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A Literature Review: Local Ecological Knowledge in Fishing Technology Aspects

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ABSTRACT

One of the essential elements of sustainable fishing technology management is local ecological knowledge (LEK). LEK provides valuable insights into fishing grounds, fishing gear, and target species, passed down through generations of experience. This study employed a Systematic Literature Review (SLR) approach, a methodological framework for conducting comprehensive and transparent literature reviews based on the preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This study aimed to evaluate the application of LEK in fishing technology by focusing on three aspects: fishing grounds, fishing gear, and target species. Data were gathered from peer-reviewed journals in the Scopus database covering the years 2018 to 2023. The results indicate that LEK is instrumental in identifying fishing grounds, selecting and utilizing fishing gear, and locating target species that hold ecological and economic value. Integrating LEK with modern science can lead to more effective and sustainable fisheries management policies, addressing the current lack of documentation, scientific recognition, and integration of LEK within contemporary scientific frameworks.

INTRODUCTION

Local Ecological Knowledge (LEK) is a unique form of knowledge shaped by local communities about the environment in which they live. LEK encompasses a profound understanding of local ecosystems, species life cycles, and sustainable natural resource management methods. Its value in capturing fisheries is unparalleled since it offers knowledge that is often not found in scientific research but is crucial for the daily lives of fishermen **(Garcia-Quigani, 2007)**.

Conventional fishermen, through years of observation and experience, have developed a deep understanding of the best places to fish. This practical knowledge, passed down from generation to generation, includes the migration patterns of fish, the right time to catch, and the locations where particular species live. As noted by **Davis *et al.* (2004)**, local ecological knowledge (LEK) is often more detailed and specific than scientific data, offering a reassuring level of confidence in its practicality. LEK is essential for sustainable fisheries resource

management. To avoid catching unwanted species, fishermen often use environmentally friendly fishing techniques, such as selective fishing gear. LEK ensures the continuity of fish populations and helps maintain the balance of the ecosystem **(Menzies, 2006)**. LEK has always offered invaluable solutions to addressing climate change. Changes in fish migration patterns caused by changes in sea temperature or seasonal shifts can often be identified by local fishermen. With this knowledge, they can change their fishing methods. This may not be easy and challenging with conventional scientific methods, which require more data collection and analysis time.

Combining LEK with modern science can enlarge and multiply the database used in fisheries management. **Pearson *et al.* (2020)** stated that collaboration between scientists and local fishermen will result in a broader understanding of aquatic ecosystems. LEK can capture environmental dynamics at a local scale, complementing and even filling scientific data.

The biggest challenge in using LEK is the need for more documentation. Much of the knowledge fishermen gain is only stored in their memories and transmitted orally. LEK will be lost if not recorded, especially if the younger generation is not interested in maintaining these traditions. According to **Morin and Akhtar (1992)** and **Pennesi (2020)**, LEK documentation is essential amidst rapid social and environmental change.

Sometimes, there is a difference of opinion between LEK and scientific methods. Although local knowledge has practical benefits in the field, some may not be considered valid or relevant in a scientific framework. This creates difficulties in integrating LEK into modern science-based resource management policies. To overcome this gap, scientists and local fishers need to talk to each other so that LEK can be more widely recognized **(Farr *et al*, 2018)**.

LEK has been used successfully in fisheries management around the world. For example, in the Solomon Islands, LEK has been used to sustainably manage fish stocks by establishing marine protected areas based on local knowledge of fish reproductive cycles **(Aswani & Lauer, 2006; Cinner & Aswani, 2007)**. These studies show that LEK results and modern knowledge can improve the sustainability and resilience of ecosystems.

LEK also helps local fishers become more involved in natural resource management. Fishing communities tend to be more committed to conservation and sustainable natural resource management when their knowledge and experience are valued **(Menzies, 2006; Tyler, 2006)**. This has been proven in community-based fisheries management in Southeast Asia, where LEK is used for resource management and decision-making **(Govan, 2009)**.

Given the importance of the role of LEK in the utilization and management of natural resources; this study was conducted to analyze the implementation of LEK in the capture fisheries aspect related to fishing grounds, fishing gear, and fish species (catch targets). Information related to these three aspects is very important to know because, so far, it is still partial and not comprehensively described. This study is expected to provide a holistic view of what and how LEK is applied to fishing technology. Thus, the findings in this study can be a reference for making sustainable capture fisheries policies based on LEK.

MATERIALS AND METHODS

Data collection

Journal search sources were accessed through the Scopus website using the following keywords: "local ecological knowledge OR determining potential fishing areas," "local ecological knowledge OR potential fishing grounds," and "potential fishing grounds." Journals were retrieved with assistance from Google Scholar and ResearchGate. Scopus was chosen as the primary source for document searches due to its strong reputation and credibility, broad and multidisciplinary coverage, availability of citation data, access to high-quality literature (Q1 to Q4), and capability to locate the latest research.

Horizon time

Journal article data were collected from 2018 to 2023. This time was chosen to ensure that the literature used in the study was the most recent and relevant to recent advances in the field of capture fisheries. It is also vital to ensure that this study reflects current research developments. 2018–2023 covers the last five years, which is enough to see new trends, innovative techniques, and significant findings in the scientific literature.

Systematic Literature Review (SLR) journal articles are selected based on the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework from several stages. The PRISMA framework allows researchers to conduct systematic reviews, assess, collect, analyze critical research, and evaluate existing studies and literature **(Satiti *et al*, 2024)** (Fig. 1).

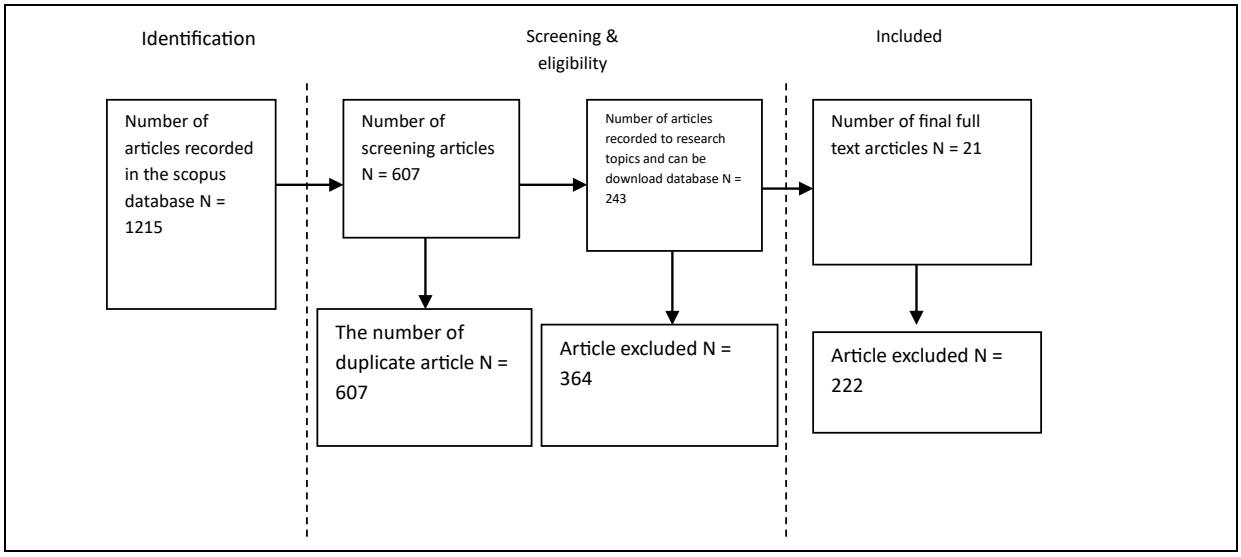

Fig. 1. Article selection process

The first stage involved identifying inclusion criteria for articles discussing local ecological knowledge and fishing areas, specifically those that have undergone a rigorous peer-review process and are available in full text. Journal articles had to be written in English and included in

a predetermined database. All data, including titles, abstracts, publication years, keywords, and publishers, were stored in a Comma Separated Values (CSV) file, exported to Microsoft Excel, and processed according to research needs. At this stage, 1,215 articles were collected from various journals and publishers. Of these, 607 were removed due to duplication.

The second stage focused on filtering and assessing eligibility; 243 articles relevant to the research topic were identified for download, while 364 were excluded. The third stage emphasized inclusion, where the selection process identified articles for the systematic review. At this stage, 21 valuable articles were retained for analysis, while 222 articles were excluded for being irrelevant or not aligned with the study of fishing technology.

RESULTS AND DISCUSSION

Local Ecological Knowledge (LEK) is a social approach method that plays a real role in capture fisheries management. This local knowledge includes aspects of fishing grounds, fishing gear, and target species

1. LEK in fishing ground

In fishing technology, local ecological knowledge (LEK) refers to the information that local fishermen possess about the location and characteristics of fishing grounds. This knowledge is typically gained through years of experience and is passed down from generation to generation. For example, research in the Adriatic Sea by **Kamberi *et al*. (2022)** demonstrated that local fishermen are highly aware of changes in fish diversity in the area, which can aid in sustainable fisheries resource management. The data indicate that fishermen can identify locations where fish populations are either abundant or sparse at any given time.

Based on this understanding, approximately 60% of fishermen in a specific region can recognize changes in fish species composition according to their fishing locations. This underscores the importance of LEK in understanding how aquatic ecosystems evolve. Research conducted in the coastal areas of Sulawesi, Indonesia, shows that traditional fishermen can pinpoint the best fishing spots based on seasonal changes and weather conditions, highlighting their adaptability to environmental shifts **(Ullah *et al*., 2023)**.

In the Amazon, **Hallways *et al.* (2020)** found that fishermen's knowledge of fish locations and abundance can inform the management of protected areas. By understanding where fish are located, it becomes possible to avoid fishing in recovery zones and maintain ecosystem balance. However, the absence of LEK in fisheries management policies poses significant challenges. According to **Farr *et al.* (2018)**, ignoring local knowledge can lead to conflicts between fishermen and management authorities, ultimately undermining sustainable resource

practices. Therefore, it is crucial to integrate local knowledge with scientific policies to achieve more effective fisheries management. In summary, LEK is a valuable asset regarding fishing locations that must be recognized and preserved. Incorporating this knowledge into fisheries management strategies can help fishing communities address challenges and sustain marine resources.

2. LEK in fishing gear

In capture fisheries, LEK is crucial for selecting and using the right fishing gear. Traditional fishermen usually understand the type of fishing gear most suitable for a particular fish species and the most suitable methods to use in various conditions. For example, a study by **Jauharee *et al*. (2021)** in the Maldives found that fishermen use a local understanding of fish behavior and environmental conditions when selecting the most effective fishing gear for catching tuna. More than 70% of fishermen in the study area used fishing gear that they had adjusted based on their years of experience. This shows that local knowledge is very important for increasing fishing effectiveness and reducing adverse impacts on the ecosystem. In Indonesia, many fishermen use traditional methods to catch fish, such as locally-made nets and fishing rods.

de Souza *et al*. (2020) conducted a study in Brazil where local fishermen used knowledge of fish behavior to select the right fishing gear. They observed fish migration patterns and used these data to determine the best times and places to fish, demonstrating how LEK can help manage fisheries resources more sustainably. However, problems arise when more efficient modern fishing gear is introduced without considering its impacts on local ecosystems. According to **Castagnino *et al*. (2023)**, using environmentally unfriendly fishing gear can destroy habitat and decrease fish populations. Therefore, LEK should be considered when designing new fishing gear and developing sustainable management strategies. In general, LEK of fishing gear is an essential component of sustainable fishing practices. Valuing and utilizing this knowledge can help support the sustainability of fisheries resources and design more efficient and environmentally friendly fishing gear.

3. LEK on targeted species

LEK also helps in ensuring the proper target catch. Local fishermen usually understand their area's most abundant fish species and the best time and techniques to catch them. A study by **Martins *et al.* (2018)** showed that fishermen in Brazil could find the most economically and ecologically valuable fish species and understand their reproductive and migration patterns. More than 80% of fishermen in the study area knew the fish species they were catching. This suggests LEK can help reduce unwanted fishing and optimize the most effective fishing. Local knowledge of targeted fish species is essential in Indonesia to maintain ecosystem balance and avoid overfishing.

Another example is found in Ghana. **Seidu *et al*. (2022)** found that traditional fishermen in the country were able to analyze the decline in the population of elasmobranch species (Blue and Devil Rays) and to relate it to changes in fishing activities (Table 1). In order to make

appropriate management plans and to prevent endangered species from extinction, it is essential to have this knowledge. Problems will arise when the catch target is not appropriately managed; it can cause fish populations to decline and disrupt the ecosystem. As stated by **Azzurro *et al*. (2019)**, species invasion and climate change can affect the distribution of fish species. Therefore, it is very important to maintain, update the local knowledge of traditional fishermen, and adjust to fishing activities. In general, LEK regarding catch targets is very important for sustainable fisheries management. Incorporating local knowledge into management policies can help maintain and preserve the balance of an ecosystem and ensure that resources remain abundant for future generations.

Table 1. Local ecological knowledge on targeted species

No	Journal	Targeted Species	Source
1	**African Journal of Marine Science**	Sawfishes	**Braulik *et al*. (2020)**
2	**Animal Conservation**	*Arapaima gigas* (pirarucu), *Colossoma macropomum* (tambaqui), dan berbagai jenis catfish (ikan lele), seperti *Pseudoplatystoma* spp. (pintado) dan *Brachyplatystoma* spp. (dourada). (Kelimpahan spesies ikan)	**Hallwass *et al*. (2020)**
3	**Ecology and Society**	Lobster (*Homarus americanus*), elver (*Anguilla rostrata*), herring (*Clupea harengus*), softshell clam (*Mya arenaria*), groundfish, urchin (*Strongylocentrotus droebachiensis*), and scallop (*Placopecten magellanicus*)	**Farr *et al*. (2018)**
4	**Environmental Biology of Fishes**	Bonefish (*Albula* spp.)	**Rehage *et al*. (2019)**
5	**Fisheries Research**	*Genidens barbus*, *Micropogonias furnieri*, *Macrodon ancylodon* and *Mugil liza*	**Martins *et al*. (2018)**
6	**Frontiers in Marine Science**	Hilsa (*Tenualosa ilisha*), Indian threadfin (*Leptomelanosoma indicum*), Blood snapper (*Lutjanus malabaricus*), Silver pomfret (*Pampus argenteus*), Chinese silver pomfret (*Pampus chinensis*), Panna croaker (*Otolithoides pama*), Black pomfret (*Parastromateus niger*), Silver croaker (*Pennahia argentata*), Indo-Pacific king mackerel (*Scomberomorus guttatus*), Sea catfish (*Arius arius*), Mackerel tuna (*Euthynnus affinis*), Smallhead hairtail (*Eupleurogrammus muticus*)	**Ullah *et al*. (2023)**
7	**Global Change Biology**	(Non-indigenous species (*Lagocephalus sceleratus*, *Fistularia commersonii*), native expanding species (*Pomatomus saltatrix*, *Sphyraena viridensis*), other indigenous species (*Sparus aurata*, *Synodus saurus*)	**Azzurro *et al*. (2019)**
8	**Human Ecology**	Blue shark (*Prionace glauca*) and devil rays (*Mobula* spp.)	**Seidu *et al*. (2022)**
9	**Hydrobiologia**	Pirarucu (*Arapaima* spp.), Tambaqui (*Colossoma macropomum*), Jaraqui (*Semaprochilodus* spp.)	**Pereira *et al*. (2021)**
10	**Hydrobiologia**	*Genidens barbus*, *Centropomus parallelus*, *Chaetodipterus faber*, *Pseudobatos* sp., *Litopenaeus schmitti*	**Nunes *et al*. (2021)**
11	**ICES Journal of Marine Science**	Demersal fish (*Gadus morhua*, *Pollachius pollachius*, *Merlangius merlangus*, *Dicentrarchus labrax*	**Shephard *et al*. (2021)**

12	**Journal of Environmental Planning and Management**	*Anguilla anguilla*, *Gadus morhua*, *Clupea harengus*, *Sander lucioperca*, *Coregonus* spp., *Esox lucius*, *Perca fluviatilis*, *Platichthys flesus*, *Salmo salar*, *Scophthalmus maximus*	**Bermúdez & Boonstra (2023)**
13	**Marine and Coastal Fisheries**	Galapagos sheephead wrasse (*Semicossyphus darwini*), Pacific goliath grouper (*Epinephelus quinquefasciatus*), Harlequin wrasse (*Bodianus eclancheri*), grape-eye seabass (*Hemilutjanus macrophthalmos*), Chino (*Medialuna ancietae*), Pacific beakfish (*Oplegnathus insignis*), broomtail grouper (*Mycteroperca xenarcha*)	**Castagnino *et al*. (2023)**
14	**Marine Mammal Science**	Indian Ocean humpback dolphin (*Sousa plumbea*), Indo-Pacific finless porpoise (*Neophocaena phocaenoides*)	**Jog *et al*. (2018)**
15	**Marine Policy**	Hammerhead sharks (*Sphyrna mokarran*), small Carcharhinids (various species in the Carcharhinidae family)	**Almojil (2021)**
16	**Marine Policy**	Acoupa weakfish (*Cynoscion acoupa*), weakfish (*Macrodon ancylodon*) dan sarden (Engraulidae)	**de Souza *et al*. (2020)**
17	**Ocean and Coastal Management**	Giant guitarfish (*Glaucostegus typus*)	**Nazareth *et al*. (2022)**
18	**Ocean and Coastal Management**	Guiana dolphin (*Sotalia guianensis*)	**Filgueira *et al*. (2021)**
19	**Ocean and Coastal Management**	mullet (*Mugil liza*)	**Morado *et al*. (2021)**
20	**PLoS ONE**	Tuna	**Jauharee *et al*. (2021)**
21	**Ribarstvo, Croatian Journal of Fisheries**	Blue crab (*Callinectes sapidus*), Bluefish (*Pomatomus saltatrix*)	**Kamberi *et al*. (2022)**

4. Similarities and differences of LEK on aspect of fishing ground, fishing gear, and targeted species

Based on the findings and discussions above, the similarities in the use of LEK by traditional fishermen to identify good fishing areas usually require an understanding of environmental components such as ocean currents, temperature, and seasons that affect the productivity of fishing areas. LEK helps fishermen adjust their fishing strategies to changes in environmental conditions and fish populations, but the use of LEK varies greatly depending on the social and geographic context. For example, Amazonian fishermen concentrate on the composition and abundance of fishery resources in protected areas, while Adriatic Sea fishermen may concentrate on the diversity of fish species **(Hallwass *et al*, 2020; Kamberi *et al*, 2022)**. In addition, changes in modern gear and fishing technology can impact how fishermen understand and interact with their fishing grounds **(Cooke *et al*, 2021)**.

When viewed from the understanding of LEK related to fishing gear, fishermen often have the same in-depth understanding of the effectiveness and characteristics of their fishing gear. This knowledge includes the methods that are most suitable for certain species. The difference lies in using traditional and modern fishing gear, which affects LEK. For example, traditional fishers may be more aware of environmental impacts than industrial fishing gear users. Economic factors can influence the choice of fishing gear, as fishers in economically

stressed environments tend to rely more on traditional fishing gear. Traditional fishers also better understand their target species, including fish behavior, life cycles, and environmental factors that influence their existence **(Silvano *et al*, 2022)**. LEK greatly helps fishers to be aware of changes in the population of a species and adjust their fishing tactics. Based on ecological and social understanding, knowledge about the target fishery can differ. For example, Amazonian fishers may have specific knowledge about the reproduction of a species different from fishers in other places **(Hallwass *et al*, 2020)**. Fisheries management procedures can affect the target species, indicating that local aspects and broader policies influence LEK.

5. Implementation of LEK in fisheries policy in Indonesia

LEK in Indonesian Fisheries Policy LEK is crucial for managing fishery resources, especially in identifying ideal fishing grounds. In Indonesia, an archipelagic country with more than 17,000 islands, local knowledge about fishing locations is diverse and influenced by environmental conditions, fish migration patterns, and human interactions with marine ecosystems. According to data from the Ministry of Marine Affairs and Fisheries (KKP), around 80% of fishermen in Indonesia use their local knowledge to determine the best fishing locations **(KKP, 2021)**.

Fishermen on the island of Bali use their traditional knowledge to find locations rich in fish resources, especially during certain seasons **(Novaczek *et al*, 2001; Satria & Adhuri, 2010)**. This is one example of the application of LEK in determining fishing grounds. According to research conducted by **Hallwass *et al*. (2020)**, fishermen in the Amazon region also show the same pattern based on their experience and observations over the years; they can find changes in the composition and abundance of fishery resources.

The government's fisheries zoning policy shows the importance of LEK in managing fishing grounds. The policies made are more relevant and sustainable since local fishermen are involved in the planning and management process through a participatory approach. For example, LEK-based fisheries zoning has reduced fishing conflicts and increased the sustainability of fish resources in South Sulawesi **(Ullah *et al*., 2023)**. However, there are still unresolved issues, especially when LEK is incorporated into formal policies, often dominated by scientific approaches. Therefore, for fairer and more efficient fishing ground management, efforts need to be made to combine local and scientific knowledge.

The use of fishing gear that is appropriate to local conditions is essential for sustainable fisheries management. LEK provides meaningful knowledge about the most efficient and environmentally friendly fishing gear fishermen use in various regions. Traditional Indonesian fishermen often use fishing gear passed down from generation to generation, such as traps, nets, and hooks, which have been adapted to the targeted fish species and local environmental conditions. For example, research by **Nunes *et al*. (2021)** showed that fishermen in subtropical coastal ecosystems use local knowledge to use fishing gear based on fish and shrimp behavior. Using environmentally friendly fishing gear is very important in Indonesia to protect vulnerable marine ecosystems.

Based on suggestions from local fishermen and research findings, the Indonesian Ministry of Marine Affairs and Fisheries has developed a program to encourage the use of sustainable fishing gear. When more efficient modern fishing gear, such as trawl nets, began to dominate the fishing industry, other problems emerged, namely declining fish populations and damaged aquatic habitats. Therefore, LEK must be included in fisheries policies to make fishing gear more sustainable and by considering local conditions. Fishermen must be involved in the decision-making process related to fishing gear. Mutually beneficial solutions that support the sustainability of fishery resources can be achieved through discussions between fishermen and policymakers.

A study conducted by **Farr *et al*. (2018)** showed that fisheries management involving LEK can produce more responsive and efficient policies. LEK also helps determine which species should be managed or protected sustainably. Local fishers have a good understanding of fish species in their area based on migration patterns, spawning seasons, and population changes. These data are beneficial for decision-making processes related to sustainable fisheries management. For example, traditional fishers in Indonesian waters usually rely on their experience catching certain species, such as tuna or grouper. Research conducted by **Rehage *et al*. (2019)** stated that local knowledge about changes in fisheries quality can help identify species whose populations are declining and need to be protected. The Indonesian government has now recognized the importance of LEK for fish species management. In recent years, efforts have been made to incorporate local knowledge information into species management policies. This includes setting minimum catch sizes and fishing quota limits. Collecting and managing LEK data systematically for evidence-based decision-making remains challenging. Fishers must also be involved in research and species management.

CONCLUSION

Local ecological knowledge (LEK) is a vital source of information for managing fishing areas. The accumulated experience of local fishermen, passed down through generations, makes them highly knowledgeable about fishing locations. LEK plays a crucial role in identifying declines in biodiversity and changes in fish populations. It is also essential for selecting appropriate fishing gear tailored to specific fish species and environmental conditions.

With this information, fishermen can enhance their fishing efficiency while minimizing negative impacts on the ecosystem. However, when environmentally unfriendly modern fishing gear is used without integrating LEK, significant problems can arise. Therefore, LEK must be leveraged to develop more sustainable fishing practices.

Additionally, LEK enables fishermen to identify economically and ecologically valuable target species, optimizing resource use. It can also inform understanding of fish migration patterns, reproduction, and population dynamics, leading to more effective resource management

and reducing the risk of overfishing. Moreover, this knowledge helps maintain the balance of aquatic ecosystems and supports responses to climate change and shifting species dynamics.

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