DOI: 10.31398/tpjf/28.2.2020-0005

RESEARCH ARTICLE

# Efficient Fishing Method to Control the Population of Rice Eel, *Monopterus albus* (Synbranchidae) in Rice Fields in Cagayan Valley, Philippines

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ABSTRACT

Rice eel (*Monopterus albus*) was introduced in the Philippines in 1905 as an aquaculture species without a thorough evaluation of its possible negative impact on the environment. In Cagayan Valley Region, it is being considered as a pest due to the economic loss it brought to farmers as it bore holes on the dikes, draining the water from the rice field, thus, contributing to the additional expense of the farmers. However, from the economic point of view, the species offered great potential as an export commodity due to its broad export market in East Asian countries. Hence, this study was conducted to determine the most efficient and effective method of controlling the proliferation of rice eel in rice fields in the Cagayan Valley region while preserving its integrity as an export commodity. Twelve (12) municipalities were chosen as the study sites based on validated reports of the high occurrence of rice eel. Three fishing methods, namely, fish trap (FT), hook and line (HL), and electrofishing (EF) gadget, were utilized. These gears were set during the dry and wet seasons. Catch and catch per unit effort (CPUE) were used to determine gear efficiency, while monetary values, net income, and ROI were used to assess the profitability of the gears. Results showed that electrofishing gadgets exhibit greater efficiency among the three fishing gears. The EF gadget also has the highest CPUE (4 individuals) per hour while only around 0–1 per hour for FT and HL. Seasonality does not affect the efficiency of the three fishing gears. Also, there is no significant interaction between seasons and fishing gears ($p = 0.525$). Computed annual net income and return on investment (ROI) is also greater using EF (PHP 407,630.40/ha/year with 569% ROI) compared to HL and FT (net incomes of PHP 113,244.68/ha/year and PHP 161,618.99/ha/year, and 261% and 309% ROI, respectively). However, the use of EF as a control measure should entail restrictions such that only within rice farm areas and not in open waters and only after harvest or before planting with issued EF licenses and permits from BFAR and local ordinances. Higher penalties should also be imposed for illegal use of EF such as use in open waters. As an alternative to EF, a combination of FT and HL with modifications or more environment-friendly fishing gears can be explored to catch and control the rice eel population.

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Received: *March 17, 2020*
Accepted*: October 4, 2021*

**Keywords:** *rice eel, electro-fishing gadgets, hook and line, fish trap, efficiency, catch per unit effort*

## 1. INTRODUCTION

Rice paddy eel, (*Monopterus albus*), locally known as “kiwet,” belongs to the family Synbranchidae. It exhibits protogynous hermaphroditic reproductive behavior. It undergoes natural sex reversal from female to male via intersex – a process accompanied by extensive morphological and physiological changes of the gonad (Zhou et al. 2003; He et al. 2010). All individuals are born and mature as females and sometime later transform into males (Shafland et al. 2010). Due to this characteristic, rice eel can increase its population in a short period. *M. albus* is a nocturnal feeder. It usually feeds on frogs, shrimps and small fish, and water loss is experienced as it creates holes into the paddies' bunds at night (Lazaro 2013; Valencia 2013 in Guerrero 2014). This affects the nutrient and weed management in rice fields.

Rice eel was introduced in the Philippines for aquaculture in 1905 without considering its impact on the environment; thus, it has become invasive (Juliano et al. 1989; Guerrero 2014). Its invasiveness has been manifested in the damages and economic loss it has inflicted in rice farming in the region (BFAR R02 2017). Reports of implicated damages are on the holes it dug on the dikes causing the draining of water resulting in additional costs of irrigating the rice fields. Plant strands are also damaged in some areas since they feed on golden apple snail (*Pomacea canaliculata*) attached to rice stalk. Additional costs on irrigation and replanting are incurred. It was reported to feed on cultured fish in fishponds, thus decreasing stock population (BFAR R02 2017).

Despite the negative impacts of *M. albus*' invasiveness in rice areas in the Cagayan Valley (Region 02), the fish has positively contributed to the Philippine economy. In the first semester of 2013, rice eel's contribution to the country's export was PHP 517 million. Fishers earn a livelihood from collection, consolidation, and trading. The fish is sold in local and international markets in Singapore, China, Japan, Taiwan, and other Asian countries (Domingo 2013) and is seen to continuously provide economic opportunities for the fisherfolk (Business World 2013). In 2015, the global production of *M. albus* reached 738,380 MT valued at USD 6.87 billion (USD 9.31/kg), with China as the top producing country with over 367,550 MT valued at USD 3.42 billion (Tridge n.d.).

Although there is confusion on reporting of production data from the Philippine Statistics Authority (PSA), the official data provider of the Philippines, with production being combined with other eel species, in 2019, around 750.61 MT eel production was reported in Region 02 and around 1,564.45 MT in the Philippines (Philippine Statistics Authority 2020).

Since rice is the country's staple food and millions of Filipinos are dependent on it for living and livelihood, efforts should be undertaken to control the population of rice eel while preserving its integrity as an export commodity. Thus, there is a need to effectively manage the rice eel resources, enhance its economic potentials, and minimize its adverse impacts on rice and fish farmers. Hence, a scientific study to determine the efficiency and effectiveness of different fishing gears used to collect *M. albus* is necessary for appropriate policy recommendations and maximizing the species' potentials.

The general objective is to determine the most effective and efficient fishing method to control the rice eel population and recommend appropriate management and maximum utilization as a livelihood opportunity for the fisherfolk. Specific objectives are to 1) determine the efficiency of the three types of gears (fish trap, hook and line, and electrofishing gadgets) in terms of catch per unit effort and profit and 2) compare the efficiency of fishing gears in terms of CPUE and profit in relation to the season.

## 2. MATERIALS AND METHODS

### 2.1 Study Sites

The experimental fishing trial was conducted in 12 municipalities of the four provinces of Cagayan Valley (Region 02), namely, Alcala, Amulung, and Solana in Cagayan; Cauayan City, San Isidro, and Alicia in Isabela; Maddela, Diffun, and Cabarroguis in Quirino; Solano, Bagabag, and Quezon in Nueva Vizcaya. These municipalities were selected based on validated reports of the high occurrence of *M. albus* in said areas (BFAR R02 2017) (Figure 1). In each municipality, three rice compartments with an area of 500 $m^2$ were selected as experimental areas (EA). These rice farms are accessible and irrigated, with a less than 15 cm water level. It is also located in areas with a high incidence of rice eel infestation.

### 2.2 Experimental Design

The three fishing gears (FT, HL, and EF) were the variables tested. Replication was done over the site. The four provinces were considered as the replication area (RA). Three (3) municipalities were chosen as sub-sample areas (SSA) in each RA. In each SSA, three rice compartments were used as EA to test the three variables using Completely Randomized Design (CRD).

On each EA, 18 collection points (0.5 $m^2$) with 5-meter intervals were assigned. FT and HL were installed one hour before the collection time in all the collection points of the rice compartment. Collection time for all fishing gears was one hour, usually from 7 PM to 8 PM. EF was moved and operated in each collecting point during the one-hour collection period. There was no repetition of operation of the gadget in the collection points during the collection period. The researcher installed and operated the fishing gears in the collecting points with the help of the agricultural technician for fisheries and the farmer. Collection of *M. albus* using the three fishing gears was done simultaneously at every point in rice paddies. The collection was done either during

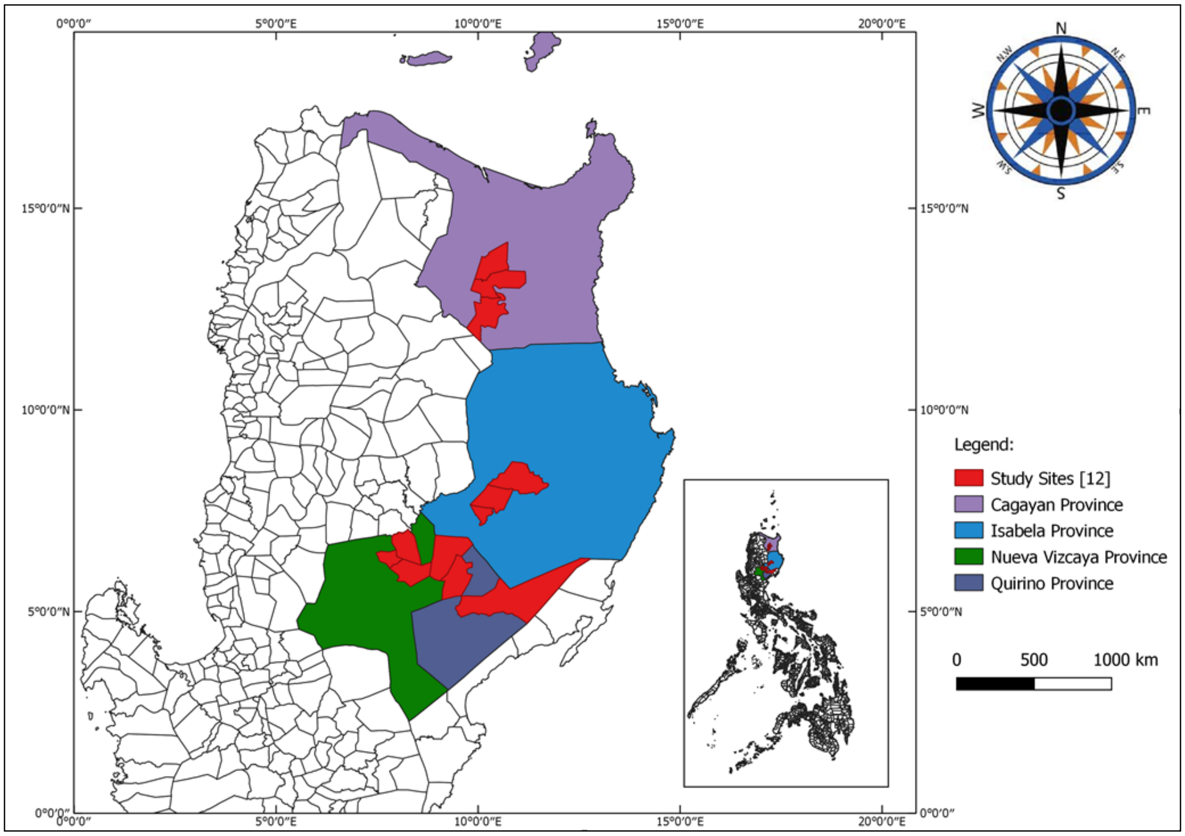


Figure 1. Location map of the study area

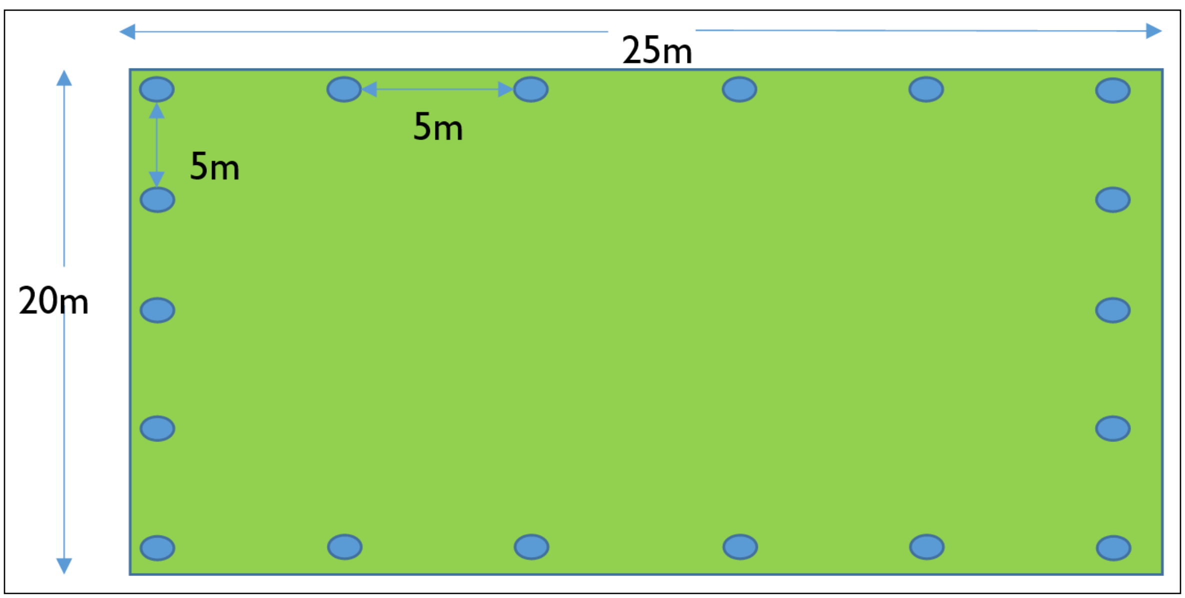


Figure 2. Experimental design lay-out for collecting *Monopterus albus*. The dots are the area where the fishing gears were laid, having a distance of 5 m away from each other.


Figure 3. Tarpaulin used in Alicia, Isabela as well as in other study areas

the vegetative stage of rice, which occurs 15 to 30 days after transplanting or after rice harvesting. Collected *M. albus* were labeled, and growth factors such as length, width, and weight of the fish were recorded every sampling. Sampling was done eight times per cropping season for two seasons in a year using the following experimental layout (Table 1).

Table 1. Experimental layout on the assessment of the efficiency of fishing gears used to catch *Monopterus albus.*

| Study site | Replication | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 | EF[1] | FT[1] | HL[1] |
| 2 | EF[2] | HL[2] | FT[2] |
| 3 | FT[3] | HL[3] | EF[3] |
| 4 | EF[4] | FT[4] | HL[4] |
| 5 | EF[5] | FT[5] | HL[5] |
| 6 | HL[6] | FT[6] | EF[6] |
| 7 | HL[7] | FT[7] | EF[7] |
| 8 | HL[8] | EF[8] | FT[8] |
| 9 | HL[9] | EF[9] | FT[9] |
| 10 | HL[10] | FT[10] | EF[10] |
| 11 | FT[11] | HL[11] | EF[11] |
| 12 | FT[12] | EF[12] | HL[12] |

Note: Complete Randomized Design (CRD) where: *EF = Electro Fishing Gadget; FT = Fish Trap; HL= Hook and Line*

### 2.3 Fishing Gears used in the Collection of *M. albus*

Three types of fishing gears were used in this experiment, namely electrofishing gadget EF (Figure 4), hook and line HL (Figure 5), and fish trap FT (Figure 6). Gear calibration under field conditions was done to determine the efficiency of the gears tested under a given operational mode. Calibration was done by setting a collection time of one hour to catch *M. albus* and 5-meter interval fishing points to all fishing gears during sampling periods. This was the method used by Bayley and Austen in 1987 to standardize the procedure and lessen the bias on gears used, EF being an active gear while HL and FT passive gears.

Before conducting the experimental fishing trial, stickers were placed in the 12 electrofishing gadgets before it was used, and tarpaulins of the research project were provided in the experimental sites. After the experiment, the tarpaulins and the fishing gears used were retrieved. A certificate of authorization allowing the use of electrofishing gadget was also secured from BFAR Central Office to ensure that this gadget was only used in the experiment and was destroyed upon project termination.

The study was conducted for one year during the wet and dry season in Cagayan Valley Region. Seasonality was based on the climatic condition of the region wherein the wet season starts from May to October while the dry season starts from April to November. Therefore, all *M. albus* caught during these months are categorized as caught during wet or dry seasons.

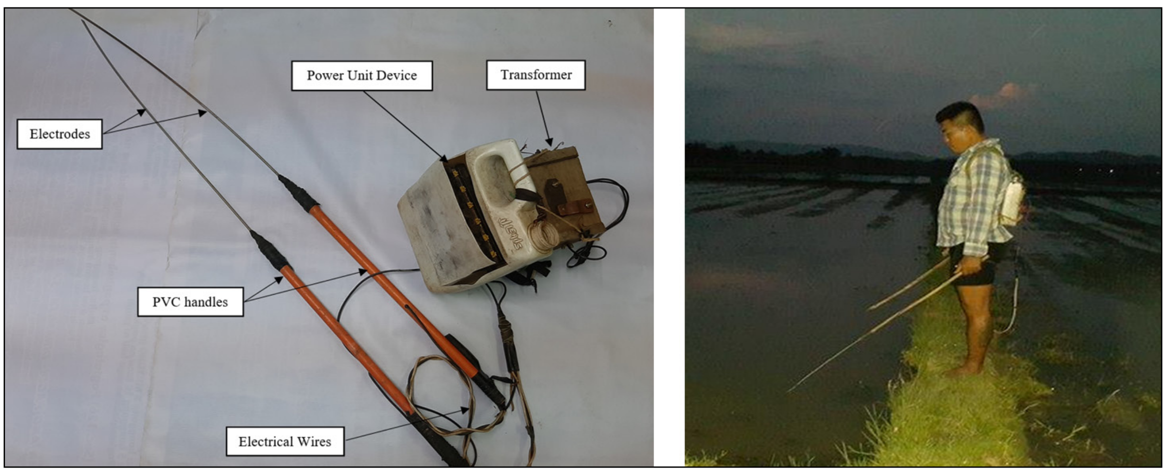


Figure 4. Electrofishing gadget used in catching *Monopterus albus*

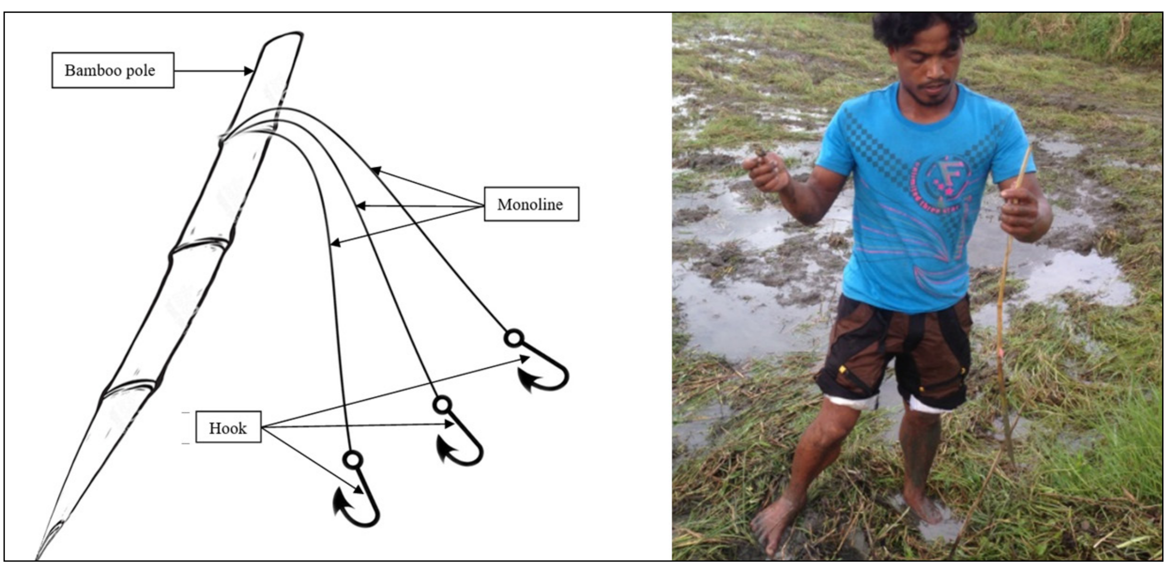


Figure 5. Hook and line used in catching *Monopterus albus*


Figure 6. Fish trap used in catching *Monopterus albus*

### 2.3.1 Electrofishing Gadget (EF)

The EF gadget used in the study consist of three main parts: a power unit device (12 volts battery), a transformer, and electrodes (Figure 4). The power unit produces alternating currents, and the unit's effect determines the maximum voltage in the water. The transformer converts the original current to a direct current of 12-voltage and produces the pulse's shape, length, and frequency. Direct current is passed into the water through the electrode connected to the transformer. It comprises two straight metals measuring 1–1.5 meters with a PVC pipe handle. The power unit produces the energy required, which increases with the conductivity of the water.

An authorization permitting the use of EF was secured to legalize the use of electrofishing gadgets in this study. However, the permit was non-transferable and could only be used by the researcher. Furthermore, the permit allows only the researcher to operate the EF gadget in experimental sites during the study duration. Therefore, BFAR R02 and the researcher are exempted from the penalties under Section 92 of RA 10654 for the length of the study.

EF gadget is being moved and operated in each collecting point of rice compartment for a one-hour collection period (7 PM–8 PM). This was done by inserting the electrode in the rice paddies. Once electrocuted, the fish will go out from the hole they created, rise to the water surface, or crawl, enabling fishers to catch them easily. Operation of electrofishing gadget was only done once in each collection point during the collection period. The researcher operated the gadget through the assistance of the agricultural technician for fisheries and the rice farm owner in 18 collection points of each EA.

### 2.3.2 Hook and Line (HL)

Hook and line is a gear where the fish is attracted by a natural or artificial bait (lures) placed on a hook fixed to the end of a line or snood, on which the fish get caught (FAO 2001). Hook and line gear used in the study consist of a bamboo pole (1.5 m length x 2 cm diameter), #6 hook (20 mm x 11 mm), and monofilament line (1 mm width) (Figure 5). One hook and line has three hooks individually attached to monofilament lines tied to the bamboo pole. The lines carry the hooks baited with crushed golden apple snail (Pomacea canaliculata). One hook and line was installed in each of the 18 collection points one hour (6 PM to 7 PM) before the collection period (7 PM–8 PM). Installation was made by digging the 0.5-meter part of the bamboo pole into the rice paddy of collection points. Then, the baited hooks were submerged into the water. The fish is being caught when it feeds on the bait. The lines were checked from time to time, and baits were regularly changed every after sampling collection. Caught fish was removed manually or by cutting the monoline. During the collection period, a hook and line with cut monoline was replaced with a new hook and line.

#### 2.3.3 Fish Trap (FT)

Traps are passive fishing gears in which the fish enters voluntarily as it is attracted to the bait. The trap used was made up of 0.8-meter PVC pipe 4" diameter with a non-return valve of 20 cm PVC pipe 4" diameter (Figure 6). The bait was tied inside the trap to lure and catch the *M. albus*. A crushed golden apple snail (P. canaliculata) was used to bait the fish trap. The baits were regularly changed every after sampling collection. One fish trap was installed in each of the 18 collection points one hour (6 PM–7 PM) before the collection period (7 PM–8 PM). The fish is being caught when it enters and traps into the gear. The fish trap was being checked from time to time, and baits were regularly changed every after sampling collection. The researcher removed the caught fish manually and returned the trap with new bait to the collection points.

### 2.4 Data Collection

The number of caught *M. albus* was counted, and their individual weight (kg) was determined using a mechanical weighing scale (10 kg capacity). The data were listed and transferred to Microsoft Excel for analysis. Catch per unit effort (CPUE) was computed using the formula CPUE = $\Sigma C1/\Sigma f1$ = *€/f* $\Sigma C_i/\Sigma f_i$ = *€/f* where $C_i$ is i$^{th}$ catch (expressed in kg weight), and $f_i$ is its respective fishing effort (Petrere et al. 2009). CPUE translates gear efficiency per 1-hour operation with the weight of *M. albus* caught within a 0.5 m$^2$ area of collection points in rice paddies. In many instances, CPUE is taken as an estimate of stock size (Lima et al. 2000).

The profitability of the fishing gears was determined through the conversion of catch into monetary values. For instance, a catch of 1-kilogram *M. albus* was converted into its prevailing average price per province. The price range per kg differs from one area to the other. In Solana, Amulung, and Alcala in Cagayan province and in Quirino province (Maddela, Diffun, and Cabarroguis), a kg is sold at PHP 100.00 while PHP 120.00 per kg for Alicia, San Isidro, and Cauayan City, and PHP 150.00 per kg in Quezon, Solano, and Bagabag Nueva Vizcaya province. These converted values were raised on a per hectare basis. Also, cost and return analysis of the fishing gears in the collection of *M. albus* in a 1-hectare rice farm area were computed. Net incomes and ROI were compared among gears to determine profitability

### 2.5 Statistical Analysis

One-way ANOVA was used to determine significant differences of efficiency in terms of the number of catch and CPUE of the three treatment fishing gears and profitability of these fishing gears used in the collection of *M. albus*. Two-way ANOVA was used to determine significant interaction between the efficiency of fishing gears and seasons. Significant differences were tested at a 0.05 level of significance using SPSS version 16. Also, frequency count was used to determining the number of caught *M. albus*. Data were presented as mean, standard deviation, and range.

## 3. RESULTS

### 3.1 Efficiency of Fishing Gears

Fishing gear efficiency in this study was measured through the CPUE to consider the time spent in fishing operation and the quantity caught per day of operation. The three fishing gears caught 821 individual *M. albus* for 96 sampling periods in the wet and dry season (Table 2).

#### 3.1.1 Percentage Catch Composition by Gear and by Area

Around 81.61% *M. albus* was caught by EF, 9.01% caught by HL, and 9.38 caught by FT (Figure 7). Percentage composition caught using EF was obtained in Cabarroguis, Solano, and Bagabag and lowest in Cauayan City (49.4%). The highest percentage was obtained in Diffun (26.83%), followed by Cauayan City (25.30%) and no catch in Amulung, Cabarroguis, Solano, and Bagabag. For the percentage composition caught through FT, the highest percentage (26.92% and 25.30%) were obtained in Amulung and Cauayan City, respectively, and no catch in Alcala, Cabarroguis, Solano, and Bagabag.

#### 3.1.2 Average CPUE by Gear by Area

The three fishing gears have an average CPUE of 1.15 kg *M. albus* per gear per hour in all experimental sites during the wet and dry seasons (Table 3). *M. albus* caught by EF has the highest average (2.75 kg/gear/hour), followed by HL (0.36 kg/gear/hour) and with the lowest FT (0.34 kg/gear/hour). The highest CPUE of the fishing gears was obtained in Amulung (7.57 kg/gear/hour),

Table 2. Number of *Monopterus albus* caught per municipality during the dry and wet seasons

| Municipality | Electrofishing Gadget | Hook and Line | Fish Trap | Total |
|---|---|---|---|---|
| Solana | 18 | 3 | 4 | 25 |
| Amulung | 76 | 0 | 28 | 104 |
| Alcala | 36 | 8 | 0 | 44 |
| Alicia | 36 | 10 | 1 | 47 |
| San Isidro | 86 | 3 | 3 | 92 |
| Cauayan City | 41 | 21 | 21 | 83 |
| Maddela | 18 | 3 | 1 | 22 |
| Diffun | 45 | 22 | 15 | 82 |
| Cabarroguis | 131 | 0 | 0 | 131 |
| Quezon | 23 | 4 | 4 | 31 |
| Solano | 64 | 0 | 0 | 64 |
| Bagabag | 96 | 0 | 0 | 96 |
| Total | 670 | 74 | 77 | 821 |

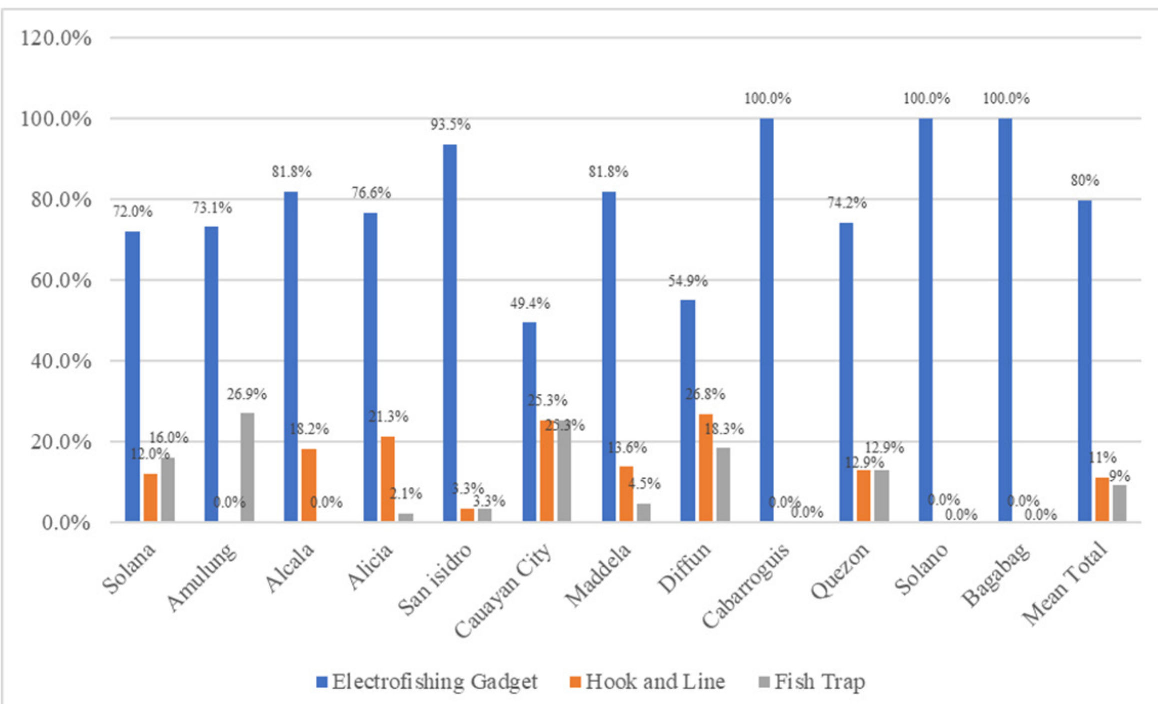

Figure 7. Percentage composition of *Monopterus albus* caught per fishing gear by area

Table 3. Average Catch Per Unit Effort (in kg) of *Monopterus albus* per fishing gear and per municipality during the dry and wet seasons

| Municipality | Electrofishing Gadget | Hook and Line | Fish Trap | Mean CPUE |
|---|---|---|---|---|
| Solana | 0.99 | 0.15 | 0.20 | 0.45 |
| Amulung | 5.77 | 0.00 | 1.80 | 2.52 |
| Alcala | 2.35 | 0.78 | 0.00 | 1.04 |
| Alicia | 1.52 | 0.70 | 0.06 | 0.76 |
| San Isidro | 4.21 | 0.13 | 0.16 | 1.50 |
| Cauayan City | 2.20 | 1.14 | 1.15 | 1.49 |
| Maddela | 0.86 | 0.18 | 0.03 | 0.35 |
| Diffun | 1.97 | 1.10 | 0.60 | 1.22 |
| Cabarroguis | 5.51 | 0.00 | 0.00 | 1.84 |
| Quezon | 1.50 | 0.17 | 0.11 | 0.59 |
| Solano | 2.88 | 0.00 | 0.00 | 0.96 |
| Bagabag | 3.26 | 0.00 | 0.00 | 1.09 |
| Mean CPUE | 2.75 | 0.36 | 0.34 | 1.15 |

followed by Cabarroguis (2.52 kg/gear/hour) and the lowest in Maddela (0.35 kg/gear/hour). For EF, experimental areas in Amulung (5.77 kg/gear/hour) and Cabarroguis (5.51 kg/gear/hour) obtained the highest CPUE and with the lowest CPUE in Maddela (0.86 kg/gear/hour) and Solana (0.99 kg/gear/hour). The highest CPUE for HL was obtained in Cauayan City (1.14 kg/gear/hour) and no catch in Amulung, Cabarroguis, Solano, and Bagabag. For FT, the highest CPUE (1.80 kg) was obtained in Amulung and no catch in Alcala, Cabarroguis, Solano, and Bagabag.

### 3.2 Efficiency of Fishing Gears by Season

#### 3.2.1 Catch and CPUE by Gear during Dry Season

The study tested the hypothesis that the three fishing gears used to collect *M. albus* are equally efficient in terms of the number of catch and CPUE during the dry season (November–April). The result shows that the electrofishing gadget has the highest number of caught and the highest CPUE among the fishing gears, followed by hook and line and fish trap (Table 4). Post Hoc Test indicated that the mean number of caught *M. albus* using EF (M = 3.270; SD = 1.938; $p < 0.05$) was significantly different to the mean number of caught using HL (M = 0.260; SD = 0.464; $p < 0.05$) and using FT (M = 0.302; SD = 0.525; $p < 0.05$).

Similarly, Post Hoc Test revealed that the CPUE of EF (M = 0.184; SD = 0.182; $p < 0.05$) was significantly different to the CPUE of HL (M = 0.024; SD = 0.050; $p < 0.05$) and to FT (M = 0.023; SD = 0.048; $p < 0.05$). On the other hand, there was no significant difference in the mean number of caught and CPUE of HL and FT. Around four pieces of *M. albus* can be caught per hour using the EF gadget and only around 0–1 piece for FT and HL, respectively, for 1 hour (Table 3).

One-way analysis of variance showed that there is a significant difference in the number of caught ($p < 0.001$) and CPUE ($p < 0.001$) among the three fishing gears.

#### 3.2.2 Catch and CPUE by Gear during Wet Season

The wet season in Cagayan Valley Region starts in May and ends in October. According to the interviews, it is during this season where *M. albus* comes out of its hiding place either to feed or to spawn. Hence, its disturbance to rice farming is mostly felt during this season. Catching the fish or lessening its population can help minimize its negative impact on farmers. The result of this trial shows that EF still has the highest number of caught and highest CPUE, followed by HL and FT (Table 5). One-way analysis of variance results indicated that the F-ratio (119.404) of the number of caught *M. albus* and F-ratio (95.497) of CPUE had associated probabilities lower than 0.001 ($p = 0.000$). The F-ratio of these three fishing gears in terms of the number of caught *M. albus* and CPUE are 618.896 and 1.257, respectively, ($p = 0.000$). It means there is a significant difference ($p < 0.001$) in the efficiency of the three fishing gears in the collection of

Table 4. Fishing gear comparison using Catch and CPUE on *Monopterus albus* caught during the dry season

| Fishing Gears | Number of caught *M. albus* (n) | CPUE, Weight of *M. albus* (kg) |
|---|---|---|
| Electrofishing gadget | 3.270+1.938 (1-10) | 0.184+0.182 (0-0.90) |
| Hook and Line | 0.260+0.464 (0-2) | 0.024+0.050 (0-0.23) |
| Fish Trap | 0.302+0.525 (0-2) | 0.023+0.048 (0-2) |

Values are mean±standard deviation (range)

Table 5. Fishing gear comparison using Catch and CPUE on *Monopterus albus* caught during the wet season

| Fishing Gears | Number of caught *M. albus* (n) | CPUE, Weight of *M. albus* (kg) |
|---|---|---|
| Electrofishing gadget | 3.447+2.545 (0-11) | 0.160+0.120 (0-11) |
| Hook and Line | 0.365+0.872 (0-5) | 0.021+0.056 (0-5) |
| Fish Trap | 0.313+0.730 (0-4) | 0.019+0.047 (0-4) |

Values are mean±standard deviation (range)

*M. albus* in rice paddies in Region 02, with EF as the most efficient.

Post Hoc Test indicated that the mean number of caught *M. albus* using EF (M = 3.447; SD = 2.545; $p < 0.05$) was significantly different from the mean number of caught using HL (M = 0.365; SD = 0.872; $p < 0.05$) and to the mean number of caught using FT (M = 0.313; SD = 0.730; $p < 0.05$). Similarly, Post Hoc Test revealed that the CPUE of EF (M = 0.160; SD = 0.120; $p < 0.05$) was significantly different to the CPUE of HL (M = 0.021; SD = 0.056; $p < 0.05$) and to the CPUE of FT (M = 0.019; SD = 0.047; $p < 0.05$). On the other hand, there was no significant difference in the mean number of caught and CPUE of HL and FT.

#### 3.2.3 Fishing Gears by Season

A collection time of one hour to catch *M. albus* was employed on all fishing gears during sampling periods in dry and wet seasons. This was to standardize the biases of gears used as active and passive gears to obtain reliable results of fishing efficiency (Bayley and Austen 1987). A two-way analysis of variance was conducted to determine significant interaction of fishing gears and seasons in the collection of *M. albus*. Results showed that there was a significant difference in the number of caught *M. albus* ($p < 0.001$) by the three fishing gears, while there was no significant difference in the number of caught *M. albus* based on seasons ($p = 0.410$) (Table 6; Figure 8). Also, there was no significant interaction between seasons and fishing gears ($p = 0.846$). This means that seasons will not affect the efficiency of the three fishing gears in the collection of *M. albus* in rice fields.

Moreover, results of two-way analysis of variance revealed that there was a significant difference in the CPUE ($p < 0.001$) by the three fishing gears while there was no significant difference in the CPUE of *M. albus* based on seasons ($p = 0.200$) (Table 7; Figure 9). Also, there was no significant interaction between seasons and fishing gears ($p = 0.525$). This means that the efficiency of the three fishing gears in the collection of *M. albus* will not be affected by seasons.

### 3.3 Profit and Monetary Values of Three Fishing Gears by Season

#### 3.3.1 Value by Gear by Dry Season

The EF has the highest monetary value of caught *M. albus*, followed by HL and FT (Table 8). One-way analysis of variance showed a significant difference in monetary value ($p < 0.001$) among the three fishing gears in one hectare. The cost per kg of *M. albus* ranges from PHP 80 to PHP 200 per kg in the market.

Post Hoc Test showed that the mean monetary value of caught *M. albus* using EF (M = 6,897.18; SD = 5,255.14; $p < 0.05$) was significantly different from the mean monetary value of catch using HL (M = 832.10; SD = 2,193.76; $p < 0.05$)

Table 6. Comparison of the number of collected *Monopterus albus* as affected by seasons and type of fishing gears

| Source | Type III Sum of Squares | Mean Square | F-ratio | Sig. |
|---|---|---|---|---|
| Seasons | 1.361 | 1.361 | 0.679 | 0.410 |
| Fishing Gears | 1190.316 | 595.158 | 296.982 | 0.000 |
| Seasons * Fishing Gears | 0.670 | 0.335 | 0.167 | 0.846 |
| Total | 3348.000 | | | |
| Corrected Total | 2334.639 | | | |

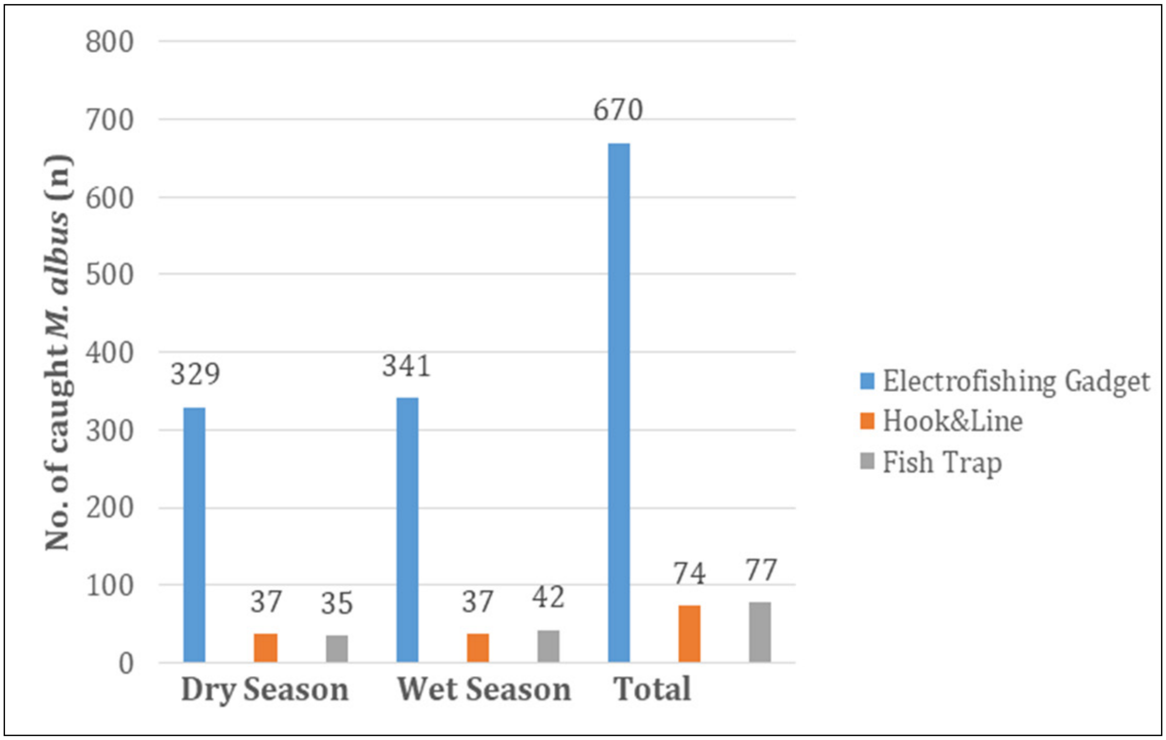


Figure 8. Total catch of *Monopterus albus* per fishing gear during the dry and wet seasons

Table 7. Comparison of the CPUE of *Monopterus albus* as affected by seasons and type of fishing gears

| Source | Type III Sum of Squares | Mean Square | F-ratio | Sig. |
|---|---|---|---|---|
| Seasons | 0.016 | 0.016 | 1.644 | 0.200 |
| Fishing Gears | 2.880 | 1.440 | 149.297 | 0.000 |
| Seasons * Fishing Gears | 0.012 | 0.006 | 0.646 | 0.525 |
| Total | 11.387 | | | |
| Corrected Total | 8.406 | | | |

Table 8. Comparison of monetary values (PHP) of fishing gears used in the collection of *Monopterus albus* per hectare during the dry season

| Fishing Gears | Monetary value of *M. albus* (PHP) |
|---|---|
| Electrofishing gadget | 6,897.18+5,255.14 (0-25,000) |
| Hook and Line | 832.10+2,193.76 (0-12,222.22) |
| Fish Trap | 757.48+1,818.60 (0-8,888.89) |

Values are mean±standard deviation (range)

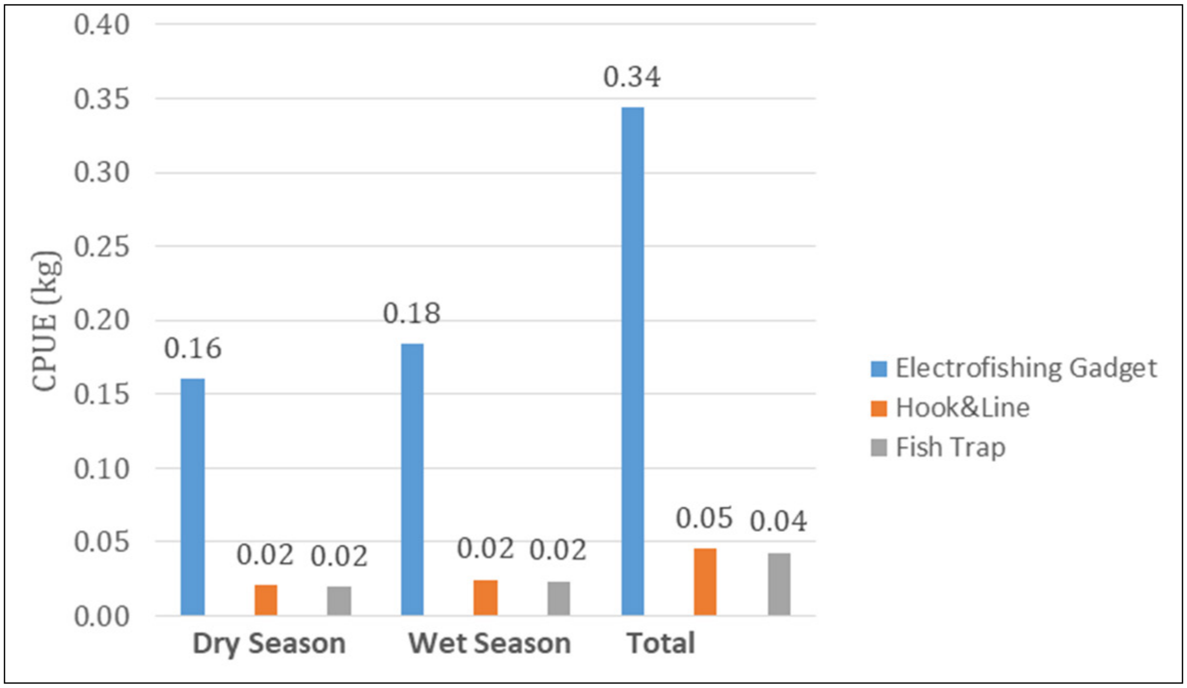


Figure 9. Catch Per unit Effort (kg) of *Monopterus albus* per fishing gear during the dry and wet seasons

and to the mean monetary value of catch using FT (M = 757.48; SD = 1,818.60; $p < 0.05$). There was no significant difference in the mean monetary value of caught *M. albus* using HL and FT.

### 3.3.2 Value by Gear by Wet Season

The EF has the highest monetary value of caught *M. albus*, followed by HL and FT (Table 9). One-way analysis of variance showed a significant difference in the monetary value of caught *M. albus* ($p < 0.001$) among the three fishing gears.

Post Hoc Test showed that the mean monetary value of caught *M. albus* using EF (M = 7,923.53; SD = 7,745.15; $p < 0.05$) was significantly different from the mean monetary value of catch using HL (M = 1,020.99; SD = 2,130.90; $p < 0.05$) and to the mean monetary value of catch using FT (M = 949.92; SD = 1,934.25; $p < 0.05$). There was no significant difference in the mean monetary value of caught *M. albus* using HL and FT.

### 3.3.3. Cost and Return Analysis per Fishing Gears in the Collection of *M. albus* in a 1-hectare Area during the Dry and Wet Seasons

The fish trap was the most expensive among the three gears, which costs PHP 22,000.00 for 100 units FT needed to collect fish in a 1-hectare rice farm during the dry and wet season (Table 10). On the other hand, only two units of EF were needed to collect the fish in a 1-hectare rice farm (costing PHP 4,200.00) while 100 units each for HL and FT (costing PHP 4,075.00 and PHP 22,000, respectively) (Table 10).

In terms of profitability of the three fishing gears in the collection of *M. albus* in a 1-hectare rice farm during the dry and wet season, the use of EF was still the most profitable among the fishing gears (Table 11). EF has the highest net income valued at PHP 407,630.40 with an ROI of 569%, while HL and FT have 261% and 309% ROI, respectively.

Table 9. Comparison of monetary values (PHP) of fishing gears used in the collection of *Monopterus albus* per hectare during the wet season

| Fishing Gears | Monetary value of *M. albus* (PHP) |
|---|---|
| Electrofishing gadget | 7,923.53+7,745.15 (0-40,000.00) |
| Hook and Line | 1,020.99+2,130.90 (0-10,222.22) |
| Fish Trap | 949.92+1,934.25 (0-8,888.89) |

Values are mean±standard deviation (range)

Table 10. Cost of fishing gears used in collecting *Monopterus albus* in a 1-hectare area

| *2 units Electrofishing Gadget* | | | | |
|---|---|---|---|---|
| Description | Quantity | Unit | Unit Cost | Amount |
| Power unit device (12 V battery) | 2 | unit | 1,000.00 | 2,000.00 |
| Transformer/capacitor | 2 | unit | 800.00 | 1,600.00 |
| Electrodes and electrical wires | 2 | unit | 200.00 | 400.00 |
| Labor for assembling the electrofishing gadget | 2 | unit | 100.00 | 200.00 |
| Total | | | | 4,200.00 |
| *100 units Fish Trap* | | | | |
| Description | Quantity | Unit | Unit Cost | Amount |
| PVC Pipe, Polyethelene black schedule 40, 6m x 4" diameter | 17 | pc | 450.00 | 7,650.00 |
| PVC Pipe cap 4" diameter | 100 | pc | 75.00 | 7,500.00 |
| Monoline 1mm dm | 2 | kg | 400.00 | 800.00 |
| P.E Rope #4/2mm diameter | 2 | roll | 250.00 | 500.00 |
| Soldering iron | 2 | pc | 175.00 | 350.00 |
| Hack saw blade | 2 | pc | 100.00 | 200.00 |
| Labor for assembling the fish trap | 100 | unit | 50.00 | 5,000.00 |
| Total | | | | 22,000.00 |
| *100 units Hook and Line* | | | | |
| Description | Quantity | Unit | Unit Cost | Amount |
| Hard bamboo full length, Bayog | 5 | pc | 120.00 | 600.00 |
| Monoline/ Pamo 210/6 | 5 | spool | 55.00 | 275.00 |
| Mustard hook #564, 80pcs/box | 5 | box | 40.00 | 200.00 |
| Labor for assembling the hook and line | 100 | units | 30.00 | 3,000.00 |
| Total | | | | 4,075.00 |

Table 11. Comparison of cost and return analysis of fishing gears used in the collection of *Monopterus albus* in a 1-hectare/annum (dry and wet season)

| | **Electrofishing Gadget** | **Hook&Line** | **Fish Trap** |
|---|---|---|---|
| Production (Kg) | 4,824.00 | 1,900.80 | 2,419.20 |
| Value/Kg | 120.00 | 120.00 | 120.00 |
| Gross Income (Sales (Php)) | 578,880.00 | 228,096.00 | 290,304.00 |
| **Operating and Maintenance Expenses** | | | |
| Labor | 72,000.00 | 72,000.00 | 72,000.00 |
| Marketing Expenses (5% of Gross Sales) | 28,944.00 | 11,404.80 | 14,515.20 |
| Depreciation Cost | 840.00 | 4,075.00 | 7,333.33 |
| **Sub-Total** | **101,784.00** | **87,479.80** | **93,848.53** |
| Net Income | 477,096.00 | 140,616.20 | 196,455.47 |
| Less Tax 12% | 69,465.60 | 27,371.52 | 34,836.48 |
| Net Income after Tax | 407,630.40 | 113,244.68 | 161,618.99 |
| **ROI** | **569%** | **261%** | **309%** |

Table 12. Computation of depreciation cost for the three fishing gears

| Items | Value | Lifespan | Depreciation Cost |
|---|---|---|---|
| EF | 4,200.00 | 5 | 840.00 |
| H&L | 4,075.00 | 1 | 4,075.00 |
| FT | 22,000.00 | 3 | 7,333.33 |

## 4. DISCUSSION

### 4.1 Efficiency of Fishing Gears during the Dry and Wet Seasons

Comparison of catch and CPUE are suitable for assessing the performance of fishing gears in catching fish species (Browne et al. 2017). In this study, CPUE was used to determine the efficiency of three fishing gears to control the population of rice eel in rice paddies. Effort, in this case, is the number of hours the fishing gears were set in the rice fields. Among the three fishing gears, the EF gadget was found to be the most efficient to catch *M. albus* in rice paddies compared to the other two fishing gears. This means that the longer time EF will be used, the higher the catch. Studies by Laffaille et al. (2005), Lasne and Laffaille (2008), and Scott (2011) support the findings of this study, especially on quantitative assessments of population size. However, there are limitations to using EF as a fishing gear for this fish. Under Republic Act 10654, the use of EF is strictly prohibited. Violation of the provisions under this act is punishable by confiscating electrofishing devices, six months' imprisonment, and a fine of five thousand pesos. With this provision, balance utilization and minimizing negative impacts (ICES 2010; Woolmer et al. 2011) on rice production and increasing income of fishers could be possible by amending the law such that the use of EF in rice areas can be delineated with that of use in open waters and that higher penalties can be imposed on the latter.

The efficiency of EF was also cited to be used in environmental studies for assessing fish populations in rivers and small water bodies in other countries (Rosenberger and Dunham 2005; Schmutz et al. 2007). It is relatively safe for fish compared with other capture methods and easily applicable to a wide range of waterways and habitats (Lyon et al. 2014). During the conduct of the study, it was also observed that *M. albus* caught by electrofishing gadgets were alive, whereas most *M. albus* caught by hook and line were dead. When placed in a styrofoam box with water regularly changed, the fish can survive for one to two weeks. This condition connotes that the fish has no notable external injuries. It can recover and be considered unharmed (Snyder 2003) and is expected to continue behaving, growing, and reproducing.

On the other hand, when electrofishing is carried out improperly, it can paralyze the fish leading to fractured vertebrae, curved spines, ruptured arteries and veins, hemorrhaging, and tissue death (Snyder 2003; Schreer et al. 2004). However, such damage can be minimized through preferential use of smooth direct current, using the lowest effective power setting, avoiding switching the power on and off when fish are near the anode, and by minimizing the exposure time through efficient hand netting of the fish (Wood-Pawcatuck Watershed Association et al. 2013).

Although electric stimulation can cause injuries and be lethal, when an appropriate field intensity and duration of exposures are applied (Snyder 2003), correct use of electric stimuli offers incredible opportunities to achieve catch results that outperform all other techniques. This stresses the importance of studying the pulse settings and optimizing them so that minimal harm and maximal performance can be balanced (Soetaert 2015).

FT and HL can also be used to control the population of rice eel. However, in terms of efficiency based on CPUE, one EF would require 382 units of FT or 404 units of HL. Regarding economic benefit, EF almost doubles the returns compared to HL and FT. Another factor that may affect gear efficiency is the quality of the fish catch. Live *M. albus* is preferred by the market. This is because it commands a higher price than the dead ones. Although all major fishing gear types involve some degree of injury to fish (e.g., internal and external wounding, crushing, scale loss, and hydrostatic effects), with the severity of the injury depending on the gear type and its operation (Suuronen 2005), caught *M. albus* using EF and FT in this study were alive while most fishes caught by HL were dead. This could be due to the injuries caused by the hook and physiological stresses caused when it struggles to escape during capture. A swallowed hook may induce a substantially greater injury than a hooked mouth (e.g., through the jaw, lips, or operculum). Fish removed from hooks automatically (e.g., by a crucifier or gaff) experience significantly higher mortality than fish removed manually (Kaimmer 1994; Milliken et al. 1999). In this study, the swallowed hook is removed manually. Also, fish that struggle intensely for a long-time during capture is usually exhausted and stressed from the accumulation of excessive amounts of lactic acid in their muscles and blood. Severe exhaustion causes physiological imbalance, muscle failure, or death (Caillouet, 1967). Hence, although HL fishing is easy and inexpensive since materials are locally available compared to other gears, hook-caught *M. albus* may suffer a range of injuries, stresses, and mortalities that degrade the fish's quality.

For FT, several designs have been used according to their configuration or place of origin. The design of FT used in the study was adopted from the creation of BFAR R02 experts under the fish capture section. Despite its design and operation suitable to the behavior of the fish, it obtained the lowest catch and CPUE among the gears, perhaps due to the baits used or some other factors. Therefore, the poor fishing efficiency can be substantially improved by using different baits and various types of attraction devices (Suuronen 2005), which can be further researched.

Fishing efficiency in terms of the number of caught and CPUE was not affected by seasons. This is because the experimental trials were conducted in an irrigated rice paddy in which the availability of waters was not a limiting factor in the collection of *M. albus* in the dry season. The collection of *M. albus* is easier when there is water since the species comes out to feed on worms, frogs, tadpoles, shrimp, crayfish, and other fishes (Hamilton 2006). However, when the ground is moist, *M. albus* burrows and can survive for a long time without water (Bricking 2002), making them difficult to collect.

### 4.2 Profit and Monetary Values of Three Fishing Gears Used in the Collection of *M. albus*

In terms of profitability, the collection of rice eel through EF was the most efficient among the gears used in this study because of the volume of catch and the profit earned by rice eel collectors. Since *M. albus* is traded in other Asian countries such as China, Taiwan, and Singapore (Gonzales 2013), management strategies which aim at ensuring sustainable and efficient fisheries while improving income, employment, and living standards of fishing communities (Borrello et al. 2013) is needed. In trying to obtain these, policymakers require information not only on the state of fish stocks but also on the profitability of the fishing gears. Therefore, economic indicators of fisheries such as fishing cost and gross revenue play an important role in economic analysis and provide helpful information for sustainable fisheries management, planning, and policymaking (Christensen et al. 2009; Lam et al. 2011). In this study, the profitability of three fishing gears was determined by converting catch into monetary values and estimating cost and return analysis per fishing gear based on the production obtained from the experiment. The highest monetary values, profit, and investment return were observed in the *M. albus* caught by EF gadget with the lowest profitability in HL. Since the EF gadget has the highest fishing efficiency in terms of caught and CPUE, it follows that it has the highest profitability when converted to monetary values. EF also has a positive net income compared to the HL and EF. Thus, it is profitable to use the EF gadget in the collection of *M. albus* compared to the other fishing gears. Considering all direct costs and economic benefits, the economic return to society associated with harvesting *M. albus* resources is most relevant to the needs of fishery managers and policymakers (Borrello et al. 2013).

## 5 CONCLUSION

Electrofishing gadget has been tested to offer a comparative advantage over FT and HL in terms of controlling the population of *M. albus* in rice fields. It is more efficient due to higher CPUE, and its efficiency is not affected by seasonal changes. The ethical issue on whether to use it or not lies in the objectives and the problems it will address. In the Cagayan Valley Region, where rice is a prime commodity and the negative impacts of rice eel are being felt by the farmers, employing immediate control measures that will eliminate the pest must be done to maximize rice productivity of their area. In such case, EF gadget may be cautiously used to collect rice eel provided that preventive measures are installed such as:

1. It should only be used within rice farm areas;
2. Only after harvest or before planting – provided the owner of the rice farm allows its use within the duration of rice culture;
3. Permits should be secured from BFAR upon recommendation by the MLGU, CLGU, or PLGU;
4. The Barangay council will issue a list of

electro-fishers within their barangays;
5. LGU should have enacted a local ordinance on its use; and
6. To increase the penalty for illegal use of EF in canals and other communal bodies of water and the use of high tension wire as a source of electricity.

As an alternative to EF, combining the two fishing gears is also recommended to increase fishing efficiency and minimize the negative impact on the environment. The type and size of hooks must be customized and complemented with proper handling to ensure the survival of fish caught and to increase profitability through a higher market price of caught live fish. Also, woven bamboo can be used instead of PVC pipe as a fish trap to reduce the cost of materials and increase profitability. Aside from *P. cannaliculata* as bait of these gears, other baits such as worms and trash fish may also be tested to improve the fishing efficiency of the fishing gears and explore various types of attraction devices.

For future studies in water bodies, the challenge is to design a more efficient fishing gear that is environment-friendly and can maximize its CPUE.

## ACKNOWLEDGMENT

The authors wish to acknowledge the support, cooperation, and invaluable assistance of the Local Government Units of the 12 municipalities included in this study, namely Alcala, Amulung, and Solana in Cagayan; Cauayan City, San Isidro and Alicia in Isabela; Maddela, Diffun, and Cabarroguis in Quirino; Solano, Bagabag, and Quezon in Nueva Vizcaya. The active participation of the farmer and fisherfolks, who have helped us complete this study, is likewise recognized. Appreciation and gratitude are also given to our Regional Director Milagros C. Morales, National Director Eduardo B. Gongona, and Dr. Angel Encarnacion for their unwavering support. The invaluable comment and suggestions of the reviewers are also recognized.

## AUTHORS CONTRIBUTIONS

**Ame EC:** Conceptualization, Methodology, Investigation, Writing–Review and Editing, Supervision, Funding Acquisition. **Mayor AD:** Methodology, Formal Analysis, Investigation, Writing–Review and Editing, Project Investigation

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in any way

## ETHICS STATEMENT

The authors obtained informed consent from all participants included in this study. Also, a Certificate of Authorization Allowing the Use of Electrofishing Gadgets for the Conduct of Scientific Research on Rice Eel was obtained from the Bureau of Fisheries and Aquatic Resources - Central Office.

## REFERENCES

Bayley PB, Austen J. 1987. Comparative Analysis of Fish Populations in Illinois Impoundments: Gear Efficiencies and Standards for Condition Factors. Aquatic Biology Technical Report 87/14. Champaign, IL: Illinois Natural History.

Borrello A, Motova A, Carvalho N. 2013. Profitability of the EU Fishing Fleet. Italy: European Union Policy Department. Joint Research Centre of the European Commission. p 1-86. https://www.europarl.europa.eu/RegData/etudes/note/join/2013/513962/IPOL-PECH_NT(2013)513962_EN.pdf

Bricking EM 2002. Introduced Species Summary Project: Asian Swamp Ele (*Monopterus Alba*). Columbia University. http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Monopterus_albus.html

Browne D, Minto C, Cosgrove R, Burke B, McDonald D, Officer R, Keatinge M. 2017. A general catch comparison method for multi-gear trials: application to a quad-rig trawling fishery for Nephrops. ICES Journal of Marine Science. 74(5): 1458-1468. https://doi.org/10.1093/icesjms/fsw236

[BFAR R02] Bureau of Fisheries and Aquatic Resources Region 02 2017. Rice eel Stakeholder's Consultation Report.

Business World. 2013. Rice eels: from pest to commodity. Business World Online Agribusiness

Caillouet CW Jr. 1967. Hyperactivity, Blood Lactic

Acid and Mortality in Channel catfish. Agriculture and Home Economics Experiment Station, Iowa State Univ. of Science and Technology. Ames, Iowa Research Bulletin .551: 898-915. https://dr.lib.iastate.edu/handle/20.500.12876/62890

Christensen V, Ferdana Z, Steenbeek J. 2009. Spatial optimization of protected area placement incorporating ecological, social and economical criteria. Ecological Modelling. 220(19): 2583–2593. https://doi.org/10.1016/j.ecolmodel.2009.06.029

Domingo LC. 2013. Rice eel export valued at $21 million. The Manila Times.

[FAO] Food and Agriculture Organization of the United Nations. 2001. Fishing Gear types Hooks and lines (nei). Technology Fact Sheets. Fisheries and Aquaculture Division [online]. Rome.

Gonzales AL. 2013. Rice Eel Exports reach 517 M. Manila Standards.net. Business section. https://manilastandard.net/business/115495/rice-eel-exports-reach-p517m.html

Guerrero III RD. 2014. The Impacts of Introduced Freshwater Fishes in the Philippines (1905-2013): A Review and Recommendations. Philippine Journal of Science. 143(1): 49-59

Hamilton H. 2006. Frequently Asked Questions about the Asian Swamp Eel. Florida Integrated Science Center: USGS. https://www.scribd.com/document/93777268/Asian-Swam-Peel

He Y, Shang X, Sun J, Zhang L, Zhao W, Tian Y, Cheng H, Zhou R. 2010. Gonadal apoptosis during sex reversal of the rice field eel: implications for an evolutionarily conserved role of the molecular chaperone heat shock protein 10. J Exp Zool B Mol Dev Evol. 314B(4): 257-266. https://doi.org/10.1002/jez.b.21333

ICES. 2010. Report of the Workshop to Assess the Ecosystem Effects of Electric Pulse Trawls (WKPULSE). Ijmuiden, the Netherlands. ICES CM 2010/SSGESST:01. p. 36.

Juliano RO, Guerrero III RD, Ronquillo I. 1989. The introduction of exotic aquatic species in the Philippines. In: De Silva SS, editor. Exotic aquatic organisms in Asia. (19-21 June 1981) Proceedings of the Workshop on Introduction of Exotic Aquatic Organisms in Asia. Asian Fish. Soc. Spec. Publ. 3. p. 83-90

Kaimmer S. 1994. Halibut injury and mortality associated with manual and automated removal from setline hooks. Fish Res. 20(2-3): 165–179. https://doi.org/10.1016/0165-7836(94)90081-7

Laffaille P, Briand C, Fatin D, Lafage D, Lasne E. 2005. Point sampling the abundance of European eel (*Anguilla anguilla*) in freshwater areas. Arch Hydrobiol. 162(1): 91–98. https://doi.org/10.1127/0003-9136/2005/0162-0091

Lam VWY, Sumaila UR, Dyck A, Pauly D, Watson R. 2011. Construction and first applications of a global cost of fishing database. ICES Journal of Marine Science. 68(9): 1996–2004. https://doi.org/10.1093/icesjms/fsr121

Lasne E, Laffaille P. 2008. Assessing the freshwater distribution of yellow eel. Knowl Manage Aquat Ecosyst. 4: 390–391. https://doi.org/10.1051/kmae/2009004

Lazaro FG. 2013. Farm pest now exported food. Manila Bulletin p. 9

Lima AC, Freitas CEC, Abuabara MA, Petrere M, Batista VS. 2000. On the standardization of the fishing effort. Acta Amaz. 30(1): 167-169. https://doi.org/10.1590/1809-43922000301169

Lyon JP, Bird T, Nicol S, Kearns J, O'Mahony J, Todd CR, Cowx IG, Bradshaw CJA. 2014. Efficiency of electrofishing in turbid lowland rivers: implications for measuring temporal change in fish populations. Can J Fish Aquat Sci. 71(6): 878–886. https://doi.org/10.1139/cjfas-2013-0287

Milliken H, Farrington M, Carr HA, Lent E. 1999. Survival of Atlantic cod (Gadus morhua) in the Northwest Atlantic longline fishery. Marine Technology Society Journal. 33(2): 19–24. https://doi.org/10.4031/MTSJ.33.2.4

Petrere Jr. M, Giacomini HC, De Marco Jr. PD. Catch per-unit-effort: which estimator is best? Braz. J. Biol. 70(3): 483-491. https://doi.org/10.1590/S1519-69842010005000010

Philippine Statistics Authority. 2020. Inland Municipal Fisheries: Volume of Production by Geolocation, Species, Year and Quarter. http://openstat.psa.gov.ph/

Rosenberger AE, Dunham JB. 2005. Validation of Abundance Estimates from Mark–Recapture and Removal Techniques for Rainbow Trout Captured by Electrofishing in Small Streams. N Am J Fish Manage. 25(4): 1395–1410. https://doi.org/10.1577/M04-081.1

Schmutz S, Cowx IG, Haidvogl G, Pont D. 2007. Fish-based methods for assessing European running waters: a synthesis. Fish Manage Ecol. 14(6): 369–380. https://doi.org/10.1111/j.1365-2400.2007.00585.x

Schreer JF, Cooke SJ, Connors KB. 2004. Electrofishing-induced cardiac disturbance and injury in rainbow trout. Journal of Fish Biology. 64(4): 996-1014. https://doi.org/10.1111/j.1095-8649.2004.00364.x

Scott R. 2011. Comparison of point and transect based electrofishing to sample American eel (*Anguilla rostrata*) in wadeable riverine habitats. Aquatic Living Resources. 24(1): 79-83. https://doi.org/10.1051/alr/2011106

Shafland PL, Gestring KB, Sanford MS. 2010. An Assessment of the Asian Swamp Eel (*Monopterus albus*) in Florida. Reviews in Fisheries Science. 18(1): 25-39. https://doi.org/10.1080/10641260903225542

Snyder DE. 2003. Invited overview: conclusions from a review of electrofishing and its harmful effects on fish. Reviews in Fish Biology and Fisheries. 13: 445-453. https://doi.org/10.1007/s11160-004-1095-9

Soetaert M. 2015. Electrofishing: Exploring the Safety Range of Electric Pulses for Marine Species and Its Potential for Further Innovation. Merelbeke, Belgium: Ghent University. Faculty of Veterinary Medicine.

Suuronen P. 2005. Mortality of fish escaping trawl gears. FAO Fisheries Technical Paper. No. 478. Rome: FAO. p. 72. https://www.fao.org/3/y6981e/y6981e00.htm

Tridge. n.d. Asian Swamp Eel Global Production. [accessed 2020 Jun 8]. https://www.tridge.com/intelligences/asian-swamp-eel/production.

Wood-Pawcatuck Watershed Association, Woonasquatucket River Watershed Council, and the Narragansett Bay Estuary Program. 2013. Urban River Fish Community Monitoring Training Manual: Fish Community Monitoring Techniques for Volunteer Monitors in Urban Rivers. p. 1-46. https://www.landandwaterpartnership.org/documents/Summit2015/B1_Electrofishing_Procedures.pdf

Valencia C. 2013. Pesky rice eel now an export commodity. Philippine Star. p. B-3.

Woolmer A, Maxwell E, Lart W. 2011. Effects of electrofishing for Ensis spp. on benthic macrofauna, epifauna and fish species. Seafish Report SR652 ISBN – 978-1-906634-58-2.

Zhou R, Liu L, Guo Y, Yu H, Cheng H, Huang X, Tiersch TR, Berta P. 2003. Similar gene structure of two Sox9a genes and their expression patterns during gonadal differentiation in a teleost fish, rice field eel (*Monopterus albus*). Mol Reprod Dev. 66(3): 211-217. https://doi.org/10.1002/mrd.10271. https://www.tridge.com/intelligences/asian-swamp-eel/production