Ecosystem approach applicability to sustain endemic fishes in Lake Laut Tawar, Aceh

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Abstract. Lake Laut Tawar is the only home for two endemic cyprinids, i.e. Rasboratawarensis and Poropuntiustwarensis, both are economically important species supporting food security and livelihood to local inhabitants. The present research was aimed to examine the applicability of EAFM, ecosystem approach to fisheries management in protecting endemic fishes in LLT. By referring to standard module, the domains and its indicators were ranked and weighted. Having given score to the domain, the composite domain and the sum of aggregation values of all domains, the performance of fishery management could be presented as flag model. Gap analysis was implied by contrasting EAFM’s recommendation against current achievement with refer to defined indicator. The applicability of EAFM to sustaining endemic fishes was assessed by means impact analysis under the scenario of three generic goals (1) augmenting the quality and quantity of habitat and sustainable utilization of fishery resources, (2) promoting higher socio-economic benefits, and (3) improving function and synergy among management institutions. The results showed that recommendations from EAFM’s model were all doable and that impact positively to sustaining endemic species. The challenges in implementation encompass authority, cooperation and coordination, stakeholders, invasive species and administration status of the lake.

1. Introduction

Lake Laut Tawar (LLT, hereafter) is a 7,000 Ha tectonic lake [1] situated in Gayo highland at 1,230 m above sea level partly to Peusangan River watershed of Central Aceh Regency. About 42 rivers drain into the lake making approximately 14,803 Ha catchment areas[2], inundated 5,742.10 Ha surface areas with 115 m maximum depths [2, 3]. For the Gayonese, the lake fully supports a variety of anthropogenic activities including agricultures, industries, and fisheries, of which to the latter is both aquaculture and capture fisheries [4]. Regarding fish species inhabits LLT was firstly reported by Muchlisin&Azizah[5], and renewed by 2012 – 2013 data with 27 taxa [6], consisting of 12 and 15 indigenous and introduced fishes, respectively. Currently, the newest alien species which potential impacts on the lake’s ecosystem is required to be regulated. Despite the threats, the two endemic species are still abundant and still supported the livelihoods to Gayo communities. This study is conducted to examine the Ecosystem Approaches for Fisheries Management (EAFM) applicability in protecting the two endemic fishes in LLT.
becoming invasive is freshwater crayfish (*Cheraxquadricarinatus*)[7]. Among indigenous fish, there are LLT’s endemic fishes named locally as “depik” (*Rasboratawarensis*) and “kawan” (*Poropuntiustawarensis*). These cyprinids were firstly described by Weber and de Beaufort in 1916 [8, 9], and are of major fishing target and supporting to livelihood of local community in Takengon, Central Aceh.

Capture fisheries in LLT is continuously depleting. Data from local Agency for Marine Affairs and Fisheries and Agency for Development 2008 showed that the catch has plunged from 455 tonnes in 1988 to 74.5 tonne in 2008. By using gill net unit, likewise, that catch production of *R. tawarensis* has sharply decreased from 1.17 to 0.02 kgm⁻² or equal to 98.3% declined [4]. In this regards, the main cause might be the introduction of non-selective fishing gear. i.e. gill nets in 1990s [10].

Scientific reports on these endemic species are relatively limited. For *R. tawarensis* has been dealt with CPUE trend [4], growth and exploitation rate [11], distribution pattern [12], reproduction, fecundity, spawning sites, and spawning frequency [4, 13, 14], whereas for *P. tawarensis* was only pertaining sperm cryopreservation [15]. For both, the available publications were on length-weight relationship [16], species authentication [17], and food preference [18].

High fishing pressure and anthropogenic impacts in LLT resulted a considerable threat on fisheries sustainability as well as biodiversity loss in particular to that of those two IUCN’s vulnerable endemic fishes[19]. Having sighted at ecological aspects, there are four major problems in LLT encompassing surface waters reduction, alien species introduction, operation of environmental unfriendly fishing gears, and water pollution [4]. In connection to fisheries management, such ecological problems are closely associated with human dimension.

Based on those facts, therefore the concept of ecosystem approach to fisheries management (EAFM) is of important management measure. This is likely as EAFM respects the balance between ecological and human through good governance [20] under which higher participation as well as better collaboration and coordination among stakeholders are promoted [20]. As a tool, EAFM may useful in evaluating the performance of certain fishery from which the outcomes are recommendations for fisheries improvement based on reference indicators during implementation period [21] and may be applied for a certain fishery, fishery management area or a prioritized species [22]. In the present paper, the EAFM’s indicators for inland fisheries are examined for its viability and applicability in the attempts to sustain endemic fishes in LLT.

2. **Materials and Methods**

2.1 **Study sites and data collection**

Research was performed in LLT and its vicinities where primary data has been gathered by mean observation, interviews with fishermen, local government, indigenous community, NGO and other stakeholders taken place during December 2018. Secondary data was gathered from reports and studies available from a variety of sources in the area of marine affairs and fisheries, environment and forestry, public works and housing, provincial and regency agencies for development board, and river management authority. The results was consulted through focus group discussion with LLT’s stakeholders, hosted by the local agency for marine affairs and fisheries in Banda Aceh in June 2019.
Figure 1. Study site at and surrounding Lake LautTawar situated in Central Aceh Regency with Takengon as the capital city (adopted and adapted from google map and [2]).

2.2 EAFM’s indicator testing
Both primary and secondary data was devoted to examine EAFM’s indicators after appropriate score is given (Table 1). In rating current management of LLT’s fisheries, the indicators clumped into seven domains, i.e. 1) habitat quality, 2) fishing technology, 3) social, 4) economy, 5) fishery resources, 6) governance, and 7) stakeholders were examined.

Table 1. Domain, indicator, relative important, and criteria for indicator using Likert’s score used in examining fishery management by mean EAFM tools in Lake Laut Tawar

| Domain | Indicator | Relative importance | Score criteria |
|--------|-----------|---------------------|----------------|
| Habitat quality | Water level fluctuation | 1 | Fluctuation: 1=absent, 2=less, 3=naturally |
| | Aquatic pollution | 5 | Compared to standard quality: 1=below, 2=equal, 3= better |
| | Lake bank formation | 3 | 1=none, 2=1-14 m, 3=>15 m |
| | Protected area | 2 | 1=none, 2=present, ill managed, 3= existed and well managed |
| | Habitat alteration (modification) | 4 | 1=high, 2=low, 3=no modification |
| | Siltation & reduction of habitat area | 6 | 1=high, 2=low, 3=no siltation |
| Fishing technology | Destructive fishing gears | 4 | 1=>25%, 2=<25%, 3=none |
| | Environmental unfriendly fishing gears | 3 | 1=frequent, 2=rare, 3=none |
| | Fishing capacity | 2 | CPUE: 1=declined, 2=stable, 3= inclined |
| | Modified fishing gears | 1 | 1=present, negative impact, 2=absent, 3=present, positive impact |
| Social | Stakeholders participation | 4 | 1=>50%, 2=50-75%, 3=>75% |
| | Fishery conflict (per year) | 3 | 1=>5 times, 2=2-5 times, 3=<2 times |
| | Adoption of local knowledge | 2 | 1=none, 2=present, ineffective, 3=present, effective |
| | Education level (dominant composition) | 1 | 1=uneducated, 2=elementary and junior high school, 3=senior high school |
| Economy | Asset ownership | 1 | 1=decreased, 2=stable, 3= increased |
| | Income (minimum regional wedge) | 3 | 1=MRW, 2=equal MRW, 3=>MRW |
| | Consumption level | 2 | 1=high, 2=fair, 3=low consumptive |
| | Economic dependence (from fishery resources) | 4 | 1=independent, 2=fairly dependent, 3= highly dependent |
| Fishery resource being | Trend in catch production | 4 | 1= -<25%, 2= -<25%, 3=stable/increased |
| | Changed in catch size | 1 | 1=(smaller), 2=(stable), 3=(larger) |
| | Catch composition | 2 | 1=imbalance, 2=shifted, 3=unchanged |
Based on actual conditions and expert judgement, each domain was rated by given a certain number between 1 – 7, therefore the weight value of a domain is an expression of domains’ number divided by 28 (sum of 1, 2, 3, …, 7). By doing this, the domain order from highest to lowest importance (shown in the parentheses) as follows: habitat quality (0.25), stakeholders (0.21), social (0.18), governance (0.14), fishery resources (0.11), fishing technology (0.07), and economy (0.04). This means that habitat quality is the most crucial aspect for managing fisheries in LLT, followed by the rests in accord with the sequence of domain’s weight values.

Next, the indicators within a domain were weighted similarly as for domain. With a given score, the composite value of an indicator is obtained by multiplying the score times the weight of correspond domain, and the weight of indicator itself. The sum of indicator composite is summed as domain aggregate. Finally all domains are aggregated as expression of actual conditions of fisheries management [21]. For simplicity, the results are shown as flag models into red (poor), yellow (fair), and green (good). This model was set up into three quartiles ranged from minimum, modus, and maximum values of each domain (Table 2).

Table 2. Criteria conditions for each domain and complete figure of fishery management for Lake Laut Tawar in the following of EAFM indicator testing for inland fisheries

| Domain                          | Composite index |
|---------------------------------|-----------------|
|                                 | Poor | Fair | Good |
| Fishery resources environment (habitat) | 0.250 | 0.500 | 0.750 |
| Fishing technology              | 0.070 | 0.143 | 0.214 |
| Social                          | 0.179 | 0.357 | 0.536 |
| Economy                         | 0.036 | 0.071 | 0.107 |
| Fishery resources being managed | 0.110 | 0.216 | 0.321 |
| Governance                      | 0.140 | 0.285 | 0.430 |
| Stakeholders & Institutions     | 0.210 | 0.425 | 0.640 |
| Domain aggregate (fishery management status) | 0.994 | 1.997 | 2.999 |
2.3 Gap Analysis
Having known the fisheries management status of LLT, by referring to a decree of the Ministry of Marine Affairs and Fisheries [22], the recommendation points for improvement of each fishery management goal was set up. A gap analysis was presented by contrasting current conditions against the ideal achievement measured from its indicator. The gaps play as management measures in protecting the endemic fishes.

3. Results and Discussion

3.1 Fishery management status of Lake LautTawar
Based thoroughly evaluation on 32 EAFM’s indicators, the existing fisheries management status in LLT is depicted as flag model (Table 3). It is shown that fishing technology and fish species being managed were poorly managed (red), whereas the others domain has been fairly managed (yellow). The whole composite index value was 1.752 just well below the median value of 1.997 (Table 2). This is to demonstrate that in general the fisheries of LLT have been fairly managed (Table 3), from which the improvements are demanded for all EAFM domains.

3.2 Actions to improve fishery management in Lake LautTawar
Taken into account the existing fisheries management status shown in Table 3, in the following by adopting “the Guidelines for Fishery Management Plan for Capture Fisheries in Inland Waters” [22]. The results come up with a series of current achievement and the gaps to be filled with recommendations referred to indicators or benchmark (Table 4, 5, and 6). It is important to note that the recommendations have been thoroughly screened through expert judgement and stakeholders consultation at FGD.

Table 3. Fishery management status of Lake LautTawar evaluated by indicators adapted to EAFM inland waters fisheries

| No | Domain                          | Composite Index | Remark                      |
|----|---------------------------------|-----------------|-----------------------------|
| 1  | Fishery resources environment   | 0.405           | Fair habitat conditions     |
|    | (habitat)                       |                 |                             |
| 2  | Fishing technology              | 0.070           | Poor fishing practices      |
| 3  | Social                          | 0.342           | Fair social conditions      |
| 4  | Economy                         | 0.088           | Fair economic conditions    |
| 5  | Fishery being managed           | 0.110           | Poor in managing fish       |
| 6  | Governance                      | 0.317           | Fair governance             |
| 7  | Stakeholders & Institutions     | 0.420           | Fair involvement of stakeholders and institutions |
|    | Aggregated composite domain     | 1.752           | Fishery fairly managed      |

Table 4. Goal 1: To improve both quantity and quality of habitat as well as sustainable use of fishery resources in LLT

| Current conditions                                      | EAFM action recommendations                      | Indicator / benchmark                                             | Potential implemented impact on endemic fish |
|--------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------------|---------------------------------------------|
| Habitat degradation and biodiversity loss of endemic and indigenous fishes | Catchment area reforestation                     | Habitat improvement and reduction in biodiversity loss            | Increased spawning success                  |
|                                                        | Spawning site rehabilitation for *Rasboratawarensis* |                                                                  | Manageable aquaculture wastes               |
|                                                        | Employing carrying capacity-based aquaculture     |                                                                  | Reduced recruitment and                     |
Reduction gill nets capacity and increasing the use of traps and hand lines
Improvement in fishing activities (limitation on didiseun and gill nets operation)
Reduction in fishing trips during low and spawning season;
Restocking

Spatial planning for protected area and fishing zone is yet to be established and formalized
- Spatial verification and mapping on allocated protected area
- Establishment of utilization zone
Availability of complete spatial planning for sustainable fisheries in LLT

Poor fishery data
- Fishing logbook facilitation and training on catch monitoring for enumerators
Availability of regular catch data

Table 5. Goal 2: To increase socio-economic benefits in assuring business continuity

| Current conditions | EAFM action recommendations | Indicator and benchmark | Potential implemented impact on endemic fish |
|--------------------|-----------------------------|-------------------------|---------------------------------------------|
| Low awareness of local community on the ecological importance of lake banks supporting fisheries | - Extension and socialization on lake banks illegal ownership and its ecological role in LLT (Decree of Ministry of Public Works and Housings No. 28/Year 2015) | Ministerial decree is accepted and implemented (increased awareness) | Reduction in anthropogenic activities and its impacts at spawning areas of Rasboratawarensis |
| Lack of knowledge on sustainable fisheries management | - Training and extension on sustainable fisheries management given to local community | Knowledge-based fishery management is effectively implemented | Higher probability for stock recovery |
| Fishery-based products diversification is limited | - Technical assistance in fishery product diversification
- Diversification of non-fisheries livelihood for local community | Skills improvement in both fishery and non-fishery products diversification, as well as products creation | Higher stakeholders participation resulted in better fisheries management |
| Low participation of fishermen and fish farmers in fishery management | - Conducting participatory-based fisheries management (co-management) across different sectors and regency
- Promoting stakeholders participation in annual meeting for planning and budgeting in Central Aceh development (transparency) | Higher stakeholders participation in lake managing LLT | Local knowledge and cultural values on fishery resources will ease fisheries management in LLT |
| Local knowledge in managing LLT is least adopted | - Incorporating cultural and local knowledge during extension on fishery management
- Integrating cultural values in the curricula of elementary and junior school (written | Local knowledge is adopted and effectively integrated into LLT management | Stock enhancement through restocking |

Fish landing port and catch monitoring data supports good fishery assessment
Fish hatchery and landing port are unavailable
- Revitalizing local hatchery and conducting technical training given to local people to support fish restocking in LLT
- To build fish landing port

Fish hatchery and fish landing port are available and well functioned

Table 6. Goal 3: To increase function and synergy of management institutions for fishery resources

| Current conditions | EAFM action recommendations | Indicator and benchmark | Potential implemented impact on endemic fish |
|--------------------|-----------------------------|-------------------------|---------------------------------------------|
| Fishery management plan (FMP) is yet to be formalized and established | - Preparing FMP document  
- Extension and socialization on FMP to all stakeholders | Establishment and formalization of FMP in LLT | The availability of FMP address problem solving, who's doing what, person in charge, and budget allocation in managing fisheries in Lake LautTawar |
| Lake management program remains framed as sectoral issue | - Effective communication and coordination among stakeholders for integrated lake management in LLT | Fisheries and other sectors are harmony and integrated | Stronger support from stakeholders in protecting the existence of endemic fishes in Lake LautTawar (through better management measures) |
| Poor decision making mechanisms in fishery management | - Strengthening decision making mechanism in fishery management through better stakeholders participation | Decision making mechanisms in fishery management is effectively implemented | Empowerment and joint ownership on the importance of protecting endemic species |
| Disharmony in policies and regulations lead to uncertainty in management authority for LLT management | - Harmonizing policies and regulations pertaining LLT management | Harmony in policies and regulations in managing LLT | Reduce conflicts and strengthening coordination and political support in endemic fishes in LLT |
| Lack of human resources | - Knowledge and skills improvement through capacity building  
- Revitalizing on local fishermen association and its associates (institutional cohesiveness) | Good human resources | Support endemic fish protection (breeding technology, restocking, sustainable harvest) |

The recommendations listed in Table 4-6 inform a series of actions to be taken in managing fisheries in LLT. However, whether these are specifically applicable or not in sustaining the two endemic species, i.e. ‘ikan depik’ and “ikan kawan”, further potential impact was provide. For the sake of simplicity, time scale and personal/institutional responsibility is not shown as it is provided in detail in the document of fisheries management plan [7].

In principle, as the recommendation come into implementation, EAFM indicators shows its important role to improve fisheries management in LLT. This is to show that EAFM is not only tools but also doable application to build the fishery into better conditions in terms of unit area, fishing gear and fisheries type-based fisheries, as well as with species level [23, 24]. The potential impacts will be better achieved whenever human and natural systems are interacting[25], therefore the results are compliment to previously addressed problems in LLT [4].
Having recognized those potential impacts for the protection of the endemic species, there are several aspects might be challenging and potentially undermined the actions, as follows:

Fishery sector play commonly as sub-ordinate of other sector secondary role in inland waters. At regency level, the principal authority is the local agency for public works and housing. This implies that fishery agency is much lesser power and weaker in bargaining process for decision making towards better fishery management. As a consequence from previous point, more intensive cooperation and coordination will fully determine the success of fishery management in Lake Tawar. However, harmonizing program and budgetting across the agencies is apparently uneasy (issues on sector ego).

Fish species composition of LLT has been dominated by the introduced and alien species (16 taxa compared to 12). On the contrary, nothing has been is mentioned pertaining invasive species management, in particular to freshwater crayfish (*Cheraxquadricarinatus*). This species is native to southern Papua and northern Australia, and has been deliberately introduced during the 1990-ies to many lakes in western Indonesia. High growth rate and better tolerance to environmental conditions will out compete the endemic fishes in LLT. Lake LautTawar is administered by regency level pointing at mislead opinion that management of the lake is fully responsibility of Central Aceh government. This would result in crucial challenges especially the least political support both from provincial and national government.

4. Conclusion
The existing fisheries activities in LLT have been fairly managed. The proposed action plans are in good agreement and highly relevant to protect endemic species, promoting the applicability of EAFM as management tools and its improvement measures. Key factors support to success includes authority, cooperation and coordination, invasive species, and administration status.

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