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*Review Article*

# Fishermen's Knowledge of Astronomical Phenomena in Fishery Activities: A Systematic Literature Review

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## ABSTRACT

Fishermen still use knowledge-based astronomical phenomena in their fishing practices in this modern age. Several scholars were interested in this aspect, producing mixed results and formulating different perspectives. The diversity of these previous data and the differences in their perspectives have geared towards a need to review these past findings systematically. Therefore, established systematic literature is required as it provides advantages related to quality control and limits systematic bias by defining, screening and synthesising studies that address the research question. Hence, this study conducted a systematic literature review on how fishermen use their knowledge-based astronomical phenomena in their fisheries activities. This study relied on the review protocol-ROSES. Two main databases, Scopus and Google Scholar, and one supporting database, Dimensions, were used. Based on the thematic analysis, three main themes were identified and, thus, have further produced 11 sub-themes. Findings show that fishermen's astronomical knowledge influences their fishery activities based on six elements; first, know the best time to catch an abundance of marine catches; second, know the best location to catch an abundance of marine catches; third, enable fishermen to assess the maturity of marine species; fourth, repeating astronomical phenomena produced a calendar to assist fishermen in carrying out fishery activities; fifth, guide the estimation time and safety for

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fishermen at sea; and sixth, guides fishermen on the most appropriate technique to use when carrying out fishery activities.

*Keywords:* Astronomical phenomena, fishermen's knowledge, fishery, systematic literature review

## INTRODUCTION

Globally, the number of fishermen has crossed a million. By 2018, approximately 38.98 million fishermen had declared fishing as their primary livelihood ensuring life continuity (Food and Agriculture Organization of the United Nations [UN-FAO], 2020). The annual increase in fishermen demonstrates that fishing is still an important livelihood, particularly for communities living in coastal areas. Based on the socio-cultural background, an interconnected relationship between nature and culture will ensure the continuation of life by fishermen on the social, historical, economic, and cultural dimensions. The global fishery operation is directly affected by wind patterns, tidal and lunar cycles (Bezerra et al., 2012), seasons, fish's life cycle, and duration of rain occur (Silva, 2005). Most fishermen are familiar with marine life, which varies annually based on environmental and astronomical factors (Johannes & Neis, 2007). Thus, the information is crucial to reduce the risk of captures dropping, as these are their primary livelihood (Kalikoski & Vasconcellos, 2007).

Fishermen have extensively established their knowledge of astronomical phenomena in fishing cultures worldwide. For example, the Bugis fishermen are aware of the moon and tides (Ammarell, 1999), and Malawi fishermen are expertise in the interpretation of natural signs (e.g. lunar cycle's effect, current and wave) to forecast the weather and improve their fisheries' efficiency (Nsiku, 2007). Furthermore, experts have identified that the optimum tidal conditions were the best time for fishing in the Vanuatu Islands as the fish migrated from deep waters to the reef region (Hickey, 2007). Additionally, the fishermen's community on the East Coast of North Sumatra knows that tidal cycles can be used for fishing (Aulia, 2019). Fishermen in the Patos Lagoon know that it is hard to capture croakers' fish during a full moon. They believe that the moon influences the time and the bounty of sea catch. Therefore, the fishermen's knowledge of the moon has constructed a calendar that guides the fisher's community (Kalikoski & Vasconcellos, 2007; Sulistiyono, 2014; Takeda & Mad, 1996). Overall, the main guideline for fishing activities is based on astronomical phenomena knowledge.

Hitherto, studies on fishermen's knowledge of astronomical phenomena in various fields have been carried out. Studies done by Nishida et al. (2006), Bezerra et al. (2012), and Jo (2018) have examined the influence of tides on the fishermen's fishing routines in Brazil and Korea, while Nash et al. (2017) studied how Oman's fishermen refer to the star when operating their fishing activities. The Gorontalo fishing community in Tomini Bay, Indonesia, also used the constellation sign to locate fish movement (Madjowa et al., 2020). Extensively, studies by Galacgac and Balisacan (2002), Lefale (2010), Carbonell (2012), Nirmale et al. (2012) and Braga et al. (2018) reviewed how fishermen in the Phillippines, Samoa, Spain, India and Brazil have relied on astronomical knowledge in weather forecasting. Existing studies and increasing research on astronomical knowledge among fishermen have contributed more to existing literature. There is a mounting need to review these data systems to provide future scholars with an organised and comprehensive understanding of the pattern of previous findings. Despite this mounting need, however, the traditional way of reviewing previous studies related to fishermen is still practised by scholars such as Muhammad et al. (2016), Viji et al. (2017), Zain et al. (2018), Thakur (2018) and Sundaram et al. (2018). Traditional literature review (TLR) faces several issues without disregarding its importance. Firstly, it does not follow a particular method, and secondly, it places less emphasis on systematic search strategies, thus making such reviews vulnerable to recovery bias and transparency (Durach et al., 2017; Kraus et al., 2020). Kraus et al. (2020) added that quality control is virtually impossible as the TLR does not perform a quality assessment.

A systematic literature review (SLR) was performed to overcome this drawback in the traditional LR. SLR is a scientific method that aims to limit systematic bias by identifying, screening and synthesising research questions using a particular and systematic methodology (Petticrew & Roberts, 2008). Thus, quality assessment is done on all relevant articles to avoid bias (Kraus et al., 2020).

Based on the mounting need to systematically review existing literature and its benefits, as well as the numerous issues with TLR, this study aims to develop an SLR regarding how fishermen use their astronomical phenomena knowledge in fishing activities. This study was based on the research question, "How does fishermen's knowledge of astronomical phenomena influence fishery activities?" Besides, this study adduces a new perspective and integration regarding fishermen's knowledge about astronomical phenomena, which involves the relationship between the community's socio-culture and environment. Therefore, the contributions of this study indirectly fulfil the need for fishermen to understand astronomy to carry out fishery activities and ensure the sustainability of fishery resources.

## METHODOLOGY

This section involves five main issues: the review protocol, formulation of research questions, systematic searching strategies, quality assessment and data extraction and analysis.

### The Review Protocol – ROSES

This study was based on the review protocol referred to as RepOrting Standards for Systematic Evidence Syntheses (ROSES). ROSES was introduced specifically for systematic review and maps, which involves environmental management and better demonstrated the nuances and heterogeneity across diverse review needs (Haddaway et al., 2018). ROSES provides methodological guidance for the researchers in the current SLR. Based on ROSES, the researchers have concluded four main methodological steps. First, the researcher designed suitable research questions. Next, researchers performed a systematic search strategy consisting of three main processes: identification, screening and eligibility. The researchers then proceeded with the quality assessment process and finalised the SLR methodology with data extraction and analysi*s* on the selected articles.

### Formulation of Research Questions

Having a comprehensive research question is important in SLR. The research question will drive the selection of articles, data extraction and reporting (Xiao & Watson, 2019). Formulating the research questions was based on specific mnemonics (PICo; Lockwood et al., 2015). PICo is a tool for building research questions based on three keywords: **P**opulation, phenomenon of **I**nterest and **Co**ntext. Based on these three keywords, their relevance to this study is Fishermen (**P**opulation), knowledge about the astronomical phenomena and fishery activities (phenomena of **I**nterest), as well as global context (**C**ontext). Thus, the research question is, "How does fishermen's knowledge of astronomical phenomena influence fishery activities?"

### Systematic Searching Strategies

There are three main phases in implementing the systematic searching strategies: identification, screening and eligibility. These three phases are shown in a flow chart in Figure 1, which is an adaptation of the flow chart by Shaffril et al. (2019).

**Identification.** The identification phase is a process that searches for synonyms, related terms and various terms related to the main keyword in this study, which are *local knowledge, fishermen, astronomy* and *fishery.* Enriching the main keywords was performed by referring to two sources: thesaurus online and previous studies' keywords. To avoid retrieval bias, as stressed by Durach et al. (2017), the researchers decided to use more than one database. Therefore, two main databases (Scopus and Google Scholar) and one supporting database (Dimensions) were used to find related articles. The reliance on Scopus as the main database is due to its status as a full indexing database that contains more than 70 million records and covers multidiscipline journals, and it has strength in terms of quality control, full-text search, maximum search string length, advanced search string and reproducibility of search results at different locations (Gusenbauer & Haddaway, 2020; Martin-Martin et al., 2018). Google Scholar was chosen as of the main databases based on several justifications. First, it provides more sources for review as it offers 389 million documents; second, it offers more documents related to social sciences and art and humanities; third, Google Scholars offers diverse publication types, as more proceedings, books, theses, chapters in the book and unpublished materials can be retrieved (Gusenbauer & Haddaway, 2020;

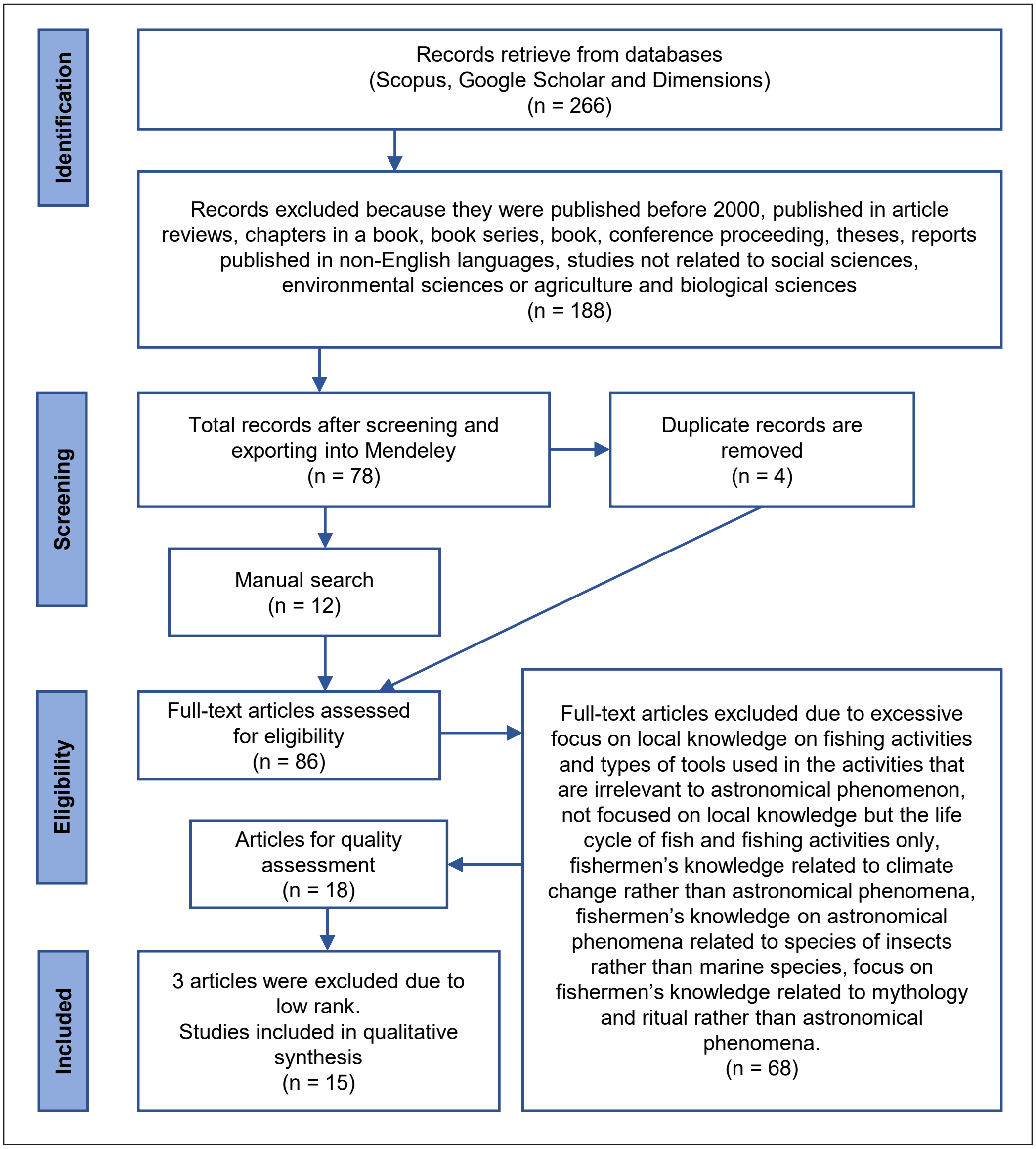


*Figure 1*. Flow chart adaptation from Shaffril et al. (2019)

Halevi et al., 2017; Martin-Martin et al., 2018).

In comparison, the Dimensions database was used as a supporting database because of its wide coverage and for discovering the right or most relevant article based on indexing, which is similar to the approach by Google Scholar (Bode et al., 2018). This database has more than 89 million publication records and more than 50,000 journals. As for the Scopus database, the search string formation process involved were field code function, phrase searching, the Boolean operator

(OR, AND), truncation and wild cards. The search process for the Google Scholar database is done via functions of phrase searching and Boolean operator (OR, AND). In addition, whenever appropriate, the combination of keywords such as “fishermen local knowledge”, “fishermen local wisdom”, “fishermen traditional knowledge”, “fishermen folk knowledge”, “fishermen celestial knowledge”, “fishermen indigenous ecology knowledge”, astronomy, ethnoastronomy, “folk astronomy”, “culture astronomy”, moon, star, tide, constellation, fishing, maritime and coastal were performed in the database. In addition to advanced searching, the authors relied on manual searching techniques such as handpicking and snowballing in Google Scholar. In another database, Dimensions, the formulation of the search string involved phrase searching, the Boolean operator (OR, AND) and the field code function. Searching for articles based on databases was carried out in August 2020. The full search string for the Scopus and Dimensions databases is shown in Table 1 below.

Out of all the searches based on the three databases, this study found 266 relevant articles.

Table 1
*The search string*

| Databases | Keywords used |
|---|---|
| **Scopus** | TITLE-ABS-KEY(("local knowledge" OR "local wisdom" OR "local practi*e" OR "traditional knowledge" OR "folk knowledge" OR "celestial knowledge" OR "ecology* knowledge" OR "traditional knowledge" OR "indigenous knowledge" OR "indigenous ecology* knowledge" OR "local ecology* knowledge" OR "traditional ecology* knowledge") AND (fisherm*n OR trawler* OR fisher* OR fisherfolk*) AND (astronom* OR ethnoastronom* OR "folk astronom*" OR "culture* astronom*" OR moon OR lunar OR tide* OR star* OR constellation*) AND ( fish* OR maritime* OR coastal)) |
| **Dimensions** | ("fisherman local knowledge" OR "fishermen local knowledge" OR "fisherman local wisdom" OR "fishermen local wisdom" OR "fisherman local practice" OR "fishermen local practice" OR "fisherman local practise" OR "fishermen local practise" OR "fisherman traditional knowledge" OR "fishermen traditional knowledge" OR "fisherman folk knowledge" OR fishermen folk knowledge" OR "fisherman celestial knowledge" OR "fishermen celestial knowledge" OR "fisherman ecology knowledge" OR "fishermen ecology knowledge" OR "fisherman ecological knowledge" OR "fishermen ecological knowledge" OR “fisherman indigenous knowledge" OR “fishermen indigenous knowledge" OR “fisherman indigenous ecology knowledge" OR “fishermen indigenous ecology knowledge" OR “fisherman indigenous ecological knowledge" OR “fishermen indigenous ecological knowledge" OR “fisherman local ecology knowledge" OR “fishermen local ecology knowledge" OR “fisherman local ecological knowledge" OR “fishermen local ecological knowledge" OR “fisherman traditional ecology knowledge" OR “fishermen traditional ecology knowledge" OR “fisherman traditional ecological knowledge" OR “fishermen traditional ecological knowledge") (astronomy OR astronomical OR ethnoastronomy OR ethno-astronomy OR ethnoastronomies OR "folk astronomy" OR "folk astronomies" OR "culture astronomy" OR "cultural astronomy" OR moon OR lunar OR tide OR tides OR tidal OR star OR stars OR constellation OR constellations) (fishing OR fisheries OR maritime OR coastal) |

**Screening.** The 266 articles identified in the identification phase had undergone the screening process. For articles obtained from the Scopus and Dimensions databases, the screening process was carried out automatically using the '*limit to'* function found in the databases. In contrast, for articles obtained from the Google Scholar database, the screening process was semi-automatic because the '*limit to'* function is limited only to the year of publication. The criteria for selecting articles were based on the research question formulated earlier (Kitchenham & Charters, 2007). The choosing criteria are important for ensuring that the selected article is related to the study (Alsolami & Embi, 2018). Therefore, the screening process minimised the number of related articles (Okoli, 2015). Table 2 shows four selection criteria chosen by this study.

A timeline publication of 20 years was selected (2000–2019). This timeline is selected since this duration has produced an adequate number of articles to be considered in SLR, and this is in line with the concepts of study's maturity by Kraus et al. (2020) and Alexander (2020). Since this study focused on fishermen's knowledge of astronomical phenomena related to fishery activities, the topic of this study related to social sciences, agricultural and biological sciences, and environmental sciences were earmarked. The choice of language used in the study was limited to only the English language because, according to Okoli (2015), a researcher can only examine an article written in a language that is easily understood. The selection of articles was also based on whether the article had been published in an indexed journal to ensure that the article was of good quality. As for the Google Scholar and Dimensions databases, articles published in indexed journals were manually selected by examining each article and determining whether the journals were listed in Scopus.

After screening the 266 articles, 78 were identified for the next process, while 78 were imported to Mendeley's reference manager software. The Mendeley software identified four redundant articles and discarded them from the software. According to Alsolami and Embi (2018), the manual searching process was also conducted with the help of Mendeley by using the '*related'* function and suitable keywords. Hence, to ensure comprehensive literature searching, both bibliographic database searching and

Table 2
*Inclusion and exclusion criteria*

| Criterion | Inclusion | Exclusion |
|---|---|---|
| **Literature type** | Indexed Journal (research articles) | Non-indexed journals, article reviews, chapters in books, book series, books, conference proceedings, theses, reports |
| **Language** | English | Non-English |
| **Timeline** | Between 2000-2019 | <2000 |
| **Subject Area** | Social Sciences, agricultural and biological sciences, and environmental sciences | Non-social sciences, non- |

supplementary search methods (Cooper et al., 2018) were used. This study used a supplementary search method in the form of manual searches using the Mendeley software and the forward references search method found in the Google Scholar database by identifying articles related to this study (Levy & Ellis, 2006). Twelve articles were identified using the manual searching method. Overall, 86 articles were identified for the eligibility phase.

**Eligibility.** The eligibility phase is a process where the researcher examines the article's relevancy to the needs of the study by examining the title, abstract, findings and discussions. Sixty-eight articles were excluded because they did not fulfil the study's needs. These articles were excluded due to excessive focus on local knowledge of fishing activities and types of tools used in the activities that are irrelevant to astronomical phenomena, not focused on local knowledge. However, the life cycle of fish and fishing activities only, fishermen's knowledge related to climate change rather than astronomical phenomena, fishermen's knowledge of astronomical phenomena related to species of insects rather than marine species, focus on fishermen's knowledge related to mythology and ritual rather than astronomical phenomena. Overall, 18 articles were selected for the next process, quality assessment.

### Quality Assessment

The examination of these 18 articles involved a screening method that used the Mixed-Methods Appraisal Tool (Hong et al., 2018). This assessment tool was used because the selected articles had used qualitative and mix-methods in their studies. It was agreed that each article should fulfil at least three of the five criteria mentioned in the checklist to be eligible for the next process. As a result, only 15 selected articles eventually proceeded with the data extraction and analysis process.

### Data Extraction and Analysis

This study relied on the qualitative synthesis of qualitative, quantitative and mixed-method studies (Okoli, 2015). This method of extracting the relevant data from the selected articles was based on the integration concept (Whittemore & Knafl, 2005). Data extraction was done by comprehensively examining the abstract, results and finding of each of the 15 selected articles. Data from the selected articles were extracted if they fulfilled several conditions. First, it can answer the determined research questions, and second, if it is related to the study's objective. As the study is performing a qualitative synthesis of mixed research designs, thematic analysis is the most appropriate technique (Flemming et al., 2019). The thematic analysis aims to identify, analyse and explain the themes and sub-themes based on the collected data (Braun & Clarke, 2006). First, the authors identify the themes and sub-themes by noting and identifying the similarities or relationships between the extracted data. Finally, the identified themes were encoded to produce the main themes. This study initially found three main themes: astronomical phenomena, fish reproduction and fishing techniques. Next, from the three themes, this study produced 11 related sub-themes and later, the main and sub-themes were named, as shown in Table 3.

## RESULTS

### Background of Selected Studies

This study examined 15 selected articles. Based on the thematic analysis, three main themes were built: *astronomical phenomena, fish reproduction* and *fishing techniques.* Then the themes were analysed to produce 11 sub-themes: moon, tides, sun, star, wind, sea, season, spawning period, breeding period, fish catching, and crab catching. Examination of the articles showed that six studies used the mixed method approach, and nine used the qualitative method. Seven studies were carried out in Brazil, while eight were carried out in eight different locations, namely Venezuela, Mexico, Spain, India, Bangladesh, Oman, Portugal and Korea. Of the 15 articles, two were published in 2006, two in 2010, one in 2011, three in 2012, one in 2015, one in 2017, three in 2018 and two in 2019.

### Themes and Sub-Themes

**Astronomical Phenomena.** Fishermen influence astronomical events such as the moon, the tidal cycles, the sun, the stars, the wind, seasons and marine conditions. Their knowledge of the moon enables them to identify abundant marine species. For example, specific marine species, such as *E. Itajara* (Gerhardinger et al., 2006), *E. polyphekadion* (Boomhower et al., 2010), *A. Narinari* (Cuevas-Zimbrón et al., 2011), species of squid (Postuma & Gasalla, 2010) and those around Farol de São Thomé Port in South-eastern Brazil (Alves et al., 2019), were found in huge schools during the full moon phase. Fishermen are also familiar with a crab's (meat, among others) condition based on the lunar phenomenon. Fishermen on the coast of Ratnagiri in India (Nirmale et al., 2012) are aware that the crab caught on the new moon has more meat, while fishermen in Bangladesh (Deb, 2015) also know that crabs caught during the new moon have much muscle and eggs, whilst crab's price at the market is much higher than at full moon.

Fishermen also know the relations between the moon and the tidal cycle, apart from helping fishermen carry out their fishing activities. Fishermen know tidal cycle forces depend on moon phases (Carbonell, 2012). For instance, the tidal-cyclical force of fishing in Paraiba State, Northeast Brazil, has been predicted based on the moon-rise and setting (Nishida et al., 2006), while fishermen in Bangladesh (Deb, 2015) know that when the full moon, tidal force is higher and stronger than the new moon. The relationship between the knowledge of fishermen of tidal cycles and the lunar cycles produced a calendar for the support of sea fishing in Northeastern Brazil (Bezerra et al., 2012), Bangladesh (Deb, 2015) and Gomso Bay, Korea (Jo, 2018).

Knowledge of the lunar phenomenon is important to ensure the success of marine

Table 3
*Table of findings*

| No | Studies | Years | Region | Astronomical Phenomenon | | | | | | | Fish Reproduction | | Techniques | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MN | TD | SN | SR | WN | SE | SS | SP | BP | FS | CR |
| 1 | Gerhardinger et al. | 2006 | Brazil | / | | | | | | / | / | | | |
| 2 | Nishida et al. | 2006 | Brazil | / | / | | | | | | | | | / |
| 3 | Boomhower et al. | 2010 | Venezuela | / | | | | | | | / | | | |
| 4 | Postuma & Gasalla | 2010 | Brazil | / | | | | | / | | | | | |
| 5 | Cuevas-Zimbrón et al. | 2011 | Mexico | / | | | | / | / | | | | | |
| 6 | Nirmale et al. | 2012 | India | / | / | | | | | / | | / | | |
| 7 | Carbonell | 2012 | Spain | / | | / | | / | / | / | | / | | |
| 8 | Bezerra et al. | 2012 | Brazil | / | / | | | / | | | | | / | |
| 9 | Deb | 2015 | Bangladesh | / | / | | / | / | / | | | | | |
| 10 | Nash et al. | 2017 | Oman | | | | / | | | / | | | | |
| 11 | Takahashi & Nishida | 2018 | Brazil | | / | | | | | | | | | / |
| 12 | Jo | 2018 | Korea | / | / | | | | | / | | | | |
| 13 | Braga et al. | 2018 | Brazil | | | | | | | | / | | | |
| 14 | Braga et al. | 2019 | Portugal | | | | | | / | / | / | / | | |
| 15 | Alves et al. | 2019 | Brazil | / | / | | | | | | | | / | |

*Note.* **Astronomical Phenomenon:** MN= Moon; TD= Tides; SN= Sun; WN= Wind; SE= Sea; SS= Season; SR= Star; **Fish Reproduction: SP=** Spawning Period; BP= Breeding Period; **Techniques:** FS= Fish catching; CR= Crab catching catches and the tidal cycle phenomenon. For example, in Northeastern Brazil (Nishida et al., 2006), fishermen in the state of Paraiba prefer to catch crabs at low tides during spring tides because the islets were not then covered with water. This practice differs from fishermen along the Ratnagiri coastline in India (Nirmale et al., 2012), who catch crabs at high tide at night due to a larger catch at that time. On the other hand, fishermen in Bangladesh (Deb, 2015) and Gomso Bay, Korea (Jo, 2018) prefer to carry out fishery activities during the spring tide. Fishermen in Bangladesh refer to the spring tide period as the *Jo period*, which is between the 11th to 20th and the 26th to 5th, according to the Bengali lunar month, where they cast their nets into the water during the spring and collect them during the neap tide. Therefore, in Domso Bay, Korean fishermen also prefer to fish during the spring tide because the neap tide is at its lowest. Nonetheless, depending on the marine species, fishermen in Domso Bay, Korea, engage in neap tide fishing. Small shrimp, for example, are typically caught during the neap tide because it is a better time to catch species that live in shallow waters or at the sea's bottom.

In addition, fishermen in Farol de São Thomé Port in Southeastern Brazil (Alves et al., 2019) carry out fishery activities based on tidal cycle conditions. The fishermen's community knows that tidal cycle conditions determine which species are in abundance. For example, shrimps are caught during a big, launch, and full tide, whereas bony fishes are usually caught during dead, breaking and dried tide. Hence, although most fishermen say that the moon and tidal cycles influence their marine catches, some fishermen catch blue land crabs in Mamanguape Estuary in Paraiba State, Brazil (Takahashi & Nishida, 2018) who are not influenced by the lunar or tidal cycle phenomena because this species lives in higher land compared to crabs that live in the lower land areas (Nishida et al., 2006). These fishermen communities carry out fishery activities at high tides during the full moon and new moon because, at that time, there are plenty of mosquitoes, and this disrupts their activities.

Moreover, fishermen's knowledge about the seasonal phenomenon also helps them to carry out fishery activities. This seasonal phenomenon is a yearly cycle. For example, the *E. Itajara* fish species in Southern Brazil is caught in abundance in December (Gerhardinger et al., 2006). In contrast, the sea lamprey species along the Minho river in Portugal (Braga et al., 2019) are caught in abundance in January, February and April. As for the fishermen community in Catalonia, Spain (Carbonell, 2012), January is the fishing season, and it is not encouraged to go fishing in February because of dangerous weather. Other than January, June, which is during spring, is the best time to go fishing because, at that time, the fish are constantly moving to the water's surface, and it is easier to net the catch. Conversely, for the fishermen community in Oman (Nash et al., 2017), the best time to fish is during winter (22 August until 17 October) because the fish species there are easily caught when the water is cold. The seasonal phenomenon also influences crab catching along the Ratnagiri coastline in India. There are more crabs during the monsoon season when the rains come, while small shrimps in Domso Bay, Korea, are abundant from July to August (Jo, 2018).

Fishermen's knowledge about the seawater condition phenomenon also helps them to carry out fishery activities. For example, more squid is caught when the seawater is moderately warm, which is when it rains during the summer (Postuma & Gasalla, 2010). On the other hand, some species are abundant when the seawater temperature is low, such as the *A. Narinari* species in the Southern Gulf of Mexico (Cuevas-Zimbrón et al., 2011). This species is also easily caught when the waters are shallow. Furthermore, seawater conditions also help some species to breed. For example, the sea lamprey species in Minho River, Portugal (Braga et al., 2019) need warmer temperatures for breeding purposes. Besides the knowledge that marine products can be captured, the sea condition also helps fishermen when they are lost at sea. For example, the fishermen in Bangladesh use water currents to decide their position at sea (Deb, 2015). The current moves towards the coast in the high tide, while in the low tide, it moves away.

Therefore, seawater conditions also help fishermen to determine when it is safe to carry out fishery activities. Fishermen in Catalonia, Spain (Carbonell, 2012) determine wind conditions based on seawater conditions. For example, the sight of white horses (wave breaks or foams) at sea indicates that the wind speed will increase by 1–2 knots. When the sea surface resembles fish scales, the wind becomes much stronger, and when the whole surface is filled with white horses, the wind speed increases to 8–10 knots, and when the whole sea is filled with foam, it is an indication that the sea is stormy and unsafe for fishermen.

Knowledge of the wind phenomenon helps fishermen understand the weather situation in Catalonia in addition to knowledge of marine water. For example, the weather will be good when the wind blows to the sea, and when the wind blows southwest in the morning, it indicates that the weather will fit and fishing can be done. The wind phenomenon also helps fishermen to determine if fish are abundant. If, for example, the cold front blows through the cold wind, the temperature drops to the hot wind, and there is a great abundance of *A. Narinari* stingray species (Cuevas-Zimbrón et al., 2011). Fishermen in Bangladesh know that the best time to fish is when the wind is blowing from the north and east to the west (Deb, 2015), whereas fishermen in Barra de Mamanguape and Tramataia in Northeastern Brazil (Bezerra et al., 2012) know that the best time to fish is when the wind is blowing from the north, east, southwest, and northeast, while the southerly winds are indicative of an unsuitable time for fishing, because of the strong southern winds and the strong currents that cause fish to move towards the open sea.

Fishermen's knowledge about the sun also helps them to determine wind conditions. For example, fishermen in Catalonia (Carbonell, 2012) know that when the sky is covered with clouds, the weather is likely to be windy, and rain is expected. Knowledge about the stars' phenomenon helps fishermen carry out fishery activities (Deb, 2015; Nash et al., 2017). Fishermen in Bangladesh (Deb, 2015) use the stars to determine their time and position at sea. For example, the North Star is always positioned in the north, and Venus appears when the Sun is about to rise. The evening stars (*Sandhyatara*) will set at 8 pm, when the *Borotara* star rises and when the *Borotara* star sets, Venus (*Suktara*) rises.

**Fish Reproduction.** The life cycle of species involves the spawning and breeding periods. Fishermen know that the spawning period for a certain species differs (Boomhower et al., 2010; Braga et al., 2018, 2019; Gerhardinger et al., 2006). The *E. Itajara* species found in southern Brazil (Gerhardinger et al., 2006) spawns in December during summer. Other species of fish spawn in December, namely sardines in Southeast Brazil (Braga et al., 2018). This sardine species spawns from early December until March; the peak season is in the summer. Fishermen in Minho river, Portugal, also know that sea lamprey spawns from April to June when the river water is at a high temperature (Braga et al., 2019). The *L. Analis* species spawns from May to June (Boomhower et al., 2010). Knowing the spawning period is important to prevent fishermen from fishing without disrupting the aggregation of eggs.

Fishermen's knowledge about the breeding period of a species is important to determine when it is best to catch the matured fish. For example, the breeding season for fish in Catalonia, Spain, is also in June (Carbonell, 2012), as the fish move around more and are easier to catch. Moreover, fishermen in Ratnagiri, India (Nirmale et al., 2012) know that the breeding season for crabs is during the monsoon season, which is from June to July and for the sea lamprey species in Minho river, Portugal, also starts from January to June (Braga et al., 2019).

**Fishing Techniques.** Fishery catches such as fish (Alves et al., 2019; Bezerra et al., 2012) and crabs (Nishida et al., 2006; Takahashi & Nishida, 2018) must be caught using techniques suitable with the tidal cycle, moon phases and wind conditions. Farol de São Thomé Port, Southeastern Brazil fishermen use various techniques to catch marine life based on tidal cycles and moon phases (Alves et al., 2019). The fishing community uses six tools to catch marine life: trawl nets, gillnets, cast nets, longline, cage and handline. Trawl nets are used during the high, launch and full tides. Currently, the tides are strong and facilitate marine life fishing, such as shrimps. The gillnet is used during dead, breaking and dried tides. The tidal currents are weak at this time, which helps to catch marine life using this tool, such as bony fish and cartilaginous fish.

Cast nets are suitable during breaking tide for catching bony fish, such as mullets, because, at this time, the water level is low and moves slowly, which facilitates the catch. Next, the longline is used during the dead, breaking and dried tides. The long line is usually installed at night, and the catch is collected in the morning. Fish species suitable for this kind of net is the herring hake. Next, the cage is suitable for catching bony fishes (e.g. snapper and dolphinfish) during the launch tide, when the water level is high and strong, forcing the fish into the cage. Finally, handlines can be used to catch fish during all types of tides. This technique uses a hook when the tides are not influential. This equipment catches bony fish such as snappers, wreckfish and grey triggerfish. The fishing community in Barra de Mamanguape and Tramataia in northeastern Brazil also use various techniques to carry out fishery activities based on tidal cycle conditions (Bezerra et al., 2012). Eight fishery techniques are used by these fishermen, such as siege fishing, fishermen pay out the net, vertical fixing of a mullet net, gillnet, mesh net of silk, dragnet, cast net and longline. Siege fishing is carried out by three fishermen who row their boats to identify the movement of a school of fish. Then, the fishermen beat the water surface with a stick for the school of fish to swim towards the net. This technique is used at low tides during the big tide phase to catch small fish species, such as sardines and catfish. Finally, the 'fishermen pay out the net' technique is carried out at high tides during the big and flushing tides. This technique is assisted by strong seawater currents that manoeuvre the fish into the net. Finally, the vertical fixing of the mullet net technique is when the net is placed across the canoe's bow, and a kerosene lamp is attached. Fish are attracted to the light and jump towards the source of the light.

In the case of dead tides or flushing, the gillnet is used since the current is slow at that time. Next, during the full moon/new moon, the mesh net of silk is used, and tides are flushed and broken. This technique is applied in three phases: installed on the rod during the low tide and nets in the muddy soil. Next, the network is lifted and placed at the end of the rod when the water is at the highest level. Finally, the fishermen remove the fish caught in the nets when the water level decreases. In the case of breaking and flushing tides, the drag and casting nets are also used, while the longline is used during all tides.

The crab-catching technique usually involves bare hands and several tools such as the hoe, straight blade sickle and wooden shirt-handled hook. The fishing community in the State of Paraiba in northeast Brazil usually uses two techniques to catch mud crabs: the *braceamento* and *tapamento*. The *braceamento* technique is used during breaking or flushing tides. Fishermen put their hands into the hole and catch the crabs by holding the dorsal carapace part if the crab is not far into the hole. However, if it is far into the hole, the fishermen use *tapamento*, where the fishermen close the hole with mud and tree roots and then return to collect the crabs. In this situation, the crab moves towards the sediment surface independent of the tides. However, this technique is unsuitable during high tides because it would be difficult for the fishermen to determine the hole.

The catching techniques mentioned above are unsuitable for catching blue land crabs (Takahashi & Nishida, 2018) because this species lives in highlands that are higher than the high tide level. Hence, one of the techniques used is the mousetrap. The mousetrap is made of a wooden stick, an oil can, a strip of rubber, a circular piece of wood or plastic and wire. A variety of materials can substitute the oil can when making the mousetrap, for example, a PET bottle and PVC tubes. The PET bottle and PVC tube are used because they last longer than an oil can that would eventually rust. Besides, the PVC tube can also catch more blue land crabs compared to using an oil can and PET bottle because of its larger size.

## DISCUSSION

Indications of the fishing community at sea regarding astronomical phenomena relating to the moon phases, tidal cycles, seasons, wind and the repeated rainy seasons are provided (Hanapi & Hassan, 2017; Silva, 2005). Most fishermen understand marine life movement, which differs yearly depending on habitat type, seasons, weather, moon phases and other factors (Johannes & Neis, 2007). This is important to reduce the risk of failure to land a large crop, their main source of revenue (Kalikoski & Vasconcellos, 2007). Fishermen should also be provided with in-depth fishery information, navigational information, fish characteristics, various fish species and oceanography (William & Bax, 2007). Knowledge of astronomical phenomena influences fishermen's fishing activities through six elements. First, fishermen's knowledge of when the best time to catch the abundance of marine catches; second, fishermen's knowledge of the best location where to catch an abundance of marine catches; third, help fishermen to determine the maturity period of a marine species; fourth, repeating astronomical phenomena help produce a calendar to assist fishermen in carrying out fishery activities; fifth, guide the estimation time and safety issues for fishermen at sea or land; and sixth, guides fishermen on the most appropriate technique to use when carrying out fishery activities.

First, the astronomical phenomenon allows fishermen to know the best time to catch the abundance of marine catches. This astronomical phenomenon comprises moon phases, tides, seasons, wind and seawater conditions. The success of catches of any marine species depends on the optimal duration. For example, the full moon phenomenon (Alves et al., 2019; Boomhower et al., 2010; Cuevas-Zimbrón et al., 2011; Gerhardinger et al., 2006; Postuma & Gasalla, 2010) and the new moon (Deb, 2015; Nirmale et al., 2012) produce various catches for each marine species. This distinction depends on marine species' biology and habitat. Fishermen also learn about fishing seasons through their experience of seasonal phenomena. It is practised in the Oman fishing community (Nash et al., 2017), where these fishermen fish in the winter because it is easier to catch the species in this region when the water is cold. However, a fishing group also carries out wind phenomena-guided fishing activities. For example, in the southern Gulf of Mexico, fishing communities will catch *A. Narinari* stingrays when hot winds blow, as this species usually occurs in low waters (Cuevas-Zimbrón et al., 2011).

Second, the astronomical phenomenon guides fishermen to know the location of the abundant marine catches. For example, fisherman's knowledge of seasonal phenomena (Gerhardinger et al., 2006), tidal phenomena (Jo, 2018), and lunar phenomena allow fishermen to know the presence of fish at that time. For example, the Southern Brazilian fishing group realises that several species of fish are in the winter under the sea. Therefore, underwater fishing operations will focus during the winter. Furthermore, during the neap tide, small shrimps live at the sea's bottom (Jo, 2018). Thus, in the Domso Bay group's tradition in Korea (Jo, 2018), it will happen during the neap tide to catch small shrimps at the bottom of the sea.

In addition, fishermen can know the position of readily available fish, particularly the group of fish species, by knowing about new moons and full moon phenomena (Ruddle, 1994). For example, the aggregation time of coral fish is longer during the new and full moon cycles, making it easier for fishermen to track and locate the fish. This forecast period of fish aggregation is not only for the day and month it takes place but also for the tidal movements (Ruddle, 1994). Knowledge of fish-rich areas is also important because it ensures that fishermen get a large catch when they go out to sea and that their fishing activities are productive. Furthermore, this knowledge is also important since fishermen catch only marine species they like.

Third, knowledge about astronomical phenomena helps fishermen determine marine species' maturity period. The maturity period depends on a species' spawning and breeding season, each with its reproductive season. Reproductive knowledge determines the larvae's maturity (Bezerra et al., 2012). Fishermen's knowledge is also used to determine the location of fish spawning aggregation (Bezerra et al., 2021). In this way, catches can be kept at an optimal level, and the natural situation of a certain fish species cannot be disturbed (Poepoe et al., 2007). Disruptions in marine life's natural habitat may result in the extinction of some species. Additional aspects which should be considered to ensure that fish are caught in time are based on an appropriate fishing method (Bezerra et al., 2012). In addition, the breeding period is important because certain fish species breed in schools. Fishermen are in-depth aware of fish breeding in schools through moon or seasonal understanding. This knowledge helps them to increase catch at a certain place or time (Colin, 2012). Knowledge about fish breeding in groups is based on seasonal understanding (Boomhower et al., 2010).

Knowledge of tide cycles and the moon and season phenomena is essential for understanding a species' reproduction period (Nishida et al., 2006). According to Naylor (2015), the species' reproduction is determined by the physiological rhythm of the yearly reproductive period, which is interacted during the spawning period by the semi-lunar gonadal rhythm. For species that breed according to the semi-moon cycle, the oocyte maturity stage occurs during high tide and the species breed during low tide, whereby the oocyte maturity stage occurs during high tide and in daylight. The biological nature of fish has a bearing on reproductive activity. For example, in fish, melatonin reacts to night light levels, magnetic fields, and tidal cycles (Takemura et al., 2010). It, therefore, shows that every species reacts differently depending on the conditions of life around it.

Fourth, knowledge about repeating astronomical phenomena helps produce a calendar that assists fishermen in carrying out fishery activities. Astronomical phenomena repeated every day, monthly or annually help fishing communities develop a calendar to help fishing activities. For example, fishermen have used the relationship between knowledge about tidal cycles and moon phase in the Barra de Mamanguape and Tramataia fishing community, northeastern Brazil (Bezerra et al., 2012), Bangladesh (Deb, 2015) and Gomso Bay, Korea (Jo, 2018), to promote and support fishing. Fishermen can indirectly help them plan their fisheries with knowledge of tide cycles and moon phases. Furthermore, the community can develop a calendar of the main fish species' spawning periods by observing the behaviour, size and breeding conditions (Poepoe et al., 2007). The Hawaiian fishery community used traditional fishing knowledge to determine the breeding periods of major species to prevent the species' natural environment from being disturbed (Poepoe et al., 2007).

Fifth, knowledge about astronomical phenomena provides a guide about time and direction and ensures fishermen's safety. Astronomical phenomena are normally used to guide sea currents, seawater conditions, winds, sun and stars. This guide is a traditional way of guaranteeing their safety at sea by fishermen (Alves et al., 2019). The wind guide, sea currents and wind type can be used in hours or days to help predict the weather (Carbonell, 2012; Galacgac & Balisacan, 2002; Shalli, 2016). Timmers (2012) states that bad weather restricts fishing and indirectly affects fishermen's life and equipment (Shalli, 2016). In Brazil, fishermen's knowledge is more favourable to ensure their safety and success in fishing activity (Alves et al., 2020). One of the most dangerous fishing lives is due to the working environmental factor (Levin et al., 2010). In order to ensure their safety during fishing, it is therefore important for fishermen to understand astronomical phenomena.

Sixth, knowledge about astronomical phenomena guides fishermen when carrying out fishery activities based on a suitable technique. They understand that each species requires a different fishing technique (Bulengela et al., 2019) based on its size, characteristics, and habitat (Alves et al., 2019). The right technique ensures an optimal catch (Nishida et al., 2006) and the capture of only mature fish from a species (Bezerra et al., 2012). The proper technique also increases the amount of catch of a specific species while reducing the number of fishermen needed. For instance, innovation in the catch technique was involved in the catch of blue land crabs (Takahashi & Nishida, 2018), using PVC tubes rather than oil cans. Thus, the number of crabs caught in PVC pipes increased. Furthermore, the right technique ensures the catch is anticipated (Bezerra et al., 2012). Consequently, fishermen must know the location of certain fish species as it ensures that the correct technique is used (Deepananda et al., 2016). Some fishing techniques affect the ecosystem, so immature marine life can be avoided (Truchet et al., 2022). For example, the mesh net of silk catches marine species of different dimensions and at different stages of development (Bezerra et al., 2012). It is, therefore, important from the aspect of fish management and overfishing, which ensures the sustainability of a species, especially an endangering species.

## CONCLUSION

This study offers several suggestions that future studies should take into account. First, fishermen's knowledge of astronomical phenomena should be investigated in more places around Asia. Results show that there have been very few studies in Asia. It is because the population of fishermen in Asia is 85% highest than the world population of fishermen (UN-FAO, 2020). Therefore, the fishing population in Asia indirectly produces far more diverse knowledge of the cultural, language, and local and geographical astronomical phenomena. For example, Indonesia, the world's largest archipelagic state, has over 17,500 islands, 10,666 coastal villages, and a population of 16.42 million, all of whom have a long fishing tradition and culture (Sunaryanto, 2010). Therefore, there is a larger and more robust discussion about their fishermen's knowledge. Furthermore, the diversity and variations of Asian societies, cultures, and religions often lead to different perspectives on studying fishermen's astronomical knowledge. In contrast to the study on ethnoastronomy discussed by Western scholars, Sulaiman and Hassan (2020) discuss fishermen's knowledge of astronomical phenomena in terms of religion, known as ethno-*falak*.

Second, fishermen's knowledge of solar and lunar eclipses should be discussed. There is an effect on the behaviour of reef fish due to solar eclipses (Jennings et al., 1998). Based on this research, the author discovered that none of the works discusses knowledge of the sun and moon phenomena and their effects on catching fish. Third, rather than focusing solely on optimum marine catches and ensuring fishermen's safety, studies on fishermen's knowledge of astronomical phenomena should also focus on sustainable fish development. Data from 1974 to 2017 based on UN-FAO (2020) show an increase of 34.2% in overfishing. According to Bezerra et al. (2012), fishermen's knowledge of astronomical phenomena can help prevent overfishing in certain communities. Fourth, fishermen's astronomical knowledge must be preserved among young fishermen. While today's technological sophistication, such as GPS, fish finders, and sonar, is aimed at replacing fishermen's astronomical knowledge, this knowledge is still important to practise because modern technology has limitations. For example, the fishing community in Farol de Sao Thome, Brazil, still uses local knowledge such as wind, tides and lunar cycles in fishing activities, although this information can be obtained from the Internet because this knowledge is particularly important to know the natural events that occur in a specific coastal area that is used daily by fishermen (Alves et al., 2018). Supporting dialogue networks and providing workshops regularly with the help of public authorities, local administrators, researchers, and fishing communities can help to maintain and share fisherman's astronomical knowledge with younger fishermen. This initiative will help ensure the fishing industry's long-term viability and the quality of life of the people working there.

The main intention of this study was to systematically review studies related to fishermen's knowledge of astronomical phenomena on fishery activities. This study has produced several significant contributions to the existing corpus of knowledge relevant to the field of study. This study found an integrated relationship between the fishermen's community's socio-culture and nature, which concerns their knowledge of astronomical phenomena. The main findings indicate that fishermen's knowledge about astronomical phenomena influences their fishery activities on six elements. First, fishermen's knowledge of when the best time to catch the abundance of marine catches; second, fishermen's knowledge of the best location where to catch an abundance of marine catches; third, help fishermen to determine the maturity period of a marine species; fourth, repeating astronomical phenomena help produce a calendar to assist fishermen in carrying out fishery activities; fifth, guide the estimation time and safety issues for fishermen at sea or land; and sixth, guides fishermen on the most appropriate technique to use when carrying out fishery activities.

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