Management policy of invasive species red claw crayfish (*Cherax quadricarinatus*) at Lido Lake, Bogor Regency

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Abstract. Red claw crayfish (*Cherax quadricarinatus*) is nationally and globally classified as an invasive species. One of the main distribution areas of this species is Lake Lido, Bogor regency resulting from private fish cage development. This invasive species is highly possible as either competitor, predator, pathogen, or parasite carrier to the native species that are harmful to the lake water ecosystem equilibrium. Unfortunately, there is still a lack of policy management to limit the potential of its wider distribution. The research aims to analyze policy priorities in managing invasive species of *C. quadricarinatus* in Lido lake Bogor. The Analytical Network Process (ANP) was then utilized as the method for this research. Based on ANP analysis, the top-three-priority policy criteria for managing *C. quadricarinatus* are the presence of competitor inferior species, the economic value of resources and community involvement. Overall, the most priority alternative policy for managing the red claw crayfish in Lido lake is allowing the community to utilize it with tied monitoring and suppressing of population growth. The rater agreement among the stakeholder of this alternative policy is high (0.61) that expresses the stakeholders' similar expectations.

Keywords: ANP; competitor; parasite; predator; pathogen

1. Introduction

Invasive species as animals or plants [1] have been distributed worldwide in the global ecosystem. It is founded in both terrestrial and aquatic ecosystems [1], lowland [2] and highland [3], which is in the mainland or islands [4, 5]. Besides climate, the invasive species distribution is highly connected to global human connections throughout transportations, trades and other anthropogenic factors [1, 6]. Those factors are most dominantly connected to economic issues, and then according to Epanchien-Niell [7], the economy is the important key to understand invasion, impacts and policy decisions. There is a global trend to demand handling the negative effects of invasive species [6].

Red claw crayfish (*Cherax quadricarinatus*), origins out of Australia and Papua New Guinea [8], lives in shallow and muddy freshwater habitats [9]. According to Patoka et al. [10], *C. quadricarinatus* presented the Indonesian waters as an aquaculture development commodity in 2003 and became a potential protein source for the population [11]. Under the decree of Head of Fish Quarantine and Inspection Agency (FQIA) No. 31/2017, this species was classified as an invasive species.
Crayfish is globally identified as a major aquatic invasive species in Europe [12, 13] and North America [14, 15]. According to Solano et al. [16], the existence of red claw crayfish can destroy native species, as the similar hypothesis of extinction of river prawn *Macrobrachium sintangense* in Lido Lake-Bogor [17]. Regarding the distribution pattern of invasive species red claw crayfish (*C. quadricarinatus*), which is highly related to the economic factor, this paper aims to formulate the policy strategy to minimize either direct or indirect negative impacts of red claw crayfish in Lido Lake Bogor.

2. Material and Method

2.1. Location and Time

This analysis was conducted in 2019 and to formulate a management strategy for the case of invasive species *C. quadricarinatus* in the Lido Lake-Bogor aquatic ecosystem, as in figure 1.

![Research Location at Lido Lake, Bogor Regency](image)

**Figure 1.** Research Location at Lido Lake, Bogor Regency.

2.2. Data Collection and Analyses

Both primary and secondary data were exploited during the research analyses. Primary data was collected by observation, focus group discussion (FGD) and in-depth interview. The observation was conducted in Lido lake ecosystem condition, fishing gear for fishing, and fishermen's socio-economic profile. FGD was conducted by a discussion with stakeholders related to the research subject in a forum. The interview was conducted with local fishermen, traders and policymakers. Interview lead by the questioner was conducted to 11 respondents from the different stakeholders and background based on the purposive sampling technique approach. The criteria for selected respondents, as in table 1, are basically based on their relation to the existence of red claw crayfish in the Lido Lake Bogor due to their economic preferences, authorities and scientific interests. The secondary data was collected through a relevant literature review on research and policy documents for national and local governments.

Data analysis was conducted based on the Analytic Network Process (ANP) method. The ANP method is a tool to assist prioritized decisions with some priority setting [18]. The ANP analyses used computer software *SuperDecision* 2.6.0. The criteria and its element for ANP analysis are in table 2. *Kendall’s Coefficient of Concordance* was applied to examine the consistency of respondent’s answers.
The biological characteristic of *C. quadricarinatus* was based on the secondary data of the previous studies. The distribution network analysis was based on the interview result from the fishermen and fish traders regarding the marketing pattern.

**Table 1. List of Research Respondents Sample.**

| No. | Respondent | Number (person) | Position |
|-----|------------|-----------------|----------|
| 1   | Fisheries and Poultry Office, Bogor Regency | 2 | Section Head of fisheries hatchery and Section Head of Fish Health and Environment |
| 2   | Local Technical Implementation Unit-Water Management Office West Java-River Area Ciliwung Cisadane | 1 | Section Head of rivers, lake, and coastal water |
| 3   | Technical Implementation Unit Center for Animal Health Unit IV Bogor Regency | 1 | Head of Center |
| 4   | Cooperation of Ornamental Fish Trader-Laladon | 1 | Head |
| 5   | Crustacean fisherman, Lido Lake | 1 | |
| 6   | *Cherax quadricarinatus* researcher | 5 | |

**Table 2. Criteria and element criteria for ANP analysis.**

| Criteria Factors | Elements of the criteria |
|------------------|--------------------------|
| Ecology Cluster  | Aquatic Resource Diversity |
|                  | Existence of competitor inferior species |
|                  | Resource Abundance |
| Economy Cluster  | Number of fishermen |
|                  | Ease of market access |
|                  | Resource Economic Value |
| Local Government Policy Cluster | Policy implementation |
|                  | Bureaucracy capacity |
|                  | Regulation completeness |
| Social Cluster   | User Conflict |
|                  | Community Role |
|                  | Community Knowledge |

The aquatic resources diversity represents the diversity of aquatic fauna in the Lido Lake ecosystem. The competitor inferior refers to native loser species due to the existence of *C. quadricarinatus*. Resource abundance reflects all fishes which live in the lake ecosystem. The market access of the commodity is reflected in the market's ease, while the resource economic value is market price based.

The local government's capacity to regulate and manage the invasive species is expressed in the bureaucracy capacity, which is also referred to as their capacity to issue required sufficient regulations that are articulated in the regulation completeness. The community knowledge is all of their knowledge related to *C. quadricarinatus*, including potential benefits and costs that are not merely reflecting...
formal education but also their experiences. Community role is related to potential actions taken by local people for supporting *C. quadricarinatus* effective management.

3. Result and discussion

3.1. Biological classification and characteristics of Cherax quadriacarinatus von Martens, 1868

In Papua New Guinea and Australia's original habitats, *C. quadricarinatus* mostly founded in the lake, swamp and river waters. Red claw crayfish in the Lido Lake water live in the bottom area with less than 3 m water depth [19]. The local fishermen catch this species using bamboo-made trap gears. The bamboo is settled down in certain ways to be a tube with a diameter of 15 cm and 60 cm long. *C. quadricarinatus* naturally mature and reproductive annually [20] and physically grows fast in the various freshwater ecosystems. According to Dina *et al.* [21], the red claw crayfish stipulate in Mei-September and its peak is in August annually. The male red claw crayfish is smaller than the female with a bright red claw, and the color of the female claw is dark blue. The difference between the male and the female is also distinguished in the form of walking legs. There is gonopore as the stuff in the fifth leg of male species, while the female gonophore is convex oval. There is a small hole in the middle of the third walking female species. The species have five pairs of walking legs, and the first walking legs are its claws.

3.2. Market distribution of red claw crayfish (*C. quadriacarinatus*) from Lido Lake Bogor

Lido lake is one of the important sites for red claw crayfish distribution in West Java. The actors contributing to its distribution from the habitat to the end consumers are local fishermen, traders/collectors, seafood restaurant managers, or owners. The fishermen catch the crayfish daily and sell them to traders/collectors at Rp.10,000/individual. The only routine trader/collector comes from out of the area and collects 50-100 individuals (approximately 10 kilograms) for every coming and sells it to seafood restaurant managers or owners in Jakarta, Depok, and Bekasi areas. The restaurants serve crayfish-based food on the various menu, with a total individual length is approximately 10-5 cm each. The distribution channel of *C. quadricarinatus* is simple and the direct marketing channel is in figure 2.

![Figure 2](image)

**Figure 2.** The market distribution network of crayfish *C. quadricarinatus* from Lido Lake, Bogor Regency.

3.3. Factors of policy management

The management of invasive species *C. quadricarinatus* involves many interrelated aspects. Then it is important for policy decision-makers to consider its significant and interrelated factors. The factors
include ecological, economic, policy and social aspects. For each aspect, there are some criteria as factors to set up prioritized management policies.

ANP network structure considers either internal aspects (criteria within an object) or external aspects (criteria in different objects). The ANP structure was able to determine the different level influences based on the analysis. The involved criteria in the ANP network structure are classified into ecology, economy, social and policy, and then it is weighted scored by each respondent. Criteria in the environmental aspects include biodiversity, resource abundance, and the existence of inferior competitor species. The economic criteria are the resource's value, the number of fishermen, and the ease of market access. The policy aspect criteria consist of policy implementation, completeness of regulations and bureaucracy capacity. Then, the social aspect criteria include community roles, understanding and knowledge, and conflicts among users. The two policy alternatives will be simulated include (1) allow of use of the crayfish but under tight control and suppression, and (2) forbidden to distribute and to admit it in.

The criteria analysis results are in table 3. Regarding table 3, there are no dominant criteria for developing a management strategy for managing invasive species *C. quadricarinatus*. However, ecology has the highest value, which means it must be considered the first to be compared to economy, policy, and social. However, the ecology and policy aspects have to be more considered than the rest aspects for a certain reason.

**Table 3. The Criteria Values of Management Cluster Aspects.**

| Aspect Cluster | Criteria Value | Percentage (%) |
|----------------|----------------|----------------|
| Ecology        | 0.2675         | 26.75          |
| Economy        | 0.2457         | 24.57          |
| Policy         | 0.2581         | 25.81          |
| Social         | 0.2287         | 22.87          |
| Total          | 1              | 100            |

**Table 4. The priority value of factors constructing management criteria (Normalized by Cluster and Limiting).**

| Criteria Factors for Red claw Crayfish Management | Normalized by Cluster | Limiting |
|---------------------------------------------------|------------------------|----------|
| Ecology Cluster                                   |                        |          |
| Aquatic Resource Diversity                       | 0.2866                 | 0.0332   |
| Existence of competitor inferior species          | 0.4143                 | 0.0476   |
| Resource Abundance                               | 0.2992                 | 0.0344   |
| Economy Cluster                                  |                        |          |
| Number of fishermen                              | 0.2793                 | 0.0314   |
| Ease of market access                            | 0.3219                 | 0.0365   |
| Resource Economic Value                          | 0.3988                 | 0.0453   |
| Local Government Policy Cluster                   |                        |          |
| Policy implementation                            | 0.3332                 | 0.0382   |
| Bureaucracy capacity                             | 0.3177                 | 0.0363   |
| Regulation completeness                          | 0.3491                 | 0.0399   |
| Social Cluster                                   |                        |          |
| User Conflict                                    | 0.2555                 | 0.0288   |
| Community Role                                   | 0.3850                 | 0.0430   |
| Community Knowledge                              | 0.3595                 | 0.0399   |

Note: the italic is the highest priority value within each cluster.
Each factor's role determines the management criteria for managing invasive species *C. quadrirarinatus* in Lido Lake-Bogor is in table 4.

The highest value of contributing factors reflects each aspect's most priority criteria (normalized by cluster) and among the whole criteria (limiting value). The existence of an inferior competitor is at the highest priority criteria in the ecology aspect. The resource's value includes its inferior competitor has the most prioritized factor in the economic perspective, and the regulation completeness of the local government has the most important among the policy factors. In contrast, the community role is the highest priority among the social criteria (see table 3).

3.4. Management Alternatives of *C. quadrirarinatus* in Lido Lake, Bogor

Management alternative was build based on the combination of review on related papers and expert’s suggestion. According to this approach, two alternatives were identified and then scored by all respondents for the prioritized analyses. The result of the analyses is in table 5.

**Table 5. Management Alternative Values (Normalized by Cluster and Limiting).**

| Code | Alternative | Normalized by Cluster | Limiting |
|------|-------------|-----------------------|----------|
| A1   | Allow to utilized with tight control and suppression | 0.6567 | 0.2985 |
| A2   | Forbidden to distribute and to admit it in | 0.3433 | 0.1561 |

The ANP analyses result, the most priority management alternative for managing invasive species *C. quadrirarinatus* in Lido Lake is allowing the local community to utilize tight control and suppression. *Kendall’s Coefficient of Concordance* is high (0.61) and shows the respondents agree with no contradiction among them. However, this management priority is under special notes with appropriate control and suppression to reduce its potential spread to another aquatic ecosystem. This conditional confirms to Nurhafidzoh [19] and Kodiran *et al.* [22] on its invasive characters of *C. quadrirarinatus* in the Lido Lake that leads to potential economic loss due to the extinction of native local Sunda river prawn.

3.5. Policy Synthesis

Darwin and other scholars have been concerned with invasive species for more than half a century [23, 24]. Exotic species became globally significant and treated humans and another biota [23], it treats ecosystems, reduces native species, and negatively impacts social-economy [23, 25, 26]. The biodiversity loss due to invasive species is the initial process of extinction of certain species [27].

The potential economic loss due to *C. quadrirarinatus* as invasive species consists of potential economic loss of its inferior competitors' species due to predator-prey relation, loss of the competition, its potential negative impact of the invasive species as the pathogen carrier, and disturb the equilibrium of the aquatic ecosystem. The competition includes both feed competition and habitat (space) competition. These economic criteria need to be more considered because of the trade-off value between invasive species' existence and the distinction of inferior competitor species. In fact, there is a potential economy of the red claw crayfish for locals, but there is also the opportunity cost of its inferior competitor. Basically, the higher value of the inferior competitor, the more economically sensitive invasive species are. This performance will determine a comprehensive understanding of the whole resource values within an aquatic ecosystem. Thus, the red claw crawfish' negative impacts are assessed from both ecological and economic perspectives. The cost of opportunity of the invasive species is not only deal with damage value and cost of controlling measure. However, it includes the impact on its ecosystem and the population number who depend on the ecosystem [28].

It must be strongly concluded that invasive species' impact includes the impact on the biodiversity and ecosystem, economic and human health [29]. The economic impact of red claw crayfish encloses three economic cost forms i.e., cost of environmental damage, cost of management, and direct impact on other species [22].
After its arrival in Indonesia water in 2003 as an aquaculture commodity, the red claw crayfish has spread away to the freshwater aquatic ecosystem in Borneo, Sumatera, Java and Sulawesi, with the highest density is in Java [10]. It is presumed that this species invades and will be permanently established (more than a spontaneous establishment step) and possibly spreads in the new area. Then the invasion stage becomes the new habitat occupation phase.

However, there is still an unclear status of C. quadricarinatus under governmental regulation. The red claw crayfish neither included in the Minister Regulation (Permen) of Ministry of Marine Affairs and Fisheries (MoMAF) No. No 41/2014 as dangerous aquatic species nor Minister Regulation (Permen) of Minister of Environment and Forestry (MoEF) No. No 94/2016 on alien invasive species. The status of invasive species was listed in the Decree of Head of Fish Quarantine and Inspection Agency (FQIA)-MoMAF (BKIPM) 2017 on the technical guidance of distribution mapping of invasive species. However, the decree is hierarchically under of minister regulation level. The biggest weakness is that the decree strongly controls and regulates internally but less power to stimulate and control beyond the agency parties.

The research results that the miss of operational regulation prohibiting and controlling this invasive species distribution across domestic areas make completeness regulation the most priority criteria. The completeness regulation will be a basic reference for implementing invasive species' management policies for national and local government-related bodies. The general pattern of current national regulation still relies on detention and prevention of invasive species across Indonesian areas at the port gate/borders through fish quarantine agencies and instruments. There is still a lack of further national policy to manage the domestic distribution for the invasive species (including red claw crayfish), which has already intruded on Indonesian waters. This situation currently leads to no guidance condition for local governments to develop, such as controlling the red claw crayfish policy at the waters under their authority.

The invasion level of C. quadricarinatus has presumed reached the new habitat occupation, but conversely, these species become socioeconomically important for local livings. The Minister Regulation of MoEF (Permen KLHK) No. No 94/2016 provides three options for managing domestic origin invasive species, i.e., eradication, investment extermination and distribution restriction through population control. Regarding those three options, the analyses result that the distribution restriction is the most optimal policy compared to prohibition, investment extermination and eradication actions. So, Holmes et al. (2009) in Kelly [30] suggested improving control and pressure development and growth and its distribution.

Meanwhile, Carbonares et al. [31] reported that 900 invasive species exist and spread over Europe; 52.7% out of them escaped and this higher proportion than released (8.2%). It means 52.7% distributed without any control. This pattern most likely happens to red claw crayfish distribution over Indonesian waters. Consequently, implementing the optimal policy by allowing its utilization by the local community must be strictly controlled. It is critical to be followed by strong supervision of red claw crayfish release and its escape prevention measures. This strategy is required to be taken to avoid its potential distribution to inland water such as rivers, natural lakes, man-made lakes, small creeks and even fish ponds. Nonetheless, the authority management of such inland waters includes Lido Lake is under local government, i.e., Bogor District, which has not issued any regulation about invasive species control mechanisms.

Based on the current legal basis performances, the local officers could not legally combat invasive species' illegal release to Lido Lake waters. Because of that, social engagement on community control of invasive species is crucial. Control over red claw crayfish and other invasive species release to and distribution out of inland water, including Lido Lake, must be supported by effective collaboration among Lido Lake stakeholders.

The National Strategy and Action Plan Guidance for Alien Invasive Species Management (Stranas JAI) consist of measures and actions on prevention, early detection and quick response, impact control and mitigation, monitoring and evaluation [29]. These works need both collaboration among national governmental agencies (national and intergovernmental level) and collaboration between
governmental agencies and non-governmental organizations. The collaboration will be easily acquired when there is an adequate understanding of each agency’s decision-maker on potential benefit and potential risk (opportunity cost) due to invasive species’ existence. Concerning this study, most of the respondents argue that the main reason for the non-existence of the operational regulation (especially local government regulation) is a lack of understanding of policy decision-maker to the risk and benefit. So that command hierarchy is not operable at the field level.

In fact, most regulation on invasive species is commonly deal with the prohibition of importation and exportation activities that reflect cross country policies. Nowadays, it is required to develop a policy to facilitate collaboration among local governmental authorities to deal with the well-distributed red claw crayfish with the invasive stage to take new habitats.

4. Conclusion and policy implication

Based on previous analysis, admitting the local community to under tightly monitoring and suppressing *C. quadricarinatus* population distribution is the optimal management policy. Thus, it is important to develop operational policy (local government regulations and technical guidance) to monitor and mitigate its impact. Improving the knowledge and capacities of policymakers at both national and local levels and increasing community awareness are mandatory actions immediately. This effort will be increasing stakeholder awareness of the potential risk and benefit of *C. quadricarinatus* as an invasive species. It is expected to contribute significantly to developing the appropriate management policies and actions to support any effort for controlling and reducing population growth of *C. quadricarinatus* and finally forcing its distribution rate.

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