

Towards Ecological and Social Balance: Balanced Management for The Conservation of *Bilih* Fish (*Mystacoleus Padangensis* Bleeker) in Singkarak Lake

Mochammad Nadjib¹, Achsanah Hidayatina¹, Agus Hadiarto¹, Yani Mulyaningsih^{1*}, and Mahmud Thoha²

¹Research Center for Behavioral and Circular Economy, BRIN, 12710 Jl. Gatot Subroto No.10, Jakarta, Indonesia

²Research Center for Macro Economy and Finance, BRIN, 12710 Jl. Gatot Subroto No.10, Jakarta, Indonesia

Abstract. Symptoms of over exploitation in *bilih* fish (*Mystacoleus padangensis* Bleeker) fishing in Singkarak Lake are indicated by a decline in population and the decreasing size of caught fish. To prevent over exploitation, management of the lake area and its resources, especially *bilih* fish, is needed so that it can be utilized sustainably. This article is written comprehensively to provide an overview of the challenges and opportunities faced in maintaining the sustainability of *bilih* fish in Singkarak Lake. In addition, a balanced management approach is presented that integrates ecological and social aspects as an alternative solution for the conservation of *bilih* fish in the Singkarak Lake aquatic ecosystem. Data were obtained through literature studies and analysis of various information sources related to fisheries management and *bilih* fish conservation in Singkarak Lake. Primary data were obtained through direct observation and interviews with stakeholders. The important finding in this article is the need for an Adaptive Collaborative Management approach in the management of lake aquatic ecosystems for the conservation of *bilih* fish. Adaptive Collaborative Management is an approach that emphasizes the importance of collaboration between various stakeholders.

1 Introduction

Singkarak Lake is one of the five lakes in West Sumatra Province. Administratively, the Singkarak Lake area stretches across two districts, Solok and Tanah Datar. The lake waters included in the Solok Regency area are narrower (around 33%) compared to those in the Tanah Datar Regency (around 67%).

Economically, Singkarak Lake is utilized for rice irrigation, hydro power, tourism, and fish-catching and cultivation businesses. There are 12 species of fish living in Singkarak Lake [1]; this number of species is lower than Syandri's research [2], which found as many as 19

* Corresponding author: mulyaningsihyani9@gmail.com

species. Of the 19 species, three species have high population densities, namely *Bilih/Biko fish (Mystacoleus padangensis Bleeker)*, *Asang/Nilem (Osteochilus brachmoides)* and *Rinuak*. However, *bilih* fish remains the prima donna. *Bilih* fish is an endemic species [3,4]. As an endemic fish species, *bilih* fish has become the identity of Singkarak Lake's uniqueness, although various other types of fish also breed in the lake area. The high demand for *bilih fish* commodities has caused efforts to catch this fish to continue to increase every year. Currently, the people around the lake are maximizing their efforts to catch *bilih* fish (Figure 1), not only for local consumption but also marketed outside the province and even to Malaysia in the form of processed fish. The impact of birth fish exploitation is the occurrence of overfishing [5], which is marked by a decline in population [1] and the decreasing size of caught fish [2]. The phenomenon of over exploitation carried out by the community in catching *bilih* fish is worrying for the sustainability of this endemic fish population, and the impact is the decline in the welfare of the local community. So far, *bilih* fish commodities have been able to support economic activities around Singkarak Lake, even as one of the attractions of local tourism.

Many factors play a role in determining the conservation of *bilih* fish in Singkarak Lake, including cultural factors. Talking about cultural factors must be distinct from the ethnicity of the people who live around Singkarak Lake. The people around Singkarak Lake, based on ethnic classification, are included in the Minangkabau ethnic group. One of the living philosophies of the Minangkabau people that continues to be lived and passed down to the present generation is the view contained in the phrase "*Alam takambang jadi guru*". The essence of this philosophy is the basis for the way of thinking of the Minangkabau people, which shows that the surrounding environment is a good teacher, providing experience as a basis for solving, overcoming, or managing the environment [6]. The question is, to what extent do the philosophy and local knowledge of the community allow for the sustainable use of resources to ensure well-being? Furthermore, can the government-initiated management accommodate all parties in utilizing the Singkarak Lake area wisely?

Considering the various problems that occur in the management of Singkarak Lake and to ensure the optimization of the sustainable use of *bilih* fish, it is inspiring to carry out inter-party management based on collaborative adaptation (Adaptive Collaborative Management). This approach is based on the assumption that the management of the Singkarak Lake area can be optimally realized if there is a balance between government-initiated management (state-led) and community-based management (community-led). This management balance can be optimally achieved for collective goals if there is a strengthening of the coordination function both vertically and horizontally and across stakeholders. This paper seeks to understand the existing reality, with the aim of finding answers to the questions raised and alternative management proposals.

Literature Review

1.1 Local wisdom practices in the utilization of Bilih Fish in Singkarak Lake

Hills with forest and garden areas surround the Singkarak Lake area, while the flat areas on the lakefront are home to fertile settlements and agriculture. Thus, the lake and land are complementary economic subjects because the community's economic involvement depends not only on the lake's existence but also on agriculture and plantations.

The land is utilized for agriculture, and plantations and forest areas have an essential function in the economic, ecological, and sociocultural needs of the community. In managing forests, there are protected areas (called *rimbo tuo*) and utilization areas (called *palak*). The utilization of protected areas is only intended for taking non-timber forest products, but wood

utilization is still allowed as long as it is used for public purposes. Likewise, the utilization of garden areas (*palak*) can be used to plant economic crops, such as coffee, rubber, etc. However, customary law prohibits the use of this area without considering ecological principles, such as a prohibition on cutting down trees in steep areas, watersheds, and riverbank areas [7].

Local communities utilize the lake for fish farming and fishing, even though *bilih* fish remains the mainstay. *Bilih* fish spawn by following the flow of rivers that flow into the lake [8]. *Bilih* fish eggs hatch in the lake after 19 hours, and the larvae develop in the lake into adult *bilih* fish. *Bilih* fish spawn every day throughout the year from evening to the next morning. The spawning of *bilih* fish is partial. Namely, the eggs that have matured sexually (mature gonads) are not released at once but only partially in one spawning period. The spawning habitat for *bilih* fish is clear river waters with relatively low temperatures and a riverbed that is pebbled and sandy. These specific environmental factors greatly influence the spawning of *bilih* fish, namely the existence of water currents and bottom substrates. In addition, *bilih* fish also spawn in sandy areas overgrown with *dedalu* plants or known as Indian Willow. The typical *dedalu* tree grows in sandy soil that is submerged in water, so if the water recedes, this plant will die. Therefore, the stability of the water surface is significant for the sustainability of the growth of *dedalu* plants.



Fig. 1. *Bilih* fish (left) and *Dedalu* tree (right)

The habits of *bilih* fish in spawning have given rise to local fishing technology that pays great attention to the aspect of sustainable resource utilization. The existing community tradition of catching *bilih* fish must still pay attention to the aspect of ecological sustainability. This condition can be seen from the environmentally friendly fishing gear, which is traditionally owned and operated by members of the *kaum* and installed in the *kaum's* ancestral areas. This fishing technology is a form of local wisdom of the communities around Singkarak Lake in utilizing *bilih* fish. The most critical *bilih* fish-catching technology [7] is:

1.1.1 *Alahan*

Alahan is a technology for catching *bilih* fish in Singkarak Lake by making artificial canals at the mouths of clear rivers pebbled or sandy rivers that have relatively low temperatures. Artificial embankments limit this canal to separate it from other canals (Figure 2). The width

of the canal is around 4 meters, with a length of tens to hundreds of meters. With the presence of this *alahan*, the river mouth will be formed into a number of canals that are arranged side by side. The working method of this tool is to intercept *bilih* fish when they return from laying eggs with equipment called *hirok* so that the *bilih* fish that are caught are the parents. Furthermore, the *bilih* fish eggs will drift with the water into Singkarak Lake.



Fig. 2. *Alahan: Bilih* fish-catching technology

Bilih fish-catching technology using *alahan* is only found in the mouths of certain rivers in Singkarak Lake, especially in Nagari Paninggahan and Nagari Muaro Pingai. Only some have the right to catch *bilih* fish in *alahan*; only members of the ancestral community¹[9] from the local *Kanagarian* have the right to catch *bilih* fish in the river mouth using *alahan* fishing gear. Apart from the aforementioned ancestral areas, anyone has the right to utilize it for fishing on condition that they do not use environmentally damaging technology such as poison, fish booms (*badia*), and electricity.

1.1.2 *Tinasah*

Tinasah is a gill net technology used to catch *bilih* fish. To catch *bilih* fish, the *tinasah* net is statically planted parallel to the water flow. The installation is done parallel to the water flow because the *tinasah* net is woven from fibers of certain trees that live around the lake. Therefore, the shape is a bit rough; if immersed in water, the *tinasah* net becomes very heavy and easily damaged. The *tinasah* net is not strong enough to withstand the waves, and the push of the lake waves can easily tear it. Installing the net parallel to the water flow in a perpendicular position to the land makes the water splash less intense than when installed across against the water flow.

¹ In the Minangkabau ethnic group, '*kaum*' (*paruik*) refers to a social unit that forms the core of the kinship system, based on the matrilineal line. Traditionally, a *kaum* was comprised of several core families living in a single *gadang* house. The emotional bond within a *kaum* is not only based on blood ties but also on shared ownership of heirlooms, descendants, and burial places, among other factors [9].

Installing the *tinasah* net perpendicularly parallel to the water flow has a positive effect, especially on efforts to conserve *bilih* fish. This installation does not hinder the movement of *bilih* fish that will spawn on the sandy shores of the lake overgrown with *dedalu* plants or to the river mouths which are their spawning habitat. *Bilih* fish that are caught in the *tinasah* net are *bilih* fish that have finished laying eggs on their way back to the middle of the lake. *Bilih* fish that are not under the pressure of the spawning instinct, their direction of movement is not always perpendicular to when they go to the edge to lay eggs. This statement is where the meaning and role of local wisdom in environmentally friendly *bilih* fish catching lies. The *tinasah* net is a particular net that is owned by the ancestral community and operated only by the *kaum* itself. In addition to the *kaum*, other residents are prohibited from operating this net.

In operating fishing equipment, the community understands the wisdom and sustainability of resources. Fishing technology is very environmentally friendly, so only fish that have finished spawning and have a specific size can be caught. It is through the *Nagari* government that the management of the lake and land areas is carried out.

Nagari is a social-political organization in West Sumatra, which has the lowest autonomous government; *Wali Nagari* leads *Nagari*. *Nagari* is an administrative area that has a unique identity and autonomous entity; where this area has its own customary law regulations regarding economic and ancestral resources, in addition to having characteristics that are not the same between one *Nagari* and another[10]. Regarding the ancestral area, ownership is based on communal principles whose distribution and utilization are subject to customary law[11]. *Nagari* plays an essential role in distributing and regulating its utilization, but all decisions are based on the approval of the *Nagari Adat* Council. The three types of ancestral land ownership systems include: (1) *Ulayat Nagari*, under the responsibility of the *Nagari Adat* Council; (2) Tribal *Ulayat*, under the responsibility of all *datuks* under the coordination of *Datuk Pucuak*; (3) *Kaum Ulayat*, under the responsibility of *Kaum* members and coordinated by *Datuk*.

People from outside the local tribe can be permitted to manage natural resources in the *Nagari* on a profit-sharing basis with the community that controls the area (*nagari*, tribe, or *kaum*). Thus, the meaning of ancestral land for the *Minangkabau* people has a broader value than just economic value but also social, cultural, and ecological value[11]. Control of ancestral land is carried out collectively with an inheritance system based on the maternal lineage (matrilineal). Because of its collective control, there is little possibility of transferring rights to other parties because the process must obtain the approval of all ancestral land residents.

People from outside the local tribe can be permitted to manage natural resources in the *Nagari* on a profit-sharing basis with the community that controls the area (*nagari*, tribe, or *kaum*). Thus, the meaning of ancestral land for the *Minangkabau* people has a broader value than just economic value but also social, cultural, and ecological value [11]. Control of ancestral land is carried out collectively with an inheritance system based on the maternal lineage (matrilineal). Because of its collective control, there is little possibility of transferring rights to other parties because the process must obtain the approval of all ancestral land residents.

The role of the *Nagari* government is very colorful in managing the Singkarak Lake area and the surrounding land. There are 13 *Nagari* around Singkarak Lake; seven are in the *Solok Regency* area, and six are in the *Tanah Datar Regency* area. Because each *Nagari* around Singkarak Lake has its own *Nagari* Regulations, the vision contained in the customary rules between *Nagari* is different. However, the diversity of these regulations is connected daily through a "common thread" that shows harmony.

1.2 Deviations from local wisdom practices in managing *Bilih* Fish

The lowest administrative area in the Singkarak Lake area is the *Nagari* government. *Nagari* is an autonomous administrative area that has customary law regulations regarding economic and ancestral resources.

Since the government policy no longer adopts customary power in line with the enactment of Law No. 5 of 1977 concerning Villages, which was then changed to Law No. 5 of 1979 concerning Village Government. The enactment of this law has changed the government system from *Nagari* to Village government as a form of centralized policy and standardization of government at the lowest level. The change in the *Nagari* government system to the Village government system has caused customary institutions to experience changes in function and role, including a shift in traditional management practices in West Sumatra. The Minangkabau people are gradually being eroded from their cultural roots [12–14]. The change from the *Nagari* government to the Village government has caused local customary institutions to experience a shift in function and role. This institution no longer has an essential meaning in village governance, and that of the formal village government has replaced its position. There is no longer any right to regulate their territory in the context of controlling ancestral territory, and the role of *ninik mamak* is increasingly ignored.

Since the enactment of Law No. 22 of 1999 and Law No. 25 of 1999, it has shown that there is autonomy in Local Government. This law is a new paradigm that gives freedom to regions to regulate and manage themselves, including adjusting the form and structure of government according to the local sociocultural situation and conditions. In response to the existence of this law, the West Sumatra Provincial Government issued Provincial Regulation of West Sumatra No. 9 of 2000 to return the lowest government from the Village administration to the *Nagari* Government. In the context of this Regional Regulation, *babaliak ka Nagari*, or returning to *Nagari* is expected to reflect better and accommodate local culture so that the existence of the government will remain based on the noble values of Minangkabau adat and culture [12,14].

In connection with the utilization of Singkarak Lake, the government's return to the *Nagari* system has, in fact, yet to be able to change government policy to manage the area wisely. Policies in managing the environment need to balance the great authority of the regions in managing the region. Initially, the edges along the distance of a stone's throw (*sapambaian*) became ancestral areas in each *Nagari*. In fact, this area has become an open area. As an open-access area, everyone can freely fish, except in certain places where the ancestral community has made and installed *bilih* fish-catching equipment in the form of *alahan* and *tinisah*. Apart from the aforementioned ancestral areas, it is an open-access area; anyone has the right to utilize it for fishing. According to [15] and [16], open resources will be freely owned, utilized, and exploited to the maximum by anyone without regard to the negative consequences of their actions. Thus, the community around the lake interprets the essence of "*Alam takambang jadi guru*" only for economic purposes. If everyone has the same mindset to be able to exploit the existing resources as much as possible, it will be able to destroy the biological, ecological, and economic conditions of natural resources.

In connection with fishing for fish resources in Singkarak Lake, fishing models that are considered environmentally damaging have emerged, including fishing for *bilih* fish using booms, poison, electric currents (shocks), and lift nets (floating nets) that use small (<4 mm) *waring*² size. The use of dense *waring* allows small *bilih* fish to be trapped inside. The Provincial Government through the Governor of West Sumatra Regulation Number 81 of 2017 concerning the Use of Fishing Gear and Materials in Singkarak Lake Waters prohibits the use of such destructive fishing gear and materials. The use of destructive materials in

² *Waring* is a net made from woven plastic rope

fishing often causes fatal casualties, not only to the environment but also to the perpetrators themselves. This alarming situation calls for immediate action to protect our environment and the safety of our fishermen.

In addition, the practice of fishing with *langli* nets has also developed and increased. *Langli* nets are new fishing gear made from nylon to address the problem of *tinasa*h nets that are heavy and easily damaged (Figure 3). Therefore, these nets are not included in prohibited fishing gear. *Langli* nets have been known to fishermen in Singkarak Lake since the mid-1970s [17]. As with *tinasa*h, *langli* nets are gillnets that must be anchored to the bottom of the lake to operate. The only difference is that *tinasa*h nets are operated on the basis of wisdom that respects conservation principles, while the operation of *langli* nets is more based on meeting immediate economic needs. The position of installing the *tinasa*h net is parallel to the water flow in a perpendicular position to the land so that the net does not block the movement of fish to the edge of the lake to lay eggs. Conversely, *langli* nets are installed parallel to the coastline. This installation position blocks the path of *bilih* fish moving towards the edge of the lake. The position of the net parallel to the coastline of the lake means that the *bilih* fish that are caught have not had a chance to lay eggs [17]. In addition to less wise fishing practices, the ownership pattern of *langli* nets is different from that of *tinasa*h nets. If *tinasa*h nets are only owned and operated by ancestral communities, *langli* nets can be owned and operated by every citizen. The more people who own *langli* nets, the more the *bilih* fish population will be exploited, so overfishing can occur at any time, which will then affect the fish population.



Fig. 3. *Langli* nets to catch *bilih* fish in *tanatang* area

In addition to *langli* nets (Figure 3), the community also makes *tanatang*, which is fishing by creating an artificial area as a place for *bilih* fish to roam when they want to spawn by imitating their natural habitat. This *tanatang* is an imitation of the *alahan* area where *bilih* fish that will lay eggs roam the edges of the lake. This *tanatang* is generally small in size and generally round like a net. The system is similar to *alahan*; only *tanatang* does not use traps to allow fish to enter and exit. After enough *bilih* fish have gathered in the *tanatang*, the fish are then caught using a throw net. Although this *tanatang* is similar to *alahan*, the principle of how it works is different. The *alahan* method is considered a form of local wisdom because it only catches *bilih* fish that have spawned on their way back from the upstream river to the lake. Conversely, *tanatang* is a gathering place for fish that have yet to spawn.

Bilih fish also spawn in sandy areas overgrown with *dedalu* plants (Figure 1). This typical tree grows in sandy soil that is submerged in water, so if the water recedes, this plant will die. The stability of the water surface is significant for the sustainability of the growth of *dedalu* plants. The existence of the Singkarak PLTA (Hydroelectric Power Plant), to a certain extent, is considered an external factor that causes the decline in the *bilih* fish population in Singkarak Lake. The use of lake water for the Singkarak PLTA has resulted in a decrease in the lake water level, and the impact is that the roots of *dedalu* trees stick out of the water. The role of the roots of *dedalu* trees is important in the spawning process of *bilih* fish, and the emergence of the roots of *dedalu* trees causes *bilih* fish to be unable to reach the roots of the trees.

In fact, using the lake for PLTA will directly produce a large amount of electrical energy, which can then be used to generate economic activities in various sectors of life. However, PLTA can also negatively impact the economic activities of the community and the preservation of the environment around Singkarak Lake, such as lake silting and waste accumulation, as well as declining fish production.

2 Research method

2.1 Data collection

This article was written using data obtained through literature studies and analysis of various information sources related to fisheries management and *bilih* fish conservation in Singkarak Lake. The research also involved direct observation in the field and interviews with stakeholders.

Field data was obtained through in-depth interviews with a number of resource persons and critical informants, as well as by conducting focus group discussions. The resource persons interviewed included economic actors in the Singkarak Lake area, local communities, village and *Nagari* governments, and other stakeholders. The writing method in this article includes a qualitative approach with descriptive and comprehensive analysis. This comprehensive understanding places the object of study in the context of causal relationships and empathy as an approach. The intended empathy approach seeks to understand field problems from the perspective of the actors.

The key informants interviewed included policymakers, academics from local universities, and several community leaders who live around Singkarak Lake. These are people who know and understand a lot about the lake's problems.

2.2 Data analysis

The data obtained was then analyzed using qualitative data analysis techniques. The analysis process includes data reduction, data display, and data verification/validation. Data reduction is the process of selecting, focusing, summarizing, and transforming raw data into a more manageable form. Data display is the process of organizing and presenting analyzed data clearly and concisely. Data verification/validation is the process of checking the accuracy and credibility of the data.

3 Results and Discussion

3.1 Community-based management for Bilih Fish conservation in Singkarak Lake

Community-based management is one of the management models that entirely originates from the traditions, customs, and wisdom of the community. The other model is management, which is solely initiated formally by the government (state-led) with a top-down approach.

Community-initiated management (community-led) has the advantage of being able to provide direct benefits to the community. In the case of Singkarak Lake, the community can utilize *bilih* fish resources according to their needs. The disadvantage is that community-initiated patterns are generally traditional; in Singkarak Lake, they are only suitable for local areas or certain ancestral territories (*Nagari, Suku, or Kaum*). Its existence is indeed known, but it is rarely adopted in government-initiated management [18]. Therefore, in the case of Singkarak Lake, community management (community management), in reality, has not been able to guarantee the sustainability of the existence of *bilih* fish.

On the other hand, if the management is carried out entirely by the government, even though it has advantages, it also has disadvantages. The advantage is that there are standard benchmarks in managing resources, involving stakeholders to determine management rules and how the management rules that are made can be adjusted to local conditions. The disadvantage is that the Singkarak Lake area stretches across two administrative districts (*Solok District and Tanah Datar District*) and 13 *Kanagarian* areas. Therefore, problems related to *bilih* fish resources cannot be solved by one government administration and *Kanagarian*, but cross-government and *Kanagarian* cooperation is needed. Conflicts of interest often occur between economic actors in different administrative areas.

In the long term, this situation will create an ecological degradation phenomenon that can reduce the *bilih* fish population because *bilih* fish resources are considered a resource that can be freely owned and exploited by anyone. Borrowing [15] analysis, common-pool resources (Common-Pool Resources), if there is a conflict of interest that causes overlapping roles between various interests, can lead to the tragedy of the commons or a disaster for all parties. Hardin's opinion is reinforced by Wantrup and Bishop [16], who state that resources that are considered to have no owner allow everyone to exploit them to the maximum without regard to the negative consequences of their actions. Suppose everyone has the same mindset about exploiting *bilih* fish in Singkarak Lake as much as possible. In that case, the biological, ecological, and economic destruction of *bilih* fish resources will occur and has the potential to cause social conflicts among economic actors. The results of the study show that the management of *bilih* fish in Singkarak Lake is facing various challenges. The main challenge is the lack of effective coordination between stakeholders. This lack of coordination has led to the emergence of various problems, such as the use of destructive fishing gear, the emergence of new fishing practices that are not environmentally friendly, and the impact of the Singkarak PLTA on the *bilih* fish population.

To overcome these challenges, a more integrated and comprehensive management approach is needed. This approach should involve all stakeholders, including government agencies, local communities, and the private sector. The approach should also be based on sound scientific principles and local wisdom.

Some specific recommendations for improving the management of *bilih* fish in Singkarak Lake include:

- Strengthening the role of customary institutions in managing *bilih* fish resources.
- Improving community awareness of the importance of sustainable fishing practices.
- Conducting research to find alternative fishing methods that are more environmentally friendly.

- Enforcing regulations on the use of destructive fishing gear.
- Developing a comprehensive management plan for Singkarak Lake that takes into account the needs of all stakeholders.

Implementing these recommendations is hoped to improve the management of *bilih* fish in Singkarak Lake and ensure the sustainability of this important resource.

According to [19], joint ownership of a resource (Common-Pool Resources) does not have to lead to the tragedy of the commons if a paradigm shift is made from sector to collaborative management (collaborative management). The collaborative management pattern has actually been an old solution. Olson, in his book entitled *The Logic of Collective Action: Public Goods and the Theory of Groups* [20], stated that individuals in groups generally have a collective logic to gain their advantage at the expense of others. The solution offered is an effort to shift from the desire for one's interests to shared interests. For this reason, it is essential to manage *bilih* fish resources collaboratively or in a partnership working principle by sharing responsibilities among stakeholders, namely the government, the private sector, and the community in managing *bilih* fish [18,21]. In its implementation, this governance is participatory, involving all stakeholders actively in various management activities, including developing a shared vision, learning together, and making adjustments in the practice of managing *bilih* fish.

3.2 Principles of collaborative management for Bilih Fish in Singkarak Lake

Based on the principles of collaborative management proposed by [19], several principles can be applied to the management of *bilih* fish in Singkarak Lake, namely:

- a. Clearly defined boundaries: The boundaries of the *bilih* fish management area must be clearly defined, including the physical boundaries of the lake and the boundaries of the stakeholders involved.
- b. Shared rules: Rules for managing *bilih* fish resources must be developed and agreed upon by all stakeholders. These rules should be based on sound scientific principles and local wisdom.
- c. Monitoring and enforcement: There must be a monitoring system in place to ensure that all stakeholders are complying with the agreed-upon rules. There must also be a mechanism for enforcing the rules, such as sanctions for non-compliance.
- d. Graduated sanctions: Sanctions for non-compliance with the rules should be graduated, meaning that they should increase in severity as the frequency and severity of non-compliance increases.
- e. Most-affected decision-making: Decisions about the management of *bilih* fish resources should be made by those who are most affected by the resource. This could mean that decisions are made by a committee of stakeholders, or by a vote of all stakeholders.
- f. Conflict resolution mechanisms: There must be mechanisms in place for resolving conflicts that arise between stakeholders. These mechanisms should be fair and transparent, and they should be based on the principles of mutual respect and understanding.
- g. Flexibility: The management system should be flexible enough to adapt to changing conditions. This could mean revising the rules periodically or developing new mechanisms to address new challenges.

3.3 Benefits of collaborative management for Bilih Fish in Singkarak Lake

Collaborative management can provide several benefits for the management of *bilih* fish in Singkarak Lake, including:

- a. Increased sustainability: Collaborative management can help to ensure the long-term sustainability of *bilih* fish resources by reducing overfishing and habitat destruction.
- b. Improved equity: Collaborative management is a beacon of fairness, ensuring that the benefits of *bilih* fish resources are not concentrated in the hands of a few but shared equitably among all stakeholders.
- c. Reduced conflict: Collaborative management can reduce conflict between stakeholders by providing a forum for communication and cooperation.
- d. Increased resilience: Collaborative management, which involves all stakeholders in decision-making, can help make the *bilih* fish management system more resilient to change.

3.4 Balanced management for Bilih Fish conservation in Singkarak Lake

The management of water bodies requires a unique approach, including the management of the Singkarak Lake area, which has the main potential for *bilih* fish. The intended distinctive approach must be in accordance with the region's very diverse socio-ecological characteristics, so there is no "one size fits all" or only one model for all different lakefront areas.

According to [22], fisheries management cannot be separated from three interrelated dimensions, namely (1) fishery resources and the ecosystem, (2) their utilization for the social and economic interests of the community, and (3) policy aspects. The three dimensions are essential to creating a balance between birth fish resources and the creation of community welfare, as well as the interaction between biotic and abiotic components of the unity of function and ecosystem [23]. If the interaction between biotic and abiotic components is ignored, then sustainability can be guaranteed to be threatened. On the other hand, the management of the lake area also involves many parties; the existence of this complex relationship is what can determine whether the community is prosperous or not. The following will describe the three interrelated dimensions of fisheries management, namely:

1) *Fishery Resources and Their Ecosystem*

It is important to take an integrated and balanced approach to fisheries management in the context of the ecosystem (ecosystem approach to fisheries). By adapting the Ecosystem Approach to Fisheries Management (EAFM) model, many parties can be involved.

2) *Utilization for Social and Economic Interests of the Community*

The utilization of *bilih* fish resources for the social and economic interests of the community must be carried out sustainably. This means that the level of utilization of *bilih* fish resources must be, at most, the carrying capacity of the ecosystem. In addition, the utilization of *bilih* fish resources must also be fair and equitable so that all stakeholders can benefit from it.

3) *Policy Aspects*

Strong policies must support the management of *bilih* fish resources. These policies must be based on sound scientific principles and local wisdom and flexible enough to adapt to changing conditions.

3.5 Principles of balanced management for *Bilih* Fish in Singkarak Lake

Based on the principles of balanced management discussed above, several principles can be applied to the management of *bilih* fish in Singkarak Lake, namely:

- a. The precautionary approach: The precautionary approach is a principle of fisheries management that states that when there is a risk of serious harm to the environment,

decisions should be made based on the best available scientific information, even if it is not yet certain that the harm will occur.

- b. The ecosystem approach: The ecosystem approach to fisheries management is a holistic approach that takes into account all aspects of the ecosystem, including the interactions between fish, other species, and the environment.
- c. The fair and equitable utilization of resources: The utilization of *bilih* fish resources must be fair and equitable, so that all stakeholders can benefit from it.
- d. The participation of stakeholders: All stakeholders, including government agencies, local communities, and the private sector, should be involved in the management of *bilih* fish resources.
- e. The adaptive management: The management system should be flexible enough to adapt to changing conditions.

3.6 Fishery Resources and Their Ecosystem

An integrated and balanced approach in the context of the ecosystem in fisheries management (ecosystem approach to fisheries) is important to do. By adapting the Ecosystem Approach to Fisheries Management (EAFM) model for fisheries management, involvement of many parties can be carried out.

The EAFM approach is understood as a concept of balancing socioeconomic goals in fisheries management while still considering knowledge, information, and uncertainty about biotic and abiotic components and human interactions in aquatic ecosystems through integrated, comprehensive, and sustainable fisheries management [23]. In implementing the EAFM model, planning is required [23], which includes:

- a. Policy planning emphasizes policymakers' commitment to implementing EAFM, namely the existence of a balance between socioeconomic goals and the balance of the environment and *bilih* fish resources.
- b. Strategic planning is our proactive approach to achieving the goals set by policy planning. This comprehensive plan includes the development of instruments for rules of the game and management tools, all meticulously compiled based on a risk analysis of the sustainability of *bilih* fish resources.
- c. Operational management planning focuses on more detailed activity and action plans, inter-stakeholder coordination plans, control plans, and utilization and enforcement of the established rules of the game. In addition, a participatory stakeholder-based monitoring and surveillance mechanism has been established.

Given the complex nature of EAFM governance, its implementation in the field, including in the Singkarak Lake area, requires structural and functional adaptation at each operational level. A change in mindset is needed, not just to carry out fisheries administration functions but also to carry out fisheries management functions.

3.6.1 Utilization for social and economic interests of the community

The management of the lake area is an essential instrument for understanding the dynamics of the community related to the pattern of utilization and appreciation of resources. The basic principles in formulating a lake area management plan are integration and aspiration principles.

It is integrated in the context of a comprehensive approach that combines the dynamics of natural systems (ecological systems) and human systems (social systems) as well as between land and water areas. Aspiration is more about a bottom-up approach, where the process of planning the lake area is carried out by involving the lakeside community as both subjects and objects of the planning itself. This approach [24] is known as socio-ecological

systems (SES), where lake area management based on social ecology is a form of integration between ecological understanding (ecological understanding) and socio-economic values (socio-economic value). The social-ecological system, according [25], is an ecological system that is closely related to and influenced by one or more social systems. Social and ecological systems contain units that are interdependent and interact with each other, involving various subsystems. Thus, social and ecological systems have units that are interdependent and interact with each other, involving various subsystems. When social and ecological systems are interconnected, they create a complex social-ecological system that is adaptive and consists of several subsystems that are integrated with several larger systems.

The social-ecological system in integrated management provides an interdisciplinary approach and a framework for sustainable resource management [26]. The object of diagnosis is carried out related to everything related to the conditions of socio-ecological systems. The results of the diagnosis are collected and analyzed to see the challenges and opportunities for management options and livelihood development. The solution to improve community welfare is carried out by systematically understanding collaborative social (economic) relations. This reality shows the need for a holistic (comprehensive) perspective, integrated in seeing the symptoms of poverty, as well as efforts to overcome them collaboratively.

3.6.2 Policy aspects

The Singkarak Lake area, spanning two administrative districts and 13 Kanagarian areas, presents a unique challenge. The vastness of this area underscores the necessity for collaborative policies when it comes to *bilih* fish resources.

A solution is needed to strengthen coordination functions, both vertically and horizontally, and across stakeholders. To bridge the coordination function between government agencies, stakeholders, and the community, the concept of Joined-up government is needed. The concept of Joined-up government offers a new approach to coordination, with the aim of overcoming and melting away as much as possible the structural barriers within and between organizations so that the optimization of collective goals can be achieved [27,28]. Although in practice, it is challenging to eliminate structural barriers, at least "loosening" can be done to achieve collectively agreed temporary goals[29].

The concept of Joined-up government lies in two main elements, namely Joined-up coordination and Joined-up integration. Joined-up coordination refers to collaboration between institutions/organizations related to information systems, dialogue to build a shared understanding, program planning, and the decision-making process. The output produced is a joint agreement and consistency of collective agreements based on an understanding of how to overcome negative externalities. Meanwhile, Joined-up integration is a collaboration between institutions/organizations in implementing decisions that have been collectively agreed upon through the coordination process. At this stage, the commitment to the collective agreement resulting from coordination will be tested, and whether there is consistency between the agreement and implementation or vice versa will be tested [30]. Participatory governance that involves various stakeholders in its coordination (Joined-up coordination) requires representation in joint management. This representation is an important principle to avoid conflicts arising from differences in interests. An adaptation process is needed to unite various interests in the same understanding to manage *bilih* fish resources.

There are areas for improvement in the practice of resource governance, including the management of *bilih* fish. According to [31] and [32], the problem of uncertainty is a factor of weakness in resource governance practices, including *bilih* fish. The differences in the background of the stakeholders' interests cause the dynamics of fluctuating and constantly changing governance policies so that uncertainty in decision-making is possible. In addition, environmental risk factors also raise uncertainty problems. Generally, this environmental

uncertainty is caused by the *bilih* fish population, which is constantly changing rapidly. Running a program based on certain information will result in effective decisions.

[32] propose a solution to the dilemma of differences in interests and uncertainty in decision-making, including in governance, to conserve *billih* fish in Singkarak Lake. A governance approach is carried out that allows for systematic and sustainable decision adjustments. The process of adjusting decisions will occur after information can be collected and when there are changes. This process is known as the adaptive management model [32], which is a management approach that allows for systematic and sustainable decision adjustments. This approach allows for the correction of mistakes that have been made, then immediately corrected as often as needed (trial and error). This model combines government-initiated governance (state-led) and community-based governance (community-led).

The key to the success of adaptive governance is learning from previous experiences as input for better subsequent governance planning. In order to maximize the use of strengths and minimize weaknesses, [32] propose collaboration between models, namely the collaborative management model with the adaptive management model or what is better known as Adaptive Collaborative Management. This model allows for stakeholder representation in joint governance because the absence of representation can lead to conflicts of interest. Governance based on the adaptive collaborative management model will achieve satisfactory results if the management concept is community-based. Every different user element should be accommodated as much as possible so that integration in the true sense is achieved, namely, it can accommodate and accommodate all different interests. A severe problem in achieving integration from the various elements involved in the organization is if the fair representation of groups is not fulfilled because each element in the organization has different interests.

3.6.3 *Economic potential of Lake Singkarak's resources*

Singkarak Lake holds significant economic potential, particularly through the utilization of *bilih* fish. This research strengthens [33] finding regarding economic value to local fishermen and healthy ecosystem support for the tourism sector. The direct economic value is evident in the fisheries sector, providing income to local fishermen through the sale of *bilih* fish. Additionally, the fish processing industry, including the production of salted fish and other processed products, also significantly contributes to the local economy. Indirect economic value is equally important, as a healthy ecosystem supports the tourism sector, particularly ecotourism. Nature-based tourism activities such as boat tours, fishing, and other recreational activities attract tourists, generating income for service sectors such as hospitality, restaurants, and tour guides.

As previously researched by Nair and Nayak [34], the decline in fish population directly impacts the income of fishermen and the sustainability of the fish processing industry. The degradation of the aquatic ecosystem also diminishes tourism appeal, disrupting the livelihoods of resident's dependent on the tourism and fisheries sectors. This decline can lead to reduced regional income, increased poverty, and force local communities to seek alternative income sources that may be unsustainable or environmentally harmful. Therefore, protecting Lake Singkarak's ecosystem is crucial for the economic and social well-being of surrounding communities.

As previously stated, developing sustainable business models can be a solution to maintaining and enhancing the economic value of *bilih* fish [35]. One alternative is *bilih* fish agritourism, which involves educating tourists about *bilih* fish farming processes, thereby increasing household income and raising conservation awareness. Additionally, diversifying *bilih* fish-based products such as fish crackers, fish floss, and other processed foods can provide higher added value. Improving the quality and branding of local products to be

competitive in local and international markets is also essential. This approach can maximize the economic potential of *bilih* fish sustainably.

This research is in line with previous research, supporting the development of sustainable businesses requires policy strategies that encourage investment and private sector participation[36]. Fiscal incentives can be provided to companies investing in bilih fish conservation and sustainable business development. Training programs for local communities and entrepreneurs on sustainable farming techniques, fish processing, and product marketing are also crucial. Moreover, public-private partnerships should be encouraged to collaborate on conservation and economic development programs, such as *bilih* fish habitat restoration projects and sustainable tourism infrastructure development.

4 Conclusion

The conservation of *bilih* fish in Singkarak Lake requires a holistic and integrated governance approach. Various governance models, from community-initiated to government-driven, have their strengths and weaknesses. However, the most promising solution is the adaptive collaborative management approach.

This approach allows the government, stakeholders, and local communities to work together to manage *bilih* fish resources sustainably. By integrating traditional and scientific knowledge and involving various stakeholders in decision-making, adaptive collaborative management can increase the effectiveness and efficiency of *bilih* fish conservation.

The policy implications of the adaptive collaborative management approach are the need for increased inter-agency and cross-stakeholder coordination in the management of Singkarak Lake. The concept of Joined-up government becomes essential in ensuring synergy and consistency between policies and programs related to the conservation and management of *bilih* fish resources. On the other hand, by adapting the Ecosystem Approach to the Fisheries Management (EAFM) model in the management of *bilih* fish, it will be possible to integrate and balance socioeconomic objectives while still considering biotic and abiotic components and their interactions with humans. The integration of EAFM principles with the adaptive collaborative management approach is expected to produce policy recommendations that can increase the effectiveness of fisheries management and the conservation of *bilih* fish in Singkarak Lake while still paying attention to ecological, social, and economic aspects and sustainability aspects.

To achieve the goals of the adaptive collaborative management approach, investment is needed in capacity building for local communities, especially for natural resource management, including education on the importance of environmental conservation and livelihood diversification. The government also needs to provide incentives for communities to engage in conservation practices, such as providing economic incentives for habitat maintenance and reducing destructive fishing practices. Policy implications that can be taken from this study include:

- 1) Cross-sectoral and cross-administrative coordination is needed in the management of Singkarak Lake, which involves all relevant stakeholders.
- 2) In efforts to conserve *bilih* fish and aquatic ecosystems, a holistic governance approach that considers ecological, social, and economic aspects is needed.
- 3) Investment in local community capacity development, including skills training and education on the importance of environmental conservation, can increase community participation and support for balanced governance.
- 4) Policies that support the development of sustainable business models based on the sustainable use of *bilih* fish resources are needed to increase the economic value added for local communities and support the sustainability of the Singkarak Lake aquatic ecosystem.

References

1. R. Safitri, I. Wahidi, and E. Safitri, in *Semin. Nas. Biol.* **5** (2021)
2. H. Syandri, Disertasi Progr. Pascasarj. IPB Bogor. 138 (1996)
3. E. O. Murdy, M. Kottelat, A. J. Whitten, N. Kartikasari, and S. Wirjoatmodjo, *Freshwater Fishes of Western Indonesia and Sulawesi* (1994)
4. H. Syandri, J. Junaidi, and A. Azrita, *J. Kebijak. Perikan. Indones.* **3**, 135 (2017)
5. S. Aini, D. Sudino, A. Putra, Y. Nuraini, M. Maulita, N. R. Ramadhanty, H. Hamdani, D. Aulia, and H. Suriadin, *J. Indones. Trop. Fish. J. Akuakultur, Teknol. Dan Manaj. Perikan. Tangkap Dan Ilmu Kelaut.* **6**, 79 (2023)
6. A. M. Sari, S. Syeilendra, and H. A. Hidayat, *Satwika Kaji. Ilmu Budaya Dan Perubahan Sos.* **7**, 143 (2023)
7. M. Nadjib and Pusat Penelitian Ekonomi (Indonesia), *Optimalisasi Fungsi Ganda Perairan Umum Daratan Dalam Pengembangan Ekonomi Daerah : Kasus Danau Singkarak* (Pusat Penelitian Ekonomi, Lembaga Ilmu Pengetahuan Indonesia, 2015)
8. Y. D. S. E. R. dan R. H. D. S. Koeshendrajana, *Valuasi Sosial Ekonomi Dampak Penebaran Ikan Bilih Di Danau Toba, Sumatra Utara.* (2010)
9. M. Munir, *Sistem Keakerabatan Dalam Kebudayaan Minangkabau: Perspektif Aliran Filsafat Strukturalisme Jean Claude Levi-Strauss* (Gadjah Mada University, 2016)
10. Ibrahim, (2009)
11. N. Firmansyah, N. Gantika, M. Ali, and R. Lubis, *Dinamika Hutan Nagari Di Tengah Jaring-Jaring Hukum Negara* (Perkumpulan untuk Pembaharuan Hukum Berbasis Masyarakat dan Ekologis (HuMa), 2007)
12. E.S. Pamuncak, *Kembali Ke Nagari* (Tanpa Penerbit, Padang, 2000)
13. M. Naim, 421 (2013)
14. E. Christyawaty, *Kinerja Pemerintah Nagari Di Era “Kembali Ke Nagari” Di Sumatera Barat.* Padang Balai Pelestarian Sej. Dan Nilai Tradis. (n.d.)
15. G. Hardin, *Science* (80-.). **162**, 1243 (1968)
16. C.S.V. Wantrup and RC. Bishop, in *IR. Smith F. Marahuddin*, *Ekonomi pe* (Gramedia, Jakarta, 1986)
17. R. Ikhsan, *Penyebab penurunan produksi ikan bilih (mystacoleucus padangensis bleeker) di danau singkarak* (2010)
18. R. S. Pomeroy, *Ocean Coast. Manag.* **27**, 143 (1995)
19. E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge university press, 1990)
20. L. Midgley and M. Olson, *The Logic of Collective Action: Public Goods and the Theory of Groups* (harvard university press, 1969)
21. B. Feyerabend, in *G. Kelleher* (IUCN, Glend, Switzerland, 2001)
22. A. Charles, *Sustainable Fishery Systems* (John Wiley & Sons, 2023)
23. S. M. Garcia and K. L. Cochrane, *ICES J. Mar. Sci.* **62**, 311 (2005)
24. G. S. Cumming, *Spatial Resilience in Social-Ecological Systems* (Springer Science & Business Media, 2011)
25. J. M. Anderies, M. A. Janssen, and E. Ostrom, *Ecol. Soc.* **9**, (2004)

26. B. Glaeser, K. Bruckmeier, M. Glaser, and G. Krause, *Curr. Trends Hum. Ecol.* **21**, 183 (2015)
27. J. D. Dilulio, *J. Public Adm. Res. Theory* **4**, 277 (1994)
28. M. J. Radin, *Contested Commodities*. (harvard university press, 1996)
29. C. Pollitt and G. Bouckaert, *Public Management Reform: A Comparative Analysis*, Second Edi (Oxford University Press, UK, 2004)
30. P. Perri, *Institutional Dyn. Cult. Vol. I II New Durkheimians* **1–2**, 297 (2018)
31. K. T., Y. L., M. P., I. Y., and A. H., *Belajar Beradaptasi: Bersama-Sama Mengelola Hutan Di Indonesia* (CIFOR, 2006)
32. P. Ravi, M. Cynthia, and F. Robert, *Adapt. Collab. Manag. Community For. Asia Exp. From Nepal, Indones. Philipp.* **16** (2007)
33. M. M. Zain, H. Ibrahim, and M. Musdalifah, *African J. Food, Agric. Nutr. Dev.* **22**, 21972 (2022)
34. N. V. Nair and P. K. Nayak, *Front. Mar. Sci.* (2023)
35. V. Astari, L. Hakim, and F. Putra, *Environ. Res. Eng. Manag.* **79**, 32 (2023)
36. M. W. Barbosa, *Sustainability* **16**, 2185 (2024)