0.98.

These findings demonstrate congruency in the patterns of fishing productivity among the fishermen and the catch per unit effort among sites and sampling dates. During the visits to the sites, Amapala and Caracol coincided with the locations evaluated by CODDEFFAGOLF in 2017 and 2019, where data such as CPUE (catch per unit effort), catch yield (lbs/hr) were presented. The average values recorded by CODDEFFAGOLF before and after the installation of the reefs in Amapala were 2.8 lbs and 5 lbs/h, respectively. Similarly, in Caracol, the recorded yield values were 2.7 lbs/hr before and

4.4 lbs/hr after. However, in the data collected in 2023, lower yields of 1.3 lbs/hr in Amapala and 2.29 lbs/hr in Caracol were observed (Figure ***5***5).

Figure 5

Yield values in fishing zones through the span of 2017, 2019 and 2023



It should be emphasized that before the installation of the reefs, there was a low average catch of 2.84 lbs/h in the areas where the reefs were intended to be placed (Table 3). However, after the installation of the reefs, there was a doubling in the catch with a yield of 5.3 lbs/h. This suggests that the reefs facilitate the aggregation of fish populations from the surrounding areas, making them more accessible for fishermen and leading to an improvement in their average harvest. Nevertheless, there are concerns about the decline in the overall resource and dramatic overexploitation with potential for total collapse of the fishery. This is evident from the presently documented decrease in catches per hour, showing a yield of 1.43 lbs/h, which is lower than the rates observed during the initial years of reef installation and even lower than the percentages before the reefs were installed.

Table 3

Differences on yields through the years 2017,2019, 2023

Installation Time	Mean	E. E	
At installation	5.34	0.27	A
Before installation	2.84	0.27	B
4 years after	1.38	0.25	C

Based on the data collected from the harvest per fisherman, variables were identified to estimate the commercial value and the profit that the harvested product represents for each fisherman. The variables considered were the independent value of the product (HNL), catch yield (HNL), and total profit (HNL). The independent value of the product indicated that the individual catch´s value fluctuated around the commercial value of HNL 37.54 (Table 4). In addition, the total harvest captured by each fisherman resulted in an average gross income of HNL 210 per outing based on the pounds harvested. These findings demonstrate congruency in the estimation of commercial value and the profit based on the harvested product, highlighting the economic significance of the fishing activities for each fisherman. Regarding the previous variables mentioned, the four variables associated with harvest exhibit a significantly low standard deviation. Most of the data points are tightly clustered around the average, demonstrating minimal dispersion and a high level of consistency.

Table 4

Fishing Efficiency

Fishing efficiency indicators	Mean
Catch hour	4.4
Total weight	5.6
Total catch yield	1.4
Maximum weight	2.1
Minimum weight	1.0
Independent product value	37.5
Catch yield	210.9

Regarding the yield of the captured species in Lempiras, the harvest containing Weak Fish (*Scianiadae*) demonstrated the highest value overall the total harvests with an average of HNL 385 (Table 5). Despite the small sample size of only two individuals captured, a notable disparity in economic gains was evident between low-income species such as grunts. This finding suggests that if the populations of Weak Fish were in a healthy state, fishermen would have the opportunity to capture more appropriate individuals, resulting in higher gross incomes.

The second species that exhibited a significant commercial value was the Snook, averaging HNL 360. A total of nine individuals were captured through the artificial reefs. On the other hand, the species with the highest presence of individuals in the different harvests was the Grunt, totaling 12 individuals. Grunt yielded HNL 128.17 in the harvest of various artisanal fishermen. It is noteworthy that, similar to Snook; the Snapper species consisted of nine individuals, indicating its common occurrence in fishing sites in the data collected. Nevertheless, it only summed up to an average yield of HNL 175.06 in terms of value. The other species found in the fishing sites such as Grouper and Barracuda, were represented by only one individual each in the total harvests, resulting in a low yield of HNL 13.00 and 35.00, respectively. This information proves an insight into the commercial value reflected by the species being harvested in the local market. Prices are determined by pounds and the specific species being acquired, meaning that a species may have good commercial value, but if it Is being harvested at an unfavorable weight, the fisherman won't be obtaining the true value they would gain with an individual at an ideal weight for sale.

Table 5

Yield of capture per species valued in HNL.

Species	Mean	Price per pound (HNL)
Babosa	385	35
Catfish	Nd	Nd
Barracuda	35	35
Grouper	13	50
Mojarra	Nd	Nd
Snapper	175.06	50
Snook	360	50
Grunt	128.17	18
Saponiche	Nd	Nd

Conclusions

Most fishermen agreed with the installation of artificial reefs, with 35 fishermen (92%) actively utilizing them. Most fishermen (73.2%) perceive a significant increase in their harvest at the reef sites. However, the present data shows that the initial increase was not sustained, and current catch levels fall below pre-installation levels.

The data collected from CODDEFFAGOLF's previous monitoring showed an increase in catches during the initial months of artificial reef installation. The fish being harvested during this study were predominantly “juveniles” that have not reached reproductive maturity.

Based on the comparison of yields from 2017 (before installation), 2019 (during installation), and 2023 (4 years after installation), it can be concluded that the reefs helped concentrate the fishing resource in specific points, making extraction easier and increasing fishing yields. However, there has been no regeneration of the resource, resulting in present average yields significantly lower than those observed before installation of the reefs.

Recommendations

Establish designated no-fishing zones or safe havens where entry is prohibited to achieve the growth and replenishment of fish stock. By implementing these protected areas, it can provide a conducive environment for the future development and sustainability of fish populations.

Implement closed seasons during spawning season for commercially valuable fish such as Weak Fish, Grouper, Snapper, Grunt and Sea Bass and restrict the harvest to a minimum size depending on the species to ensure a balanced extraction and recovery of the resource.

Socialize the findings of this study, along with the results obtained by CODDEFFAGOLF, to raise awareness about the overexploitation of the fishing resource and promote the proper utilization of the reef zone.

Implement biannual monitoring and sampling protocols to ensure proper resource use, considering the extracted quantities and the potential for regeneration.

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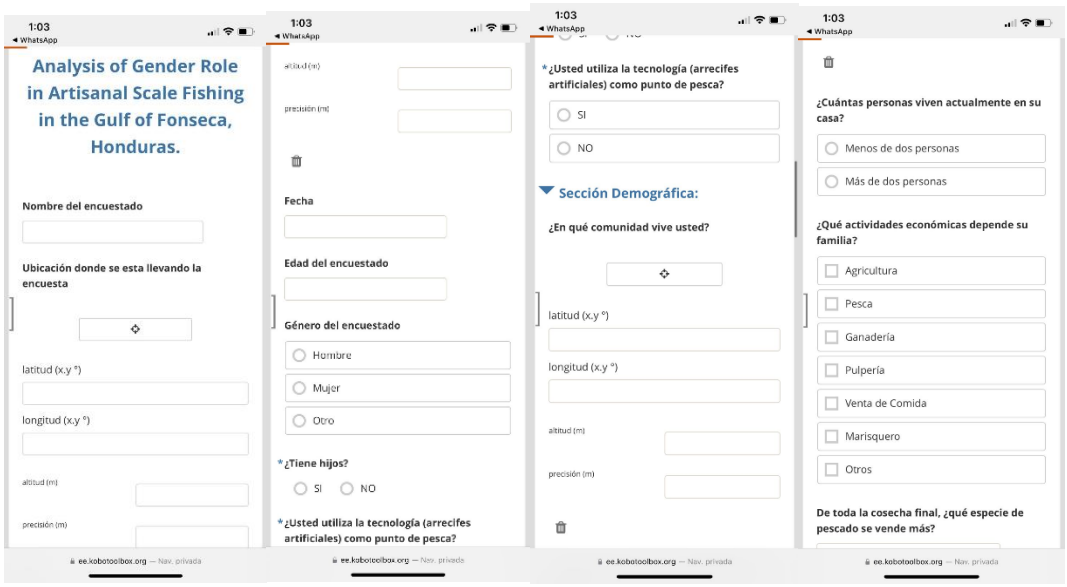
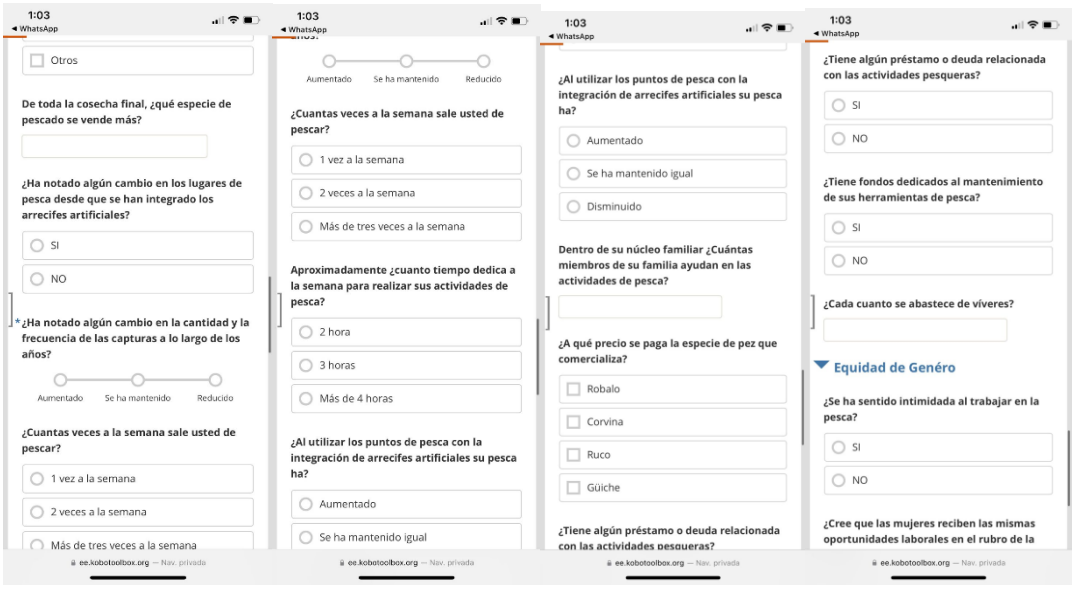
Annexes

Annex A

The survey made to fisherman





Annex B

Fishfolk preparing bait for her fishing trip

Annex C

Weak Fish (Cynoscion phoxocephalus)

Annex D

Red Snapper (Lutjanus argentiventris)

Annex E

Snook (Centropomus spp.)