E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2025; 13(1): 63-67

www.fisheriesjournal.com
Received: 12-11-2024
Accepted: 15-12-2024

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Preliminary assessment of glass eel (*Anguilla* spp.) fishery in Santa Ana, Cagayan

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DOI: https://doi.org/10.22271/fish.2025.v13.i1a.3017

Abstract
The study assessed the fishing grounds for glass eels (*Anguilla spp*.) in Santa Ana, Cagayan, Philippines, focusing on fishing gears, fishing effort, and policy recommendations for eel stock enhancement. Conducted from March to May in the Palawig and Diora-Zinungan Rivers, both critical migratory routes for catadromous fishes, the research employed a mixed methods approach, integrating qualitative observations and interviews with quantitative data collection. Results indicated favorable environmental conditions in both rivers for glass eels, with minimal variation in their length and weight. Catch data revealed higher glass eel abundance in the Palawig River, with *Anguilla marmorata* as the dominant species. The findings underscored concerns regarding the sustainability of glass eel fishing, emphasizing the need for conservation measures. The study recommended stock enhancement research, aquaculture initiatives, increased research investment, and awareness campaigns to ensure the long-term sustainability of glass eel populations and the ecological integrity of their habitats.

Keywords: *Anguilla* spp., estuaries, fyke net, water quality, life below water

Introduction
The *Anguilla* species, an emerging aquaculture commodity, holds significant potential for future development in the Philippines due to its high demand in East Asia and the declining wild populations over the past two to three decades [1, 2]. However, eel aquaculture heavily relies on wild stocks, further depleting these populations and raising concerns about the sustainability of the industry [3, 1]. This issue is compounded by the increasing risk of listing Anguillid eels in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which would impose trade restrictions, as demonstrated by the European eel's inclusion in CITES Appendix II in 2009. As a result, tropical Anguillid eels, such as the Indian mottled eel (*Anguilla bengalensis*), Indonesian shortfin eel (*A. bicolor*), and marbled eel (*A. marmorata*), have become economically significant species in Southeast Asia [4]. Eels are abundant in several regions of the Philippines, including the provinces of Cagayan in northern Luzon, Albay, Camarines Norte in eastern Luzon, Iloilo, Negros Occidental in central Philippines, and North Cotabato and Zamboanga del Sur in Mindanao [5, 1, 6]. Various fishing methods, such as traps, hook and line, fyke nets, and gill nets, are employed to catch eels at different life stages [5, 1]. However, there is a lack of regular catch-and-effort monitoring in the country. Previous studies [5, 1] have shown the need for population assessments to evaluate the biology and sustainability of eel fisheries in the Philippines. Given that the Philippines contributes about 30% of the total global supply of live eels[7], it is essential to assess the current population stocks and address areas where eel fishing is uncontrolled. This study aims to conduct a stock assessment, focusing on glass eel populations in Santa Ana, Cagayan, using a combination of catch data and fishing effort analysis. By providing a thorough evaluation of the status and sustainability of glass eel fisheries, this research contributes to the development of responsible stock enhancement strategies, ensuring the long-term viability of the industry.

Materials and Methods: Research Design: The study utilized a mixed-methods design, combining qualitative and quantitative approaches to gain a comprehensive

understanding of glass eel fisheries in Santa Ana, Cagayan [8]. Ethnographic observations were conducted to describe fishing grounds and gather insights from local fishers regarding their fishing practices and gear. Additionally, a survey was used to collect quantitative data on fishing efforts, including trip frequency, duration, and the quantity of glass eels caught. Based on these findings, policy recommendations for sustainable eel management in Santa Ana were developed, drawing from both local knowledge and best practices in fisheries management.

Documentation of Fishing Grounds for Glass Eel

Freshwater eels at the glass eel stage are usually abundant in the estuary of a river [9]. Thus, the study was conducted in the estuaries of Barangays Palawig and Diora-Zinungan where glass eel fishery exists. The fishing grounds were identified based on anecdotal evidence by residents, fishers, Municipal Agricultural Officers, and personnel from the Department of Agriculture- Bureau of Fisheries and Aquatic Resources (DA-BFAR). Initial interviews were conducted with the DA-BFAR personnel, and fishers in the identified fishing grounds. Also, monthly data on glass eel fishery on the sites were observed.

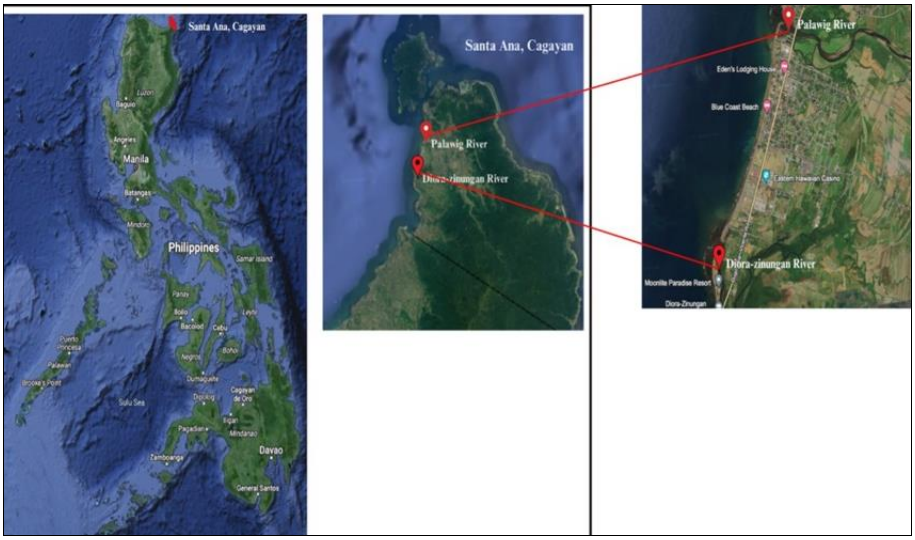

Fig 1: Map showing the location of the estuary part of the river of Barangay Diora-Zinungan and Palawig in Santa Ana, Cagayan (source: google.earth.map)

Characterization of Sampling Area

For each identified sampling site in the glass eel fishery, water quality parameters were measured once a week from March to May, with sampling times scheduled for 7:00 AM at the Diora-Zinungan River and 8:30 AM at the Palawig River. The pH was measured with a pH meter, dissolved oxygen and temperature were measured using a YSI multiparameter instrument, and salinity was measured using a refractometer. In addition to water quality, the migration of glass eels towards lower salinity is also affected by tidal fluctuations in the estuary [10]. The type of estuary, tide computations (time and height of high and low tide), and weather conditions were also recorded to understand this further.

Data collection

Gathering information regarding glass eel fishery was undertaken. This was done once a week through an interview with the fishers where the fishing gears are placed. It was conducted during the period of three months from March to May 2023. Data forms were used to facilitate the collection and recording of data and these forms were based on the National Stock Assessment Program (NSAP). Additionally, a questionnaire, adapted from Undiana (2024) [11] was employed to collect data on the profile of the gatherers, catch details, and the number of hours dedicated to catching. The following are the required data:

Fishing gear used

There is still little information on the fishing gear used for glass eel fishing in Santa Ana, Cagayan. For this study, fishing gears were identified and described. Pictures and size measurements were taken using a camera and steel tape. Parts and materials used in making the fishing gear were also noted.

Catch and effort

In direct interviews with fishers or fishing operators, data was collected on the total catch by gear (weight in kilograms), the type of fishing gear used, and the fishing effort (number of hours spent fishing). Fishing gear that yielded no catch was also documented, if effort was expended.

Sub-sampling and identification of species

For each sampling site, a sub-sample of the total glass eels caught per sampling day per month was taken to measure the length (in millimeters) and weight (in grams). After that, species identification was also conducted using the protocol of Serdiati et al., (2013) [12]. Identification was determined through the presence of tail spots using a magnifying lens.

Catch per unit effort

Catch per unit effort (CPUE) was computed in terms of the recorded weight of the total catch per fishing gear per sampling in each fishing ground. The CPUE per month in the study was determined by the average ratio between the total glass eel catch in kilograms and the number of hours of fishing.

Data analysis

Statistical methods, including descriptive statistics (mean values and frequency counts), were used to analyze water parameters, glass eel length/weight, and fisher catch/effort. ANOVA assessed differences in eel length/weight, species composition, and CPUE between the Palawig and Diora-Zinungan Rivers. A t-test was also applied to examine significant differences in average glass eel catch between the two rivers.

Results and Discussions

Description of Fishing Gears: The study highlights the utilization of fyke nets, locally known as "tanggar," as an effective tool for capturing glass eels. Fyke nets are constructed using a combination of native bamboo vines and synthetic netting materials, emphasizing a sustainable and resourceful approach to fishing. These traps are designed with a simple entry mechanism and a structure that minimizes the chances of escape, taking advantage of the migratory behavior of glass eels. A typical fyke net features wings approximately 2 meters in length, a height of 1.5 meters, and a total length of 14 meters. The capturing bag measures about 2.5 meters, supported by at least seven bamboo poles. These nets are fixed in place and often require two to three fishers to handle them during low tide. Glass eel collection typically occurs over a period of 6 to 12 hours, reflecting the efficiency of this fishing method. The use of a scoop net, locally called "sayut," further complements the glass eel collection process. The "sayut" is used to gather trapped eels from the capturing bag or funnel of the fyke net, demonstrating the integration of traditional knowledge and fishing practices in local fisheries. These findings align with observations by Jellyman and Graynoth (2005) [13], who emphasized the effectiveness of fyke nets in capturing migratory eel species due to their design and operational efficiency. The reliance on native materials, combined with the use of synthetic components, represents a sustainable fishing practice that minimizes environmental impact while maintaining productivity. Understanding the design, operation, and local practices associated with fyke nets provides valuable insights into their role in the sustainable harvesting of glass eels. It also underscores the importance of promoting traditional knowledge and its integration with modern fishing practices to ensure the conservation of glass eel populations and the long-term viability of this fishery.

Fishing Grounds for Glass Eels in Santa Ana, Cagayan

The glass eel fishing locations in Santa Ana, Cagayan, are the Palawig and Diora-Zinungan Rivers. The Palawig River covers 4.12 hectares and is approximately 0.15 kilometers from the sea. The tidal fluctuations follow a 6-hour cycle between low and high tides. The tidal patterns or sequence follow a low tide from 1:00 PM to 6:00 PM, then a high tide from 7:00 PM to 12:00 AM, followed by another low tide from 1:00 AM to 5:00 AM, and finally, a high tide from 6:00 AM to 12:00 PM. On the other hand, the fishing ground at the Diora-Zinungan River covers 0.7819 hectares and is approximately 0.03 kilometers from the sea. The tidal fluctuations of the river are the same as the Palawig River. In terms of temperature, Santa Ana, Cagayan, Philippines, typically experiences a range of 25 to 30 degrees Celsius (77 to 86 degrees Fahrenheit). This temperature range is characteristic of a tropical climate and is influenced by various factors such as the proximity to the equator, ocean currents, and local weather patterns. The proximity of the Palawig and Diora-Zinungan Rivers to the sea, along with favorable tropical temperatures and tidal fluctuations, creates ideal conditions for glass eels. These factors, supported by research from Kroes et al. (2020) [14] and Nzau Matondo et al. (2019) [15], aid in the eels' migration between freshwater and marine habitats. The rivers' connection to larger marine ecosystems, such as the Babuyan Channel and the West Philippine Sea, enhances their role as settlement areas for migrating eels [5].The ecological importance of these rivers extends to various migratory species, underscoring the need for sustainable management to protect eel populations and overall ecosystem health.

Physical Characteristics of the Fishing Ground

The study measured various water parameters in the fishing grounds of the Palawig and Diora-Zinungan Rivers, as shown in Table 1. The temperature in both locations ranged from 25.05 to 27.50 degrees Celsius. In the Palawig River, the salinity was recorded at 2 ppt, dissolved oxygen levels ranged from 14.19 to 18.76 mg/L, and the pH was slightly alkaline, ranging from 8.02 to 8.1. In contrast, the Diora-Zinungan River had a higher salinity of 4 ppt, slightly lower dissolved oxygen levels ranging from 11.85 to 14.70 mg/L, and a similar pH range of 8.00 to 8.13.

Table 1: Mean Measurements of Water Parameters for the Months of March to May in the Palawig and Diora-Zinungan Rivers, Santa Ana, Cagayan.

Fishing Grounds	Temperature	Salinity	Dissolved oxygen	pH
Palawig				
March	25.05	2	18.76	8.1
April	25.33	2	14.19	8.02
May	25.15	2	14.68	8.1
Diora-Zinungan				
March	26.65	4	11.85	8.13
April	27.50	4	14.70	8
May	27.05	4	14	8.03

The Palawig and Diora-Zinungan Rivers provide favorable conditions for glass eels, with a temperature range of 25.05 to 27.50°C, which aligns with the optimal range for glass eel survival as noted by Smith et al. (2018)[16]. The Palawig River, with a salinity of 2 ppt, dissolved oxygen levels between 14.19 and 18.76 mg/L, and a pH of 8.02 to 8.1, offers better water quality compared to the Diora-Zinungan River, where salinity is higher at 4 ppt and dissolved oxygen levels are slightly lower, ranging from 11.85 to 14.70 mg/L. Both rivers maintain a pH range of 8.00 to 8.13, which is suitable for glass eel survival [17]. These findings indicate that the Palawig River may provide more optimal conditions for glass eel populations, supporting effective fisheries management strategies.

Length and weight measurements of glass eel (*Anguilla* spp.): The study revealed that glass eels caught in the Palawig and Diora-Zinungan Rivers have similar average lengths, measuring 51.57 mm and 51.75 mm, respectively (Table 2a). This indicates that the glass eels in both rivers are at a similar stage in their life cycle and likely belong to the same population or cohorts. However, a slight difference in average weight was observed, with eels from the Palawig River weighing 0.108 grams and those from the Diora-Zinungan River averaging 0.117 grams. As shown in Table 2b, statistical analysis found no significant differences in length ($p = 0.3986$-0.4337) or weight ($p = 0.4202$-0.4764) across different months, reinforcing the similarity between the populations.

The slight weight variation may be attributed to factors such as food availability, feeding habits, or environmental conditions [18]. These findings provide insights into the growth patterns and population dynamics of glass eels, which are critical for effective fisheries management and conservation [18].

Table 2a: Mean length and weight measurements of glass eel (*Anguilla* spp.) caught along Palawig and Diora-Zinungan Rivers, Santa Ana, Cagayan, from March to May

Fishing Grounds	March	April	May	Average
Palawig				
Length (mm)	51.54	51.78	51.39	51.57
Weight (g)	0.109	0.107	0.107	0.108
Diora-Zinungan				
Length (mm)	51.83	51.69	51.74	51.75
Weight (g)	0.11	0.113	0.11	0.117

Table 2b: The difference in the length and weight measurement of glass eel (*Anguilla* spp) caught along the Palawig and Diora-Zinungan Rivers, Santa Ana, Cagayan, from to March to May

Fishing Grounds	Mean	f-ratio	Proba	Inference
Palawig				
Length (mm)	51.57	0.8441	0.4337	NS
Weight (g)	0.108	0.4764	0.4281	NS
Diora-Zinungan				
Length (mm)	51.75	0.9671	0.3986	NS
Weight (g)	0.117	0.4083	0.4202	NS

Glass Eel Identification

In total, 258 anguillid eels were collected and examined in this study (see Table 3). Species identification was determined based on the presence of tail spots observed using a magnifying lens. The identification of the species of glass eels in the Palawig and Diora-Zinungan Rivers as *Anguilla marmorata* is a significant finding, with the presence of an arrow-shaped Tail Spot (TS)[12]. The *A. marmorata*, also known as the Giant Mottled eel, is a species of freshwater eel found in the Indo-Pacific region.

Table 3: Frequency Count of glass eel (*Anguilla* spp) caught along the Palawig and Diora-Zinungan Rivers, Santa Ana, Cagayan, from to May

***Anguilla* species**	**Palawig River**	**Diora-zinungan River**
Anguilla marmorata	207	51

The confirmation of *Anguilla marmorata* in the Palawig and Diora-Zinungan Rivers expands our understanding of eel biodiversity and distribution. Known for its distinctive pattern and large size, this species plays a crucial ecological and economic role in local fisheries. Its presence highlights the importance of monitoring water quality and habitat health, as eels are sensitive to environmental changes. This finding aligns with Ame et al. (2013) [5], who documented *A. marmorata* and other eel species in Philippine waters, including Santa Ana, Cagayan, supporting the need for conservation and management of these species.

Average Catch of Glass Eels: The average catch of glass eels from March to May highlights a disparity between the Palawig River and the Diora-Zinungan River. As shown in Table 4a, the average catch in the Palawig River was 0.63 grams, while the Diora-Zinungan River recorded a lower average of 0.34 grams. A comparison of these fishing grounds, presented in Table 4b, reveals a statistically significant difference in glass eel catches, supported by a t-value of 2.778 and a probability of 0.499. These findings indicate that while the Palawig River yields a higher catch, both rivers exhibit relatively low catches compared to other estuaries in Cagayan Valley, such as the Cagayan River [5]. This disparity could be attributed to factors such as fishing pressure, environmental conditions, and the fishing practices employed in these areas. Understanding the factors influencing glass eel populations is critical for improving fishing practices and implementing sustainable management strategies to ensure the long-term viability of these fisheries.

Table 4a: Mean Glass eel (*Anguillid spp*.) caught in grams from March to May along the Palawig and Diora-Zinungan River

Fishing Grounds	March	April	May	Mean
Palawig	0.7	0.55	0.64	0.63
Diora-Zinungan	0.176	0.32	0.51	0.34

Table 4b: Comparison on the mean catch (grams) of Glass eel (*Anguillid spp.)* when grouped according to fishing ground

Fishing Grounds	Mean	t-value	Probability	Inference
Palawig	0.63	2.778	0.0499	Significant
Diora-Zinungan	0.34			

Fishing Effort for Glass Eels

The CPUE for glass eels in the Palawig and Diora-Zinungan Rivers shows significant differences. Table 5a reveals that Palawig River has a higher average CPUE of 4.4 g, indicating greater eel abundance, while Diora-Zinungan River's CPUE is much lower at 0.0378 g. These findings align with Ame et al. (2013) [5], who observed similar seasonal variations in Cagayan, with March having the highest catches. Table 5b further highlights the variations in CPUE values, underscoring the importance of understanding seasonal eel availability for optimizing harvest strategies and guiding conservation efforts to ensure sustainable eel populations.

Table 5a: Mean Catch per unit Effort (CPUE) of glass eel (*Anguillid spp*.) along Palawig and Diora-Zinungan River for the Months of March to May

Fishing Grounds	March	April	May	Mean
Palawig River	11.9	0.59	0.64	4.4
Diora-Zinungan River	0.0166	0.0488	0.048	0.0378

Table 5b: Difference between the Catch per unit Effort (CPUE) of glass eel (*Anguillid spp.*) along the Palawig and Diora-Zinungan Rivers

Fishing Grounds	F ratio	Probability	Inference
Palawig River	3.0921	0.0481	Significant
Diora-Zinungan	0.0975	0.1052	Not Significant

Policy Recommendations

The conservation and sustainable management of glass eel populations in Santa Ana, Cagayan is crucial for the health of aquatic ecosystems and biodiversity. Glass eels contribute to ecological balance and support predator populations [19]. However, improving their numbers is only one aspect of a healthy ecosystem, as estuaries are critical habitats for many species.

Declines in eel populations, due to overfishing and habitat degradation [20], highlight the need for policies to protect them. Measures such as sustainable fishing practices, habitat restoration, and trade regulation are essential for both conservation and local economic benefit. Furthermore, preserving eels' cultural significance and supporting research and education will help safeguard both traditions and ecosystems [21, 22].

The following policy recommendations aim to ensure sustainable management

1. The glass eel fisheries at Santa Ana, Cagayan may implement catch limits in March, April, and May. This is to prevent overfishing and ensure the sustainability of eel populations. 83% of the respondents recommended the implementation of catch limits during these months. This significant majority suggests strong support for measures aimed at preventing overfishing and promoting sustainability in the glass eel fisheries at Santa Ana, Cagayan.
2. Fyke nets used to catch fish other than glass eels may be monitored and regulated to prevent unintentional capture of glass eels. The Local Government Unit of Santa Ana, Cagayan should specify the minimum mesh size of fyke nets to prevent the capture of glass eels. By setting a minimum mesh size, the nets can target larger fish species while allowing smaller glass eels to pass through unharmed.

Conclusions

The study on glass eel (*Anguilla* spp.) stocks in the Palawig and Diora-Zinungan Rivers in Santa Ana, Cagayan, revealed that these rivers provide optimal environmental conditions for glass eel migration and survival, supported by their proximity to the sea and tidal dynamics. The primary fishing gear, the locally designed fyke net, demonstrates sustainable ingenuity but raises concerns over unintentional glass eel captures, prompting recommendations for mesh size regulations. Variations in glass eel abundance, measured through catch per unit effort (CPUE), showed higher values in the Palawig River compared to Diora-Zinungan. To ensure sustainability, the study proposed policy measures such as catch limits during peak spawning months, gear regulation, and long-term population monitoring. These findings underscore the ecological importance of these rivers, emphasizing the need for sustainable management to protect glass eel populations, support local livelihoods, and preserve aquatic ecosystem health in the region.

Acknowledgement

The author would like to express sincere gratitude to the faculty of Isabela State University - Roxas Campus for their unwavering academic support throughout the course of this study. The author also extends heartfelt appreciation to their family and to Mr. Johnrey A. Antipaso for their constant encouragement and dedication, which played a crucial role in the successful completion of this manuscript. Special thanks are due to the respondents who participated in the study. The successful completion of this work would not have been possible without their generous assistance.

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