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Ethnoeconomic significance and sustainability of *kepah* (*Meretrix meretrix*) harvesting in Bagan Asahan, North Sumatra, Indonesia

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Abstract. *Purwoko A, Latifah S, Bakti D, Suratman MN, Tanjung JA, Tsaqofi NU. 2026. Ethnoeconomic significance and sustainability of kepah* (Meretrix meretrix) *harvesting in Bagan Asahan, North Sumatra, Indonesia. Asian J Ethnobiol 9: y090110. https://doi.org/10.13057/asianjethnobiol/y090110.* Mangroves play a crucial role in the aquatic food chain, supporting a variety of aquatic biota, including *kepah* or Asiatic hard clam (*Meretrix meretrix*). This study aimed to determine the production and economic value of *kepah*, its contribution to household income, and the factors influencing the income of *kepah* fishermen. This study was conducted in Bagan Asahan, a center of *kepah* production in North Sumatra, Indonesia, with a global market reach. Primary data were collected through a survey and analyzed using descriptive and explanatory statistics. Backward linear regression was used to examine factors suspected of influencing the income of *kepah* fishermen. Local knowledge and practices in utilizing *kepah* natural resources were explored to enrich insights into wisdom and sustainability. This study provides data on the production and economic value of *kepah* caught by fishermen throughout the year, as well as the level of economic dependence on this resource. The study found that *kepah* fish contributed 74.64% to the total household income of *kepah* fishermen, categorized as a "major contribution". The study also produced a model to estimate the income of *kepah* fishermen, with significant variables including boat ownership, gender, age, fishing duration, and fishing gear type. The scientific implications of this study are expected to encourage stakeholders to play a more effective role in promoting the growth of *kepah* fishermen's income, while still prioritizing local wisdom in sustainable *kepah* harvesting practices.

Keywords: Bagan Asahan, economic valuation, fishermen's livelihood, *kepah* (*Meretrix meretrix*), mangrove

INTRODUCTION

Mangroves are the most productive tidal ecosystems for fishing crabs, shrimp, and mollusks in large quantities (Primavera et al. 2019). Mangroves provide protection, shelter, and foraging grounds for macroinvertebrates, including *kepah* or Asiatic hard clam (*Meretrix meretrix* (Linnaeus, 1758)), which can adapt to withstand currents and waves (Desrita et al. 2019). *Meretrix meretrix* are members of the Mollusca phylum, which includes the shellfish class and is included in the invertebrate animal group (Rimelahas et al. 2022). The presence of these Molluscs in the mangrove ecosystem plays an important role because they can aid in the decomposition process (Karimah 2017). Molluscs can tear and reduce newly fallen leaf litter, accelerating the decomposition process. Lan et al. (2024) also detailed that bivalves play a crucial role in the ecosystem, specifically through their role in filtration.

Kepah is the local name for a type of seashell belonging to the bivalve group that has two symmetrical, clean, shiny shells. This name is popular in almost all coastal areas inhabited by Malay people, including in Malaysia (Budin et al. 2013; Yadzir et al. 2015). In some coastal areas, it is called by a different dialect, namely *'kapah'*, especially in Kalimantan (Wiharyanto 2012; Pamungkas and Pryambada 2024). *Kepah* and mangrove ecosystems are closely related. For *kepah*, mangroves have a role as a water filter, food source, protection from predators, and breeding place (Wolf 2012; Kabir et al. 2014). *Kepah* eat plankton by filtering seawater, thereby improving water quality in mangrove forests and reducing eutrophication (Kreeger et al. 2018; Petersen et al. 2019; Rullens et al. 2019). The *kepah*' living behavior of attaching their shells to mangrove roots helps stabilize sediments, prevent erosion, and protect coastlines (Fillyaw et al. 2021; Schlacher et al. 2022). *Kepah* also play a role in providing habitat for various small organisms in the waters, thereby increasing biodiversity in mangrove forests. *Kepah* will ultimately attract predators and other larger animals, such as birds and fish, which utilize the mangrove ecosystem as a habitat for part or all of their life cycle (Gosling 2008; Mitra and Zaman 2016).

Kepah has potential and high economic value, but it has not been utilized optimally as a natural resource that can serve as a source of livelihood for the community (Summa et al. 2022; Bahtiar et al. 2023; Martini et al. 2023). Lan et al. (2024) also explained that various economically important bivalve species (including those other than *M. meretrix*, such as *Magallana gigas* (Thunberg, 1793), and *Perna viridis* (Linnaeus, 1758)). Sulistiyaningsih and Arbi (2020) also reported that in Indonesia, there is a type of shellfish with high economic value, namely the genus *Anadara*. This genus is primarily known for its edible marine species and

is one of the most abundant mollusk families in tropical waters. This type of shellfish is distributed in almost all coastal waters and is found at the bottom of the subsystem. The delicious taste of *kepah* is due to a combination of several factors such as the chewy and soft texture, the influence of the slightly salty taste of the sea, the savory taste from the protein content, and from fat and mineral content that enrich the taste. (Sakila et al. 2018; Bahtiar et al. 2023; Hutomo et al. 2023).

The abundant production of *kepah* caused almost all of the fishermen in Bagan Asahan Village, North Sumatra, Indonesia, to work as *kepah* catchers. Various methods and tools for catching *kepah* have long been developed in this area, indicating that the Bagan Asahan community has traditionally used it as a way of harvesting *kepah*, a possibility that warrants investigation as a form of local wisdom. In addition to being fishermen, some people still have professions that are also related to *kepah*, such as trade, processing, crafts, and *kepah*-based tourism. Various forms of traditional *kepah* processing have been mastered by the community for generations (Fitrisia 2018; Samrin et al. 2018; Hidayati 2021; Amalia and Rivai 2022; Kinanti et al. 2024; Nanda et al. 2024). From an anthropological perspective, the profession of catching *kepah* is often stated as a form of marginalisation of the Malay community in the coastal area (Hakim 2024). However, *kepah* has become the backbone of the socio-economic life of the people of Bagan Asahan. This economic culture has become a common phenomenon in coastal areas across Southeast Asia.

The mangrove ecosystem provides proven economic benefits, serving as the main livelihood of the community in Bagan Asahan (Sihotang et al. 2017; Arif et al. 2019). The benefits of this mangrove forest will significantly improve the coastal communities if appropriately managed and sustainably (Amir et al. 2021). The greater the value of the economic benefits, the greater the urgency for preserving the mangrove ecosystem that supports them. The greater the community's dependence on mangrove benefits through kephal fishing, the greater the need for community awareness, attention, and action to maintain the ecosystem's balance. Moreover, Sulistiyaningsih and Arbi (2020) reported that cultural practices and ecological pressures threaten the sustainability of various bivalve species in Indonesia. A study in the Mon Coastal Area, Myanmar (Oo 2020), also noted how habitat degradation (due to human use) threatens the community's dependence on these resources. Therefore, this study was conducted to analyze the characteristics of production and its contribution to the community's economy, examine the factors that influence the income of *kepah* fishermen, and develop a model to predict their income. A quantitative ethnoeconomic analysis approach to the *kepah* fishery was chosen to produce findings that combine quantitative dimensions and local practices to maintain the sustainability of *kepah* production in Bagan Asahan. It is hoped that this research will produce policy recommendations and practices for sustainable *kepah* fishing in Bagan Asahan, North Sumatra, Indonesia, based on local wisdom.

MATERIALS AND METHODS

This research was conducted around the mangrove ecosystem area of Bagan Asahan, Tanjungbalai Sub-district, Asahan District, North Sumatra Province, Indonesia. The geographical coordinates of Bagan Asahan Village are 30 00'53.65"N - 990 57'12.27"S, with an altitude of 2 meters above sea level.

Data collecting

Statistical model development

This study was conducted through a survey and direct observation. The population in this study was all *kepah* fishermen in the waters of Bagan Asahan Village, Tanjungbalai Sub-district, Asahan District, totaling 246 people (Bagan Asahan Village Office 2023). The sampling method used was purposive sampling, where respondents were selected based on previously determined characteristics (Campbell et al. 2020). The Slovin formula was used with a 10% error tolerance limit (Tejada and Punzalan 2012; Purwoko et al. 2023), and 71 respondents were selected as the research sample (Suparyana et al. 2022). Slovin's formula is a method for calculating the minimum number of samples (n) that are representative of a known population (N), taking into account the level of error tolerance (e). The Slovin formula used is as follows:

$$n = \frac{N}{1 + Ne^2}$$

Respondents were selected randomly. Data were collected through interviews with selected respondents at their homes and during their *kepah*-finding activities. Interviews were conducted voluntarily and independently, with the assurance that respondents' identities would be kept confidential. The questions asked were about production, economic value, *kepah* contribution to total household income, and anthropogenic factors that influence the income of *kepah* fishermen (type of fishing gear, number of groups per boat, distance of the point of collection from the mangrove, distance of the point of collection from the coast, age, gender, experience at sea, duration of fishing, and boat ownership).

Local knowledge documentation

Local knowledge documentation was conducted through in-depth interviews with representative community members. The community representatives interviewed included representatives from *kepah* fishermen, female fishermen, *kepah* processors, *kepah* traders, village leaders, and relevant officials from the Asahan District Government. The in-depth interviews were conducted with the assistance of local assistants who were familiar with the local language and culture.

Data analysis

Kepah*'s production analysis*

The economic value of *kepah* is obtained from the net selling price received by fishermen. Monthly *kepah* production is obtained by adding up the catches of all fishermen according to the frequency of catches each

month. To calculate the contribution of *kepah* fishermen's income, the income from the studied sector is compared to the total income of the respondent's household (Weldeslassie et al. 2019). The formula used by Dewi et al. (2018) and Latifah et al. (2020) in their research to calculate the contribution of community forests can also be applied in this study. To determine how large or small the contribution of *kepah* fishermen to total household income is, it is measured using the following classification (Hanum et al. 2018; Lubis et al. 2029):

- If the contribution is ≤ 50% of the total family income, the contribution is classified as small.
- If the contribution is > 50% of the total family income, the contribution is classified as large.

PKm = KCd x NC x Cfm

Where, PKm: Monthly production of *kepah* (kg/month), KCd: Daily *kepah* catch (kg/day), NC: Number of catchers, CFm: Monthly catch frequency

Economic value analysis

VK = SP x PK

Where, VK: Economic value of *kepah* (IDR/month), SP: Selling price of *kepah* (IDR/kg), PK: Production of *kepah* (kg/month)

Analysis of kepah *contribution to total household income*

To calculate the contribution of *kepah* fishermen's income, the income from the studied sector is compared to the total income of the respondent's household (Weldeslassie et al. 2019). The formula used by Dewi et al. (2018) and Latifah et al. (2020) in their research to calculate the contribution of community forests can be applied in this study as well.

$$CK = \frac{IK}{IH} \text{ x } 100\%$$

Where, CK: Contribution of *kepah* fishermen's income to total household income (%), IK: Income from *kepah* catching (IDR), IH: Household income (IDR)

Factors that affect the kepah *fishermen's income*

This study employs descriptive and multiple linear regression analysis to examine the influence of various variables. Regression analysis is a statistical technique to measure the estimated relationship between variables (Uyanık and Güler 2013). The linear regression model aims to explain the spatial distribution of the dependent variable through a combination of independent variables (Forkuor et al. 2017). Based on the results of the calculations, nine variables are to be analyzed. The multiple linear regression model used is as follows (Fumo and Biswas 2015; Torkashvand et al. 2017):

$Y = \beta o + \beta_1X_1 + \beta_2X_2 + \beta_3X_2 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + e$

Where, Y: Total income of *kepah* fishermen (IDR/month), βo: intercept or constant, β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8: regression coefficient, X_1: Type of fishing gear, X_2: Number of groups per boat (people), X_3: Distance of the catching point from the mangrove (km), X_4: Age (years), X_5: Gender, X_6: Experience in *kepah*'s catching (years), X_7: Duration of working (hours), X_8: Boat ownership, e: Standard error

Classical assumption test

Classical assumption testing is a prerequisite for testing using multiple linear regression analysis. The classical assumption test ensures that the data to be analyzed is normally distributed (normality test), and the model does not contain multicollinearity and heteroscedasticity, as used by Alita et al. (2021).

Hypothesis testing

Hypothesis testing was conducted through multiple linear regression analysis using the backward elimination method. This method was employed to obtain the best estimating model, namely one with the most efficient number of significant predictors that still yields a high coefficient of determination (Mishra et al. 2019; Mishra et al. 2019).

The coefficient of determination, which is a measure of the suitability of the regression line to the data, is used to see the magnitude of the influence of the independent variable on the dependent variable and is expressed in percentage form (Roshitafandi et al. 2018). The value of the coefficient of determination (Kd) is between 0 and 1 (0 ≤ Kd ≤ 1). The magnitude of the influence of the independent variable on the variation (increase or decrease) of the dependent variable refers to the Kd value itself, and the remaining factors are attributed to other variables not observed in this study (Printrakoon et al. 2019). The equation for determining the coefficient of determination is as follows:

$Cd = r^2 \times 100\%$

Where, Cd: Coefficient of Determination, r^2: Coefficient of Correlation

F-test (simultaneous test), used to test the level of significance of the influence of independent variables simultaneously on the dependent variable. With the provisions: H0 = all independent variables (anthropogenic) simultaneously do not have a significant effect on the income of *kepah* fishermen, and H1 = all anthropogenic variables as predictors simultaneously have a significant effect on the income of *kepah* fishermen. The F-test is carried out using the SPSS software with a significance (α) of 0.05.

T-test (partial test), used to test the level of significance of the influence of independent variables on the dependent variable. With the provisions: H0 is accepted if $\beta i = 0$, meaning that all predictor variables (anthropogenic) partially do not have a significant effect on the income of *kepah* fishermen, and H1 is accepted if $\beta i \neq 0$, meaning that there are anthropogenic variables that partially have a significant effect on the income of *kepah* fishermen. The t-test can be carried out using the SPSS program with a significance (α) of 0.05.

RESULTS AND DISCUSSION

Analysis of *kepah* production

The production of *kepah* is the total production obtained from *kepah* fishing activities by *kepah* fishermen per unit of time in Bagan Asahan Village, Asahan District. Table 1 shows that the Asahan waters still have abundant *kepah* resources. This abundance is also an ecological indication that the Bagan Asahan ecosystem is a suitable habitat for *kepah* growth and development (Filgueira et al. 2013; Su et al. 2018). Bagan Asahan is the estuary of a large river (Asahan River). This river is quite long, as it originates from Lake Toba, where an intake is used as a hydroelectric power plant, ensuring the discharge of the Asahan River is maintained even during the dry season (Riyadi et al. 2024). The flow of this river carries surface erosion from areas with various types of land use, resulting in a high substrate content (Pakpahan et al. 2024). This finding aligns with research in Paradeep, India, which indicates that *kepah* are abundant near estuaries because they prefer grassy areas and tidal zones (Yadav et al. 2019). This is due to the high abundance of organic material in the substrate and is supported by the value of physicochemical factors (Deni et al. 2020). *Kepah* can live by attaching to the surface of the substrate, inside the substrate, or on mangrove trees (Dewi et al. 2023).

The abundance of *kepah* in this ecosystem is also related to abiotic parameters that are relatively suitable as *kepah* habitat. Salinity in Bagan Asahan varies at each station, with averages of 5.66 ppt, 6 ppt, and 7.66 ppt. His research on molluscs in Kebumen, Central Java, revealed that abiotic parameters (temperature, pH, humidity, and salinity) are crucial factors influencing the existence of *kepah*, and that the optimal temperature for mollusc growth is between 20°C and 30°C (Ratih et al. 2021). His research in Muara Betahwalang Demak (Shalihah et al. 2017) explained that the optimal pH range for maintaining the existence of molluscs is 6.5-7.5. The average water temperature in Bagan Asahan, North Sumatra, varies depending on the location and time of measurement. In general, the water temperature in Bagan Asahan ranges between 25°C and 30°C. This is influenced by air temperature, solar radiation, and water currents. Korolev et al. (2021) reported on water temperature in Bagan Asahan waters during the dry and rainy seasons, with average results of 29.8°C in the dry season and 27.2°C in the rainy season. Thus, the salinity in Bagan Asahan is indeed suitable for the habitat and growth of *kepah* (Shalihah et al. 2017; Ratih et al. 2021).

Kepah in Bagan Asahan are generally found living buried in sandy substrates. This follows the findings of Triandiza et al. (2019) on Kei Island, Maluku, which spanned from the coast to approximately 300 m into the river body (Yusseppone et al. 2018). They live in fine sand that is inundated at high tide and dry at low tide (Roshitafandi et al. 2018; Printrakoon et al. 2019). The mangrove ecosystem is a habitat for a variety of mollusks. Suitable environmental conditions for mollusks' life will help them play an important role in the mangrove ecosystem (Wiraatmaja et al. 2022). Mangroves are beneficial for human life and the surrounding environment (Menéndez et al. 2020). For residents in coastal areas, mangroves have been utilized for various purposes for a long time (Barbier et al. 2016; Hochard et al. 2019).

As a comparison of *kepah* production data from field surveys, the following is presented secondary data on *kepah* production from Bagan Asahan, sourced from the Fisheries and Maritime Service of Asahan District for the past four years. Table 2 shows that there are fluctuations in *kepah* production every year in Bagan Asahan Village, but annual *kepah* production tends to be stable at 1,400-1600 tons. Seasonal factors mainly influence annual production fluctuations. If there are frequent floods or the river water discharge is too large, then *kepah* fishing activities are more challenging to do. There are several ways to catch *kepah*, from traditional to modern fishing gear, including using gloves, iron rakes, and *kepah*'s 'tank' (Figure 1). The *kepah* catcher in Bagan Asahan Village is still classified as a conventional fisherman. The Bagan Asahan fishermen used gloves and a rake (local people call it "*garuk"*). *Garuk* is a traditional tool used by fishermen to catch *kepah*, especially in muddy coastal areas such as Tanjungbalai and other parts of the east coast of Sumatra, even as far away as West Java (Desrita et al. 2019; Susilawati 2022). This tool is not only functional but also has strong ethnic and cultural dimensions. *Garuk* are made by the fishermen themselves using techniques and knowledge passed down through generations. Local fishing leaders explain that the rake's design also reflects the wisdom of the local community in understanding and adapting to the coastal ecosystem in their area. Furthermore, the use of the rake also symbolizes the tradition of cooperation, where they usually work with an average of three people in a team. The boats used by fishermen are also made of wood, designed and built by the local community themselves, based on local knowledge that has become an integral part of their culture.

Table 1. Total *kepah* production by fishermen in Bagan Asahan Village, Tanjung Balai Sub-district, Asahan District, North Sumatra Province, Indonesia (Bagan Asahan Village 2023)

Production/day (ton)	Production/month (ton)	Production/year (ton)
11.14	222.96	2,675

Note: *Kepah* fishing is carried out on average 20 days a month. Only mature *kepah* is harvested (not passed through the rake filter)

Table 2. *Kepah* production per year in Bagan Asahan, Tanjung Balai Sub-district, Asahan District, North Sumatra Province, Indonesia

Marine commodities	Year			
	2018	2019	2020	2021
Kepah production (tons)	1,420	1,394	1,612	1,495

Source: Asahan District Fisheries Service (2022)

Gloves are the traditional and simplest fishing gear used in catching *kepah* in the waters of Bagan Asahan. This method is usually used when the water has receded to around human knee level, by feeling the *kepah* at the bottom of the water-inundated mud surface, then continuing to move. In addition to using gloves, rakes are also commonly used in the *kepah*'s catching. Rakes are traditional fishing gear that are easy to use in *kepah* catching operations in the waters of Bagan Asahan, Asahan District. This tool is made of iron, measuring approximately 0.40 m × 0.25 m, with a wooden handle (1.5-2 m length). People in Bagan Asahan believe that using gloves and rakes during the *kepah*-catching process in the waters of Bagan Asahan can help maintain the marine and mangrove ecosystems. The material and design of this clam rake represent a form of local knowledge that has been passed down through generations and is sustainable. This is reflected in the diameter of the rake hole, which has been adapted to the morphology of the clam, so that only mature clams will get caught in the rake. In contrast, smaller juveniles with smaller diameters will escape and return to nature to grow. For comparison, in Rhode Island, any tools used to harvest *kepah* recreationally, such as hands, feet, and simple gardening tools like rakes, pitchforks, and hand shovels (Cygler 2016). The use of gloves and rakes also occurs in the French Polynesian atoll (Van Wynsberge et al. 2015). *Kepah* fishermen in the Downeast and Acadia regions of Maine also use the same harvesting method (using hands and gloves). Unlike in Bagan Asaha, some fishermen still use their hands. *Kepah* harvesting in both fisheries is reported to often cause wounds on the hands caused by cuts, abrasions, and cold temperatures. These wounds are caused by scratches from broken shells and sharp rocks, which often cause infections, sometimes resulting in long-term physical disabilities and chronic pain. Therefore, *kepah* harvesting with bare hands is no longer carried out in Bagan Asahan (Johnson et al. 2023).

Currently, some fishermen use illegal methods to catch *kepah* in Bagan Asahan waters, namely "*kepah*'s tank". The community uses this name to refer to a type of trawler that is specifically designed to catch *kepah*. *Kepah* trawls are also often called "Thai tank", because this type of trawl is usually imported from Thailand. This trawler type is also used in several other waters in Indonesia, such as in the Ketapang waters of West Kalimantan Province (Priyanto 2010). In Thailand itself, this trawl has been used since 1995 (Sampantamit et al. 2019). These *kepah* fishing vessels (trawlers) can catch large quantities of *kepah* at once, which can damage the marine ecosystem. Economically, the use of *kepah* trawling is detrimental to existing traditional fishermen (Fitri et al. 2018) due to their ability to catch +10 tons of *kepah* per day. In its operation, this trawl sweeps the entire shoal surface, allowing it to catch more *kepah*, but it has high destructive power on the coastal substrate. If carried out continuously, it will affect the future income of *kepah* fishermen, as fishing exceeds the carrying capacity of the aquatic ecosystem.

The existence of *kepah* trawlers operating in this area also caused horizontal conflicts. Non-trawl fishermen often carry out security raids and expel *kepah* trawls that operate in this area. However, the existence of *kepah* trawl is currently difficult to eliminate because of their financial power. The community also complains about the indifference of individuals who should be tasked with supervising and enforcing the law (Chandra 2023).

Economic value of *kepah* and its contribution to total household income

Economic value of kepah

Kepah is a very familiar seafood commodity. *Kepah* also has high nutritional content and is suitable for health (Gopalakrishnan and Vijayavel 2009; Xie et al. 2012). *Kepah* can also be used in soups, noodles, fried rice, and various other seafood dishes. The market for *kepah* and processed products is very open, from local buyers to export markets. Table 3 shows that the total economic value generated from the sale of *kepah* each year is equivalent to USD 328,768.74/year or USD 1,369.87/day. The selling prices were obtained from interviews with *Kepah* fishermen and collectors, and traders (locally known as 'toke') at Bagan Asahan Pier. The net selling price paid by traders is IDR. 2,000/kg. This price is fixed because *kepah* collectors in Bagan Asahan are often controlled by large traders who are connected to *kepah* processing companies in Tanjungbalai City, the closest port city to Bagan Asahan.

A **B** **C**

Figure 1. A. Catching *kepah* in Bagan Asahan, North Sumatra, Indonesia, using gloves in a collaborative manner involving women and young fishermen in shallower water areas at low tide, B. Catching *kepah* using a rake by Bagan Asahan fishermen, which is done in groups using a boat, C. Catching *kepah* using a *kepah*'s tank is still occurring in Bagan Asahan waters, even though it is officially prohibited

Table 3. The economic value of *kepah* in Bagan Asahan, Asahan District, North Sumatra Province, Indonesia (Bagan Asahan Village 2023)

***Kepah* production**	**Production/day**	**Production/month**	**Production/ year**
Amount of *kepah* (ton)	11.14	222.96	2,675
Economic value *kepah* (IDR)	22,296,000	445,920,000	5,351,040,000
Fishermen's income (IDR)	90,930	1,818,592	21,823,104

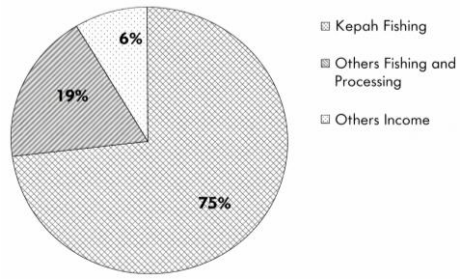

Figure 2. The contribution of *kepah* to fishermen's income in Bagan Asahan, Asahan District, North Sumatra, Indonesia

Kepah *contribution to fishermen's income*

The average total income of fishermen from catching *kepah* is IDR 1,818,592/person/month. Based on Figure 2, the average monthly income of fishermen is IDR 2,436,620/person. The contribution of *kepah* to the total income of the fisher household is 75%. According to the classification used by Hanum et al. (2018) and Lubis et al. (2019), if the contribution is ≤ 50% of the total family income, then the contribution is classified as small, but if the contribution is > 50% of the total family income, then the contribution is classified as 'large contribution'. This fact indicates that most of the household income of fishermen in Bagan Asahan is derived from *kepah* fishing. This contribution is highly significant and has become a crucial resource for the community. Catching *kepah* makes a high contribution to meeting the needs of fishermen's households, such as food, housing, education, and so on. Meeting food needs is a primary allocation, given that coastal communities generally pay little attention to housing needs (Alamsyah et al. 2020; Asmal et al. 2022). Education up to the junior high school level does not require a significant budget allocation, as the government covers it. Meanwhile, further education up to university level remains a relatively low priority for the Bagan Asahan community, a common cultural issue in coastal communities (Cahaya 2015). Other sources of income for the Bagan Asahan community include catching non-shellfish (such as fish, shrimp, and crab), aquaculture, agriculture, and trade and processing industries related to the fisheries and agricultural sectors. Fisheries cultivation in this area is hampered by the status of a large portion of the coastline as a mangrove forest area. Agricultural cultivation is also underdeveloped due to the unsuitable land characteristics in this area and the high salinity levels caused by seawater intrusion (Onrizal 2010; Ma'ruf 2019).

Decrease in fishermen's catch

Traditional *kepah* fishermen in Bagan Asahan stated that, in recent years, the catch has generally decreased, especially after the COVID-19 pandemic, with an average production of 1480.25 tons/year (Asahan District Fisheries Service 2022). In terms of quantity, the number of *kepah* fishermen does not show a significant increase, because *kepah* fishermen only come from local villagers. Traditional professions, such as *kepah* catching, are always less popular with educated young generations. The decline in *kepah* catches occurred more due to the presence of modern *kepah* fishermen who use *kepah* trawls (*kepah* tanks) in their fishing activities. In addition to its large catch capacity, *kepah* fishing with *kepah* tanks also damages the habitat and reduces the carrying capacity, thereby compromising the sustainability of natural *kepah* production. Due to being pressured by the operation of *kepah* tanks, traditional fishermen are forced to choose alternative fishing zones outside the *kepah* tank operating zone. This zone tends to lead to the edges and shallower waters with generally smaller catches.

Factors affecting fishermen's income

Classical assumption test

In linear regression analysis, we can include more parameters to find better predictors. This analysis is known as multiple linear analysis (Pandis 2016). Multiple linear regression analysis is used to analyze the factors that influence the income of *kepah* fishermen in Bagan Asahan Village. These variables include X_1 (type of fishing gear), X_2 (number of groups per boat), X_3 (distance of the point of collection from the mangrove), X_4 (age), X_5 (gender), X_6 (experience at sea), X_7 (duration of fishing), X_8 (boat ownership), and Y (fisherman's income). Before testing the hypothesis, a classical assumption test was conducted, including normality, multicollinearity, and heteroscedasticity (Ainiyah et al. 2016; Alita et al. 2021). The SPSS 25 program was used to check normality using the Kolmogorov-Smirnov test (Dalimunthe and Pane 2021). To determine the results, a Monte Carlo (2-tailed) test (Zhang 2014) was conducted. The significance value of 0.276 is greater than 0.05, indicating that the data are normally distributed (Korkmaz et al. 2014). The multicollinearity test in this study produced a VIF value <10 and a tolerance> 0.1 for all variables. This shows that there is no multicollinearity in this regression model (Daoud 2017; Atmadja et al. 2019; Senaviratna and Cooray 2019). Furthermore, a heteroscedasticity test was conducted using the Glejser test; the significance values for all variables were greater than 0.05. This indicates that there is no heteroscedasticity problem in this regression model, making it a suitable model (Nwakuya and Nwabueze 2018; Uyanto 2022) (Appendices 1, 2, and 3).

Coefficient of determination (R^2)

The coefficient of determination is used to see the predictor variable's ability to explain the diversity in the response variable. The range of determination coefficient values is 0-1 (Zhang 2017). The higher the R^2 or closer to one, the better the model used (Piepho 2019). Based on the results of multiple linear analysis using the backward method as used by Nasution et.al. (2025) and Mboya et al. (2023), the coefficient of determination from various stages of predictor elimination is obtained as follows (Table 4).

Table 4 shows that the coefficient of determination (R^2) in the best model is 0.959, illustrating a strong relationship. The Adjusted R Square value of 0.959 indicates that 96.2% of the diversity of *kepah* fishermen's income can be explained by the diversity variables in variables X_1 (type of fishing gear), X_4 (age), X_5 (gender), X_7 (duration of fishing), and X_8 (vessel ownership). While another factor (3.8%) is not observed in this study.

Simultaneous test (F-test)

Simultaneous tests will be conducted to determine the effect of X_1 (type of fishing gear), X_2 (number of groups per boat), X_3 (distance of the fishing point from the mangrove), X_4 (age), X_5 (gender), X_6 (fishing experience), X_7 (duration of fishing), X_8 (boat ownership) together on the income of *kepah* fishermen (Y). If the significance value is 0.05, it means that the independent variables simultaneously affect the dependent variable (Elamir 2020). Based on the results of multiple linear analyses using SPSS, the simultaneous significance test (F-test) yields the following results (Table 5).

Table 5 shows that, according to the F-test, there is a significant simultaneous influence of all independent variables used, including X_1 (type of fishing gear), X_4 (age), X_5 (gender), X_7 (duration of fishing), and X_8 (ship ownership). The F-count value of 328.86 is larger than the F-table value of 2.089, and the F significance value of 0.000 is far below 0.05. Simultaneously, the model predictor variables have a significant effect on the income of *kepah* fishermen in Bagan Asahan, Asahan District. With a 95% confidence level or a significance level of 0.05, it can be stated that H1 is accepted (proven).

Partial (T-test)

The t-test measures the individual influence of one independent variable on explaining the dependent variable. The test was carried out using a 5% significance level (α = 0.05). The partial test is used to test the significance of the regression coefficient of each independent variable. If the significance value is > 0.05, then the null hypothesis is accepted (the regression coefficient is not significant). This means that the independent variable does not affect the dependent variable, vice versa (Mishra et al. 2019; Mishra et al. 2019). Here is the multiple linear regression model from the SPSS results (Table 6).

Based on the regression coefficient of each variable, the following regression model is obtained:

$$Y = -9.452 + 18{,}542X_1 + 0{,}227X_4 + 11{,}690X_5 + 3{,}799X_7 + 0{,}892X_8 + e$$

This model demonstrates that the diversity of income values among *kepah* fishermen is influenced by the variables of fishing gear type, age of the fishermen, gender, duration of fishing, and boat ownership. In general, this model shows that efforts to increase the income of *kepah* fishermen can be done by intervening in the five predictor variables with a 95% confidence level.

The results of multiple linear regression testing using the backward method (Table 6) revealed that, out of the eight independent variables studied, only five had a significant influence on the income of *kepah* fishermen in Bagan Asahan Village, Tanjung Balai Sub-district, Asahan District. The four variables are the type of fishing gear, age of fishermen, gender, duration of fishing, and boat ownership. This can be seen in the Sig column, which displays the four independent variables have a significance value below 0.05 and the T-count value> T-table (1.998), namely the type of fishing gear (0.000), age (0.000), gender (0.000), duration of fishing (0.021), and boat ownership (0.048). In contrast, the other four predictor variables have significance values above 0.05, namely the number of groups per boat, the distance of the fishing point from the mangrove, and experience at sea.

Table 4. Test results for the determination coefficient value

Model	R	R square	Adjusted R square	Std. error of the estimate
1	.982[a]	.964	.960	2.94090
2	.982[b]	.964	.960	2.92196
3	.981[c]	.963	.960	2.94090
4	.981[d]	.962	.959	2.96992

Note: a: Predictors: (constant), boat ownership, distance of the point of collection from the mangrove, fishing experience, number of groups per boat, gender, age, duration of fishing, type of fishing gear; b: Predictors: (constant), boat ownership, fishing experience, number of groups per boat, gender, age, duration of fishing, type of fishing gear; c: Predictors: (constant), boat ownership, fishing experience, gender, age, duration of fishing, type of fishing gear; d: Predictors: (constant), boat ownership, gender, age, duration of fishing, type of fishing gear

Table 5. The F-test significance value result

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	14540.418	8	1817.552	210.149	.000[b]
	Residual	536.230	62	8.649		
	Total	15076.648	70			
2	Regression	14538.762	7	2076.966	243.265	.000[c]
	Residual	537.886	63	8.538		
	Total	15076.648	70			
3	Regression	14523.119	6	2420.520	279.865	.000[d]
	Residual	553.529	64	8.649		
	Total	15076.648	70			
4	Regression	14503.319	5	2900.664	328.857	.000[e]
	Residual	573.328	65	8.820		
	Total	15076.648	70			

Note: b: Predictors: (constant), ship ownership, distance of the point of extraction from the mangrove, fishing experience, number of groups per boat, gender, age, duration of fishing, type of fishing gear; c: Predictors: (constant), ship ownership, fishing experience, number of groups per ship, gender, age, duration of fishing, type of fishing gear, d: Predictors: (constant), ship ownership, fishing experience, gender, age, duration of fishing, type of fishing gear, e: Predictors: (constant), ship ownership, gender, age, duration of fishing, type of fishing gear

Table 6. The t-test significance values result

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.955	25.704		-.115	.909
	Type of fishing gear	17.885	1.535	.965	11.648	.000*
	Number of groups	.478	.402	.054	1.189	.239
	Distance from mangroves	-3.755	8.584	-.018	-.437	.663
	Age	.142	.078	.081	1.826	.073
	Gender	-11.124	3.968	-.176	-2.803	.007*
	Fishing experience	.080	.066	.047	1.222	.226
	Duration of fishing	4.589	.884	.252	5.191	.000*
	Boat ownership	.864	.377	.063	2.291	.025*
2	(Constant)	-13.816	6.616		-2.088	.041
	Type of fishing gear	17.493	1.239	.944	14.114	.000*
	Number of groups	.522	.386	.060	1.354	.181
	Age	.127	.070	.072	1.826	.073
	Gender	-10.823	3.883	-.171	-2.787	.007*
	Fishing experience	.087	.064	.051	1.364	.177
	Duration of fishing	4.627	.874	.254	5.293	.000*
	Boat ownership	.886	.371	.065	2.387	.020*
3	(Constant)	-8.263	5.224		-1.582	.119
	Type of fishing gear	18.756	.821	1.012	22.841	.000*
	Age	.150	.068	.085	2.206	.031*
	Gender	-13.673	3.284	-.216	-4.163	.000*
	Fishing experience	.096	.064	.057	1.513	.135
	Duration of fishing	3.982	.738	.218	5.398	.000*
	Boat ownership	.863	.373	.063	2.312	.024*
4	(Constant)	-9.452	5.216		-1.812	.075
	Type of fishing gear	18.542	.817	1.000	22.700	.000*
	Age	.227	.046	.129	4.898	.000*
	Gender	11.690	3.041	.185	3.844	.000*
	Duration of fishing	3.799	.735	.208	5.170	.000*
	Boat ownership	.892	.376	.065	2.369	.021*

Note: *: Dependent variable: Total income of *kepah* fishermen

The effect of fishing gear type variables on fishermen's income. The significance value of the variable X_1 (type of fishing gear) in the t-test is 0.000 < 0.05; H0 is rejected. This indicates that the variable X1 (type of fishing gear) has a significant impact on the income of *kepah* fishermen in Bagan Asahan. Each *kepah* fishing gear used has a different size. If the fishing gear used is larger, the efficiency of catching *kepah* and the catch will be better. This result is matched to the research in Sukabumi, West Java (Buntoro et al. 2022), which also reported that the fishing gear used by fishermen affects the catch. This can be seen from the distribution table (descriptive statistics) that *kepah* fishermen who use rakes as their fishing gear produce more catches than fishermen who only use gloves, thus increasing income. This finding is also in line with the empirical fact that the majority (80.28%) of fishermen have used rakes with larger boats. This is also the basis for the practice of some fishermen who use modern fishing gear in the form of *kepah* tanks, which are thought to produce better catch productivity and income. However, this *kepah* trawl fishing gear is categorized as prohibited because it is environmentally damaging and should be prohibited. Therefore, Bagan Asahan fishermen continue to use rakes as their fishing gear, which they believe is more environmentally friendly. The community is also involved in a movement to ban the use of *kepah* tanks in the Bagan Asahan waters. Public awareness campaigns to encourage the abandonment of gloves and the adoption of rakes can increase the income of *kepah* fishermen. Furthermore, numerous scientific reports indicate that the use of gloves for *kepah* fishing often results in negative impacts, including wounds and skin diseases.

The effect of the number of groups on fishermen's income. The significance value of variable X_2 (number of groups per boat) is 0.181 (> 0.05), so H0 is accepted; the number of groups per ship does not have a significant effect on the income of *kepah* fishermen. Empirically, this is because each member of the group has a profit-sharing system. The results will be divided equally among the group members, so that each person's income is relatively equal. The diversity of the number of members in each group is also small, only 2 to 9 people (depending on the size of the boat). The number of members in each group is also small, only 2 to 9 people (depending on the boat size). The arrangement of roles and tasks of each group member is measurable and does not overlap, because they already have experience in catching *kepah*. This resulted in no significant effect on the income of each fisherman. The coefficient for this variable is positive, indicating that a larger number of groups can increase the income of *kepah* fishermen. In the context of resource efficiency, including ship fuel, optimizing the number of group members according to the maximum capacity of the ship can be recommended. Currently, the average number of members in each *kepah* fishing vessel is six people/ship. This

number should be added to increase fishermen's income and resource efficiency.

The effect of distance from mangroves on fishermen's income. The significance value of the variable X_3 (distance from mangrove) is 0.663> 0.05, so H0 is accepted with a negative coefficient value. This shows that the variable does not have a significant effect on the income of *kepah* fishermen in Bagan Asahan Village. However, an interesting finding was obtained that catching *kepah* far from mangroves resulted in lower catches of *kepah*. *Kepah* fishing by Bagan Asahan fishermen is effectively carried out around river mouths that are not too far from the mangrove ecosystem (average 3.2 km). This is due to the high abundance of organic matter in the substrate at locations close to mangroves and river mouths. The results of a similar study were also reported by Putra et al. (2022) in Pacitan District, East Java, stating that *kepah* are abundant near the estuary (Wiraatmaja et al. 2022). Purwoko et al. (2025) also reported that the distribution of *kepah* in this area has a positive correlation with the existence and diversity of its mangrove ecosystem. Preservation of mangrove ecosystems is important in maintaining the sustainability of natural *kepah* production in this area. Further research is needed on the relationship between the distribution and density of *kepah* populations and the distance from mangrove ecosystems.

The influence of age variables on fishermen's income. Based on the results of the t-test, the significance value of the variable X_4 (age) is 0.000 <0.05, H1 is accepted. This shows that the variable X_4 (age) has a significant effect on the income of *kepah* fishermen in Bagan Asahan Village. This study is similar to other studies in Indonesia conducted by Suwi and Mahaendra (2024) and Rahman et al. (2025), which also stated that the age variable affects the fishermen's income. Likewise, other studies in Borneo (Sugiardi et al. 2021) and Rahim and Hastuti (2023) stated that age has a significant effect on the performance and productivity of traditional fishermen's catches. It is suspected that the age variable in *kepah* fishing activities is related to strength and physical endurance, where this work is carried out in waters and under direct sunlight. So, the physical endurance of older *kepah* catchers helps in increasing catch productivity. This argument is also supported by Boyes' explanation regarding the relationship between aging and outdoor work (Boyes 2013).

Kudrna et al. (2020) explained that the productive age of Indonesian workers is 15 to 64 years old. Most of the respondents are still of productive age, with an average age of 40.71 years. However, there is a tendency for young people to be rarely found as *kepah* catchers, with only 11.3% of *kepah* catchers being 20 to 30 years old. This fact warrants attention: planned regeneration must be prepared to ensure that the next generation can continue *kepah* catching using environmentally friendly (sustainable) fishing techniques.

The influence of gender variables on fishermen's income. The significance value of the variable X_5 (gender) is 0.039 <0.05, so H0 is rejected. This shows that the variable of gender has a significant effect on the income of *kepah* fishermen in Bagan Asahan Village. Catching *kepah* requires better physical strength and endurance, which enables male fishermen to achieve higher catch productivity and positively impact their income. In the marketing of fishery products, women typically play a more dominant role (Indriasih et al 2023; Purwanti et al. 2023). Harper et al. (2023) reported that 49.8 percent of fisherwomen were involved in the post-harvest work segment (e.g., processing, transportation, trading, sales). However, in the case of Bagan Asahan fishermen, selling *kepah* is not a significant issue. The sale of *kepah* is carried out simultaneously at the Bagan Asahan port, where buyers are always on standby to collect the fishermen's catch. Before being weighed, fishermen usually clean and sort the *kepah* in the port yard. Women generally play a more significant role in this process, often assisted by their children. Meanwhile, men perform more physical tasks, such as lifting and moving sacks containing the *kepah* they catch. In general, the practice of mutual assistance among fishermen remains very strong in Bagan Asahan. The same case was also reported in the research of Novikarumsari et al. (2023) in Jember, Indonesia, and Kusakabe and Thongprasert (2022) in the context of research on Asian women. This fact should be a concern for stakeholders to provide more gender-friendly treatment to female fishermen by prioritizing women in lower-risk fishing areas, such as shallower, closer to the coastline, and smaller areas. Considering that fishing is generally done in groups involving men and women together, it is recommended that the results be shared by teams so that women can achieve comparable results to those of physically stronger men. The practice of profit sharing that significantly differentiates between male and female members should be avoided. This is expected to encourage more women to get involved in catching *kepah*, considering that currently only 5.64% of *kepah* catchers are female.

The influence of the variable of fishing experience on fishermen's income. The significance value of the variable X_6 (fishing experience) is 0.300> 0.05, so H0 is accepted. This shows that the variable of fishing experience has no significant effect on the income of *kepah* fishermen in Bagan Asahan. Catching *kepah* does require special skills, but it is easy to learn and does not require long experience to become a productive *kepah* catcher. This empirical explanation clarifies that the variable of fishing experience is not a significant predictor of fishermen's income. The case of catching *kepah* in Bagan Asahan is different from what happened in Tanzania, where the number of fish caught by small fishermen was influenced by the fishing experience of Mramba and Mkude (2022).

The influence of the variable of duration of fishing on fishermen's income. The significance value of the variable X_7 (duration of fishing) is 0.000 <0.05, so H0 is rejected. Duration of fishing has a significant and positive effect on the income of *kepah* fishermen in Bagan Asahan. This means that the longer the fishermen spend looking for *kepah*, the greater the catch and income will be. Ergonomically, this is not a new fact, but it also illustrates that the availability of *kepah* in these waters remains quite good. The duration of catching *kepah* can still be done

normally, with an average of 8.4 hours per day. These results are in line with the research of Buntoro et al (2022) in Pangandaran District and Picaulima et al. (2021) in the Kei Islands, which concluded that the variable duration of fishing has a significant effect on the income of fishermen from fishing businesses. Likewise, in Tanzania, as reported by Mramba and Mkude (2022), the number of fish caught was influenced by the duration of time spent catching and selling the caught fish.

The influence of ship ownership variables on fishermen's income. The significance value of variable X_8 (vessel ownership) is 0.021 <0.05, so H0 is rejected. The variable of vessel ownership has a significant and positive influence on the income of *kepah* fishermen in Bagan Asahan Village. Descriptive data show that *kepah* fishermen who own their boats, especially those with multiple boats, generate a greater income than those who rent boats or are members of a boat owner's group. This finding can serve as a reference for government policy to support fishermen in owning their boats, as 64.78% of fishermen in this area still use rented boats. Based on discussions with local fishing figures, this issue is inextricably linked to the exploitative economic practices of coastal communities (Nurliani et al. 2023). Coastal communities tend to prefer renting boats or profit-sharing rather than saving to own their own. Local government sources even mentioned that numerous government programs and Corporate Social Responsibility (CSR) programs from state-owned and private companies provide opportunities and facilities for fishermen to own their boats. However, fishing communities are often unable to utilize or sometimes even misuse this assistance, leaving them trapped in a situation of "boatlessness." Some fishermen are even trapped in patron-client economic relationships with more powerful business owners in their communities (Miñarro et al. 2016; Roberts et al. 2022).

Discussion

The role of kepah *on the economic and social*

The Asahan River is a primary area for *kepah* fishing, providing a significant source of income for local fishermen. One type of *kepah* caught is *kepah* (*Meretrix* sp.) (Matondang 2018). Not only are fishing activities a source of income, but local people also process *kepah* into various derivative products, making it their main economic activity. These products include dried *kepah*, shredded *kepah*, *kepah* satay, and creative products made from *kepah*/*kepah* shells (Anggraini 2017; Hodriani et al. 2022). Catching *kepah* provides direct employment in the form of fishermen, traders (collecting traders, wholesalers, and exporters), *kepah* meat processors, shell craftsmen, and tourism and service sectors related to *kepah*. The typical Tanjung Balai *kepah* shellfish has a distinctive taste and is made into a famous souvenir, and is exported to various countries in Southeast Asia and to America (Harianja 2015). *Kepah* also encourages the emergence of various local culinary MSMEs. Traditionally, *kepah* is prepared by boiling, made into shellfish satay or smoked curry, and served with pineapple, ground nuts, and Malay spices. This has led to Tanjungbalai often being nicknamed the “Shell City”. *Kepah* inspired the design of the port of Tanjungbalai City, the closest trade and shipping center to Bagan Asahan (Panjaitan et al. 2021). As the primary source of livelihood for the fishing community in Bagan Asahan Village and its surroundings, *kepah* fishing must be carried out in the most effective way possible while maintaining its sustainability. The fishing method and equipment used must be chosen wisely to produce high economic value, without changing to environmentally unfriendly methods and equipment. The current fishing method is an indigenous knowledge that is still worth maintaining, but a conservation strategy is needed that follows the scientific facts resulting from this study. One of the important findings is related to factors that significantly influence the income of *kepah* fishermen, including the type of fishing gear, gender, duration of fishing, and boat ownership.

Fluctuations in fishermen's catches, annual production, and the contribution of *kepah* to fishermen's income are primarily influenced by seasonal factors that are difficult for humans to control (non-anthropogenic). Therefore, these factors are not explicitly discussed as variables predicting *kepah* fishermen's income. These natural factors include flooding in the Asahan River, high tides, or excessive river discharge. However, these events also have a positive impact on the supply of nutrients in the waters of Bagan Asahan, which are needed by *kepah* to grow and develop (Pakpahan et al. 2024). In this case, the mangrove ecosystem in the Bagan Asahan River estuary area plays a crucial role. Ecologically, the mangrove ecosystem creates a stable microhabitat and protects the substrate from erosion, allowing *kepah* to thrive (Dos Santos et al. 2023). The Bagan Asahan community already has a good understanding of this, so they currently have a reasonably positive attitude and play a significant role in protecting the mangrove ecosystem. In addition, they possess traditional knowledge that helps mitigate the risk of disasters and work-related accidents caused by natural factors, enabling them to determine when it is possible or impossible to catch *kepah* safely. This local knowledge is gained from experience observing natural phenomena such as tidal cycles, seasonal cycles (annual to five-year periods), rainfall, changes in color, quality, and discharge of river water, and other natural phenomena. The fishermen of Bagan Asahan understand the relationship between these natural indicators and the best time and method for harvesting *kepah* and other marine resources. For example, local fishermen tend to avoid harvesting during heavy rains, as *kepah* are more challenging to reach, resulting in reduced catches. Scientifically, the rainy season affects water turbidity and nutrient levels, which impact the distribution and activity of *kepah* in the muddy substrate (Sihotang et al. 2017).

The difference in fishing gear has been shown to produce significantly different results, so it is recommended that fishermen prefer to use rakes rather than gloves. Fishermen use traditional fishing gear in the form of a rake, locally called a "tojok."

Figure 3. Sorting and packaging of *kepah* at the dock is carried out collaboratively

The tojok is a small rake operated by a small boat and a 4-5m long wooden pole. The tank *kepah*, on the other hand, is a large, iron rake capable of actively raking the seabed with the power of a powerful engine. The use of *kepah* tanks is certainly not recommended, although technically capable of generating higher economic value, it threatens their sustainability. The fishing methods traditionally practiced by the community and already part of indigenous knowledge are still worthy of preservation. However, conservation strategies that refer to the scientific evidence generated by this research are needed. Conflicts still exist between shellfish fishermen and octopus fishermen because shellfish fishing gear sometimes damages octopus traps (locally called *bubu/tangkul*). However, fishermen in Bagan Asahan have long understood the principles of sustainability in *kepah* fishing (Ramadhani 2020). Traditional fishermen in this area are accustomed to working together and have implemented fairly strict regulations regarding the tools and zones for catching shellfish, especially *kepah*, to maintain the sustainability of *kepah* and their ecosystem (Figure 3). Traditional fishermen typically find it easier to catch manually (using rakes) during low tide. At this time, modern fishing gear, such as *kepah* tanks, is strictly prohibited. Furthermore, the larger *kepah* tanks are difficult to navigate in shallow water (Nababan et al. 2017). Despite frequent friction, the community still maintains local values and solidarity among fishermen. Local communities often collaborate to campaign and conduct operations aimed at banning the use of environmentally unfriendly fishing gear (Chandra 2023). To increase fishermen's income from *kepah* fishing without relying on fishing expansion, one program developed is a home industry for processing *kepah* shells and *kepah*. The local government supports this program, targeting women's groups (Anggraini 2017).

Sustainable *kepah* fishing methods are not only related to *kepah* caught, but also the aquatic ecosystem. This is because bivalves are considered sensitive biological indicators (Chahouri et al. 2023). They are a valuable tool for monitoring marine ecosystems (Caza et al. 2016). Most species have relatively short life cycles that can quickly reflect environmental changes. (Steeves et al. 2018). Bivalve molluscs make up most of the coastal benthic community (Casebolt and Kowalewski 2018). Of course, the practice of catching *kepah* using *kepah* tanks must be strictly enforced by the local government to preserve the ecosystem in Bagan Asahan Village.

A phenomenon found in Bagan Asahan is that although the younger generation is involved in *kepah* fishing activities, the proportion of young *kepah* catchers is relatively small. From various sources interviewed, no specific traditions or rituals were found where sustainable *kepah* fishing skills are passed down from the older generation to the younger generation. Skills transfer is generally carried out only through a learning-by-doing approach, where fishermen's children often help their parents catch *kepah* during school holidays, eventually mastering the skills gradually. This is also consistent with a report (Sihotang et al. 2017), which states that traditional *kepah* fishing techniques and specialized skills in processing simple products in Bagan Asahan are acquired through informal sources and processes. There are no reports of formal education or training related explicitly to the transfer of *kepah* fishing skills to the younger generation. The majority of children in Bagan Asahan complete their education to high school or its equivalent. Afterward, they tend to choose preferred professions, namely working in urban areas and/or the service sector in surrounding cities such as Tanjung Balai, Kisaran, and Medan. A small number of those who do not continue their education to upper secondary education or who do not find work in other sectors will return to the sea and work as *kepah* catchers. Thus, catching *kepah* is still the last job option for the young generation in Bagan Asahan.

Men’s income is generally proven to be higher than women's, which suggests that this job requires physical strength and endurance, typically possessed by men. Therefore, it is necessary to consider implementing local policies that provide positive incentives for female fishermen, enabling them to generate income equal to that of men. This policy aims to establish a multi-gender group work system with an even division of roles. The division of tasks in a team that is more gender-friendly should also be considered, so that all group members can contribute their best role to shared income in the *kepah* fishing group. For fishing carried out by groups whose members are primarily women, the dividing fishing zone policy can be a local wisdom choice. Female *kepah* fishing groups should be given priority access to fishing zones closer to the coastline or in shallower waters. In this way, female fishermen will be able to produce better catches, equal to those of male fishermen. In addition to fishing activities, women's roles can be strengthened in post-harvest segments such as processing, trading, and services based on *kepah*, which represent a more potential role for women (Harper et al. 2023). This is also because, according to Rice et al. (2023), women play a key role in the fisheries value chain, particularly post-harvest processing and marketing of fishery products. However, gender inequality in small-scale fisheries value chains often limits livelihood benefits for many women and their households.

The duration of going to sea is one of the variables that has a significant effect on the income of *kepah* fishermen. *Kepah* fishing cannot be done all the time, because it is

generally only done at low tide. Once the water starts to rise, catching *kepah* becomes more difficult, especially using gloves. Extending fishing duration as an effort to increase the income of *kepah* fishermen can only be done in several ways. First, the use of fishing gear in the form of rakes with sticks that vary in length, from short to longer, so that fishermen can catch *kepah* when the water starts to recede, at the lowest tide, until the water begins to rise again. Second, regulate the flow of the fishing zone, where fishing is carried out starting from a zone closer to the beach line so that it can be done earlier, then heading to a zone further from the beach following the receding water, then ending by catching again in a zone closer to the shallower shoreline, so that the total duration of catching *kepah* can be longer. In this way, *kepah* fishermen will get a better income.

Shellfish fishing plays a significant economic role, has strong cultural roots, and is a crucial part of local identity. Shellfish is the common name for bivalves, and *kepah* are the most dominant shellfish species in Bagan Asahan. Shellfish have even inspired the design of harbors and historic buildings, such as the Tanjung Balai City Square, the closest trading and shipping center to Bagan Asahan (Panjaitan et al. 2021). Furthermore, the shellfish fishing tradition holds significant cultural value for the coastal communities of Bagan Asahan. Every year-end, or to coincide with the city's anniversary, a "Shellfish Festival" is held at the Tanjung Balai City Square, designed in the shape of a shellfish icon. This event celebrates seafood, especially shellfish, and reinforces the city's identity as a center for shellfish fishing. It also serves as a symbol of pride as a shellfish-producing city, widely recognized by both locals and international visitors. Shellfish Festival also serves as a promotional opportunity for local products and a culinary tourism opportunity to boost the regional economy and income. Several local festivals, such as Senandung Melayu, Langgam Melayu songs, and the Gubang Dance, are not only artistic expressions but also a means of reflecting the Tanjung Balai community's dependence on and relationship with the sea and its natural resources, such as the *kepah* (Sahril 2018; Damanik 2023). The Senandung Melayu festival, for example, always includes narratives or performances that highlight the role of *kepah* as a source of livelihood and food security for the community. Malay songs and traditional dances, such as the Gubang Dance, often depict the daily lives of coastal communities, including the activities of catching *kepah*, *kepah*, and other seafood. The lyrics of Senandung or Langgam Melayu songs typically contain verses that convey the hard work of fishermen, including traversing mudflats or mangrove forests in search of *kepah*. The Gubang Dance, a traditional coastal dance, reflects the culture of work and collective spirit in the activity of sourcing seafood, including *kepah* (Swastiwi and Hussin 2007; Suliyati and Ramli 2012; Purwanto et al. 2023).

Implications for management policies and sustainability

Fishermen in the waters surrounding the Bagan Asahan mangrove ecosystem in Asahan District, North Sumatra, Indonesia, produce 2,675 tons of *kepah* (*M. meretrix*) annually. The economic value of *kepah* contributes significantly to the total income of *kepah* fishing households. The fishing community in Bagan Asahan relies heavily on *kepah* fishing and other related economic activities. Furthermore, the Bagan Asahan community also possesses indigenous knowledge stemming from their long history of sustainably catching *kepah*. For example, fishermen in Bagan Asahan have long used *kepah* rakes with wide holes, allowing only adult *kepah* to be caught, while young *kepah* escape and return to the wild to grow and develop. This indigenous knowledge relates not only to *kepah* fishing but also to the trade and utilization of *kepah* in various derivative products, including *kepah* meat and shell. This has enabled *kepah* fishing, which has been ongoing for a long time, to continue to this day. Therefore, the technical, social, and institutional models of *kepah* fishing activities in Bagan Asahan must be continuously maintained and strengthened by all relevant stakeholders to ensure sustainability.

One of the important findings of this study is the factors that significantly influence the income of *kepah* fishermen, including the type of fishing gear, age, gender, length of time at sea, and vessel ownership status. These five factors are proven and can be leveraged to increase fishermen's income significantly. The above findings should serve as a guide for future policy to ensure sustainable *kepah* production in Bagan Asahan. The sustainability of *kepah* production in Bagan Asahan is threatened by the use of fishing gear that damages the environment and the existence of *kepah*. Improving the welfare of fishing communities in Bagan Asahan requires policy support in the form of increased access to vessel ownership (capital or affordable access to capital sources), increased support and access to gender roles, the transfer of environmentally friendly knowledge and skills to the younger generation (Figure 4), and prevention of the use of environmentally damaging fishing gear by entrepreneurs with capital.

Figure 4. Children's involvement in helping sort *kepah* during school holidays is one of the media for transferring skills in sustainable *kepah* harvesting in Bagan Asahan, North Sumatra, Indonesia

Stakeholder policies that can strengthen the existence and increase the effectiveness of *kepah* fishing as the primary source of livelihood for the Bagan Asahan community are crucial and require continued promotion. Strengthening access to capital can be achieved, for example, by improving the legal and institutional framework for fishing businesses, both individually and through cooperatives, thereby increasing capacity and access to capital sources. Strengthening gender roles can be achieved by facilitating the formation of a local consensus on supporting gender participation, enabling women to achieve equal income potential. Women's empowerment institutions within local governments can be encouraged to take on this role.

The transfer of environmentally friendly knowledge and skills to the younger generation can be achieved through field practice, informal learning (via fishermen's group forums), or formal approaches that utilize local content schemes in the local education curriculum. Local wisdom and sustainability efforts can be packaged in the form of mutually agreed-upon village regulations. Although national and regional regulations related to the sustainability of natural resources and the environment are already in place, local legislation can be established to facilitate and legitimize the role of local communities in preventing, monitoring, and taking action against various threats to the sustainability of *kepah* production in Bagan Asahan. Given that *kepah* is a source of economic dependence for the community, has extensive linkages with other sectors and downstream economic activities, is a leading export commodity, and holds cultural significance, the policy implications of this study are crucial for sustainable fisheries development in Asahan District and North Sumatra Province.

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Appendix 1. Normality test result

One-Sample Kolmogorov-Smirnov Test			
			Unstandardized Residual
N			71
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		2.68922846
Most Extreme Differences	Absolute		.116
	Positive		.092
	Negative		-.116
Test Statistic			.116
Asymp. Sig. (2-tailed)			.019[c]
Monte Carlo Sig. (2-tailed)	Sig.		.276[d]
	99% Confidence Interval	Lower Bound	.265
		Upper Bound	.288

Appendix 2. Multicollinearity test result

Coefficients[a]			
Model		**Collinearity statistics**	
		Tolerance	**VIF**
1	(Constant)		
	Type of fishing gear	.116	8.626
	Number of groups	.285	3.514
	Distance from mangroves	.398	2.513
	Age	.303	3.299
	Gender	.173	5.770
	Fishing experience	.378	2.648
	Duration of fishing	.276	3.622
	Boat ownership	.834	1.199

Appendix 3. Heteroscedasticity test results

		B	**Std. Error**	**Beta**	**T**	**Sig.**
1	(Constant)	14.879	11.271		1.320	.192
	Type of fishing gear	.711	.618	.352	1.150	.254
	Number of groups	-.303	.191	-.309	-1.584	.118
	Distance from mangroves	.468	3.822	.020	.123	.903
	Age	-.048	.037	-.242	-1.279	.206
	Gender	-2.496	1.767	-.353	-1.412	.163
	Fishing experience	-.014	.032	-.074	-.438	.663
	Duration of fishing	-1.246	.404	-.611	-3.082	.063
	Boat ownership	-.022	.172	-.014	-.127	.899