The vulnerability of fish, crabs and prawns resources in the Mahakam Estuary

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Abstract. River estuary in coastal areas, is highly affected by inland water conditions such as freshwater and sediment flows, ocean water such as tides, waves, and the substitution of saltwater to land. Large ecological and economic potential causes logical consequences for ecosystem changes, including the condition of fish resources that have habitat and life cycles directly related to conditions that occur upstream. The purpose of this study was to examine ecological stresses and fishing activity in Mahakam Estuary represented by mangrove crabs, cat fish and giant prawns. The main analysis in this study was the calculation of vulnerability values with concepts and approaches to vulnerability of catfish populations, giant prawns and mangrove crabs, based on two functions of vulnerability, namely exposure and sensitivity. The vulnerability analysis of three types of fisheries commodities refers to the method used by NOAA with some modifications to the assessment component. It is known that catfish are in a low level of vulnerability, giant prawns are at a high level of vulnerability, mangrove crabs are in a very high level of vulnerability or very vulnerable.

1. Introduction

Estuary is a type of ecosystem that has a high complexity and very productive in terms of economic, social and environmental. Stated in [1] that estuaries and coastal areas contributes for almost 75% of the world's population and are dynamic because they continue to grow. Tropical estuary is a bio-chemical hotspot based on high primary productivity, high organic material content and habitat diversity for aquatic organisms on the other side of this ecosystem subject to anthropogenic stress [2][3].

The Mahakam Estuary is an area consisting of several islands formed by the sedimentation at the mouth of the Mahakam River with the Makassar Strait, East Kalimantan. Administratively, the area of estuary to the Mahakam Delta is within the area of Kutai Kartanegara District (Muara Badak District, Anggana District, and Muara Jawa District). There is an ecological linkage with the upstream Mahakam River that flows downstream in the Makassar Strait, a coastal area which is also a meeting place for freshwater and salt water and is affected by tides also, where the ecosystem communities in such areas are usually as a mixture of several species from two different habitats, there for the Mahakam Estuary has a high biodiversity.

Number of fish in estuarine and tropical subtropical regions reaches to 100 - 200 species or greater than in the moderate region where only 20 species were found [4]. [5] Reported 131 demersal fish species in the Mahakam Estuary from 61 families. Dominant species come from 4 families, namely Leiognathidae, Carangidae, Serranidae and Lutjanidae. While species commonly found include Ponyishes, Goatfishes, Sylver biddies, Snappers, Trevallies, Grouper, Kingfish, Black Kingfish, Moonfish, Flutomouth and Bigeye.
Fish landing Port Selili as a base of fish landing in Samarinda (East Kalimantan), is a fish landing area originating from the upstream, middle and downstream areas of the Mahakam. Fish production fluctuates in both quantity and species. Based on PPI Selili data, it is known that freshwater fish contributes around 35%, and about 65% marine fish. Other information states that contribution indeed reaches to 65%, 25% of freshwater fish come from outside Samarinda and 10% from Samarinda [6].

Along with the great potency of Mahakam ecological-economically, the development of the population in this region is increasing rapidly and causing logical consequences for changes in coastal ecosystems, also the ecological stresses including other physical pressures. Ecological pressures that occur in the Mahakam Estuary include 2 major causes, namely habitat degradation and mining. In addition, fishing pressure also occurs that is suspected to cause a decrease in fish populations both in the upstream and downstream areas, among others due to the use of fishing gear that is not environmentally friendly and over-exploitation of resources [7].

Data and the real facts about fish resource indicates a considerable risk and vulnerability to the population of the fish resource. The focus of this research is mainly on the vulnerability of three types of resources, namely catfish, giant prawns and mangrove crabs. The objective of this study is to analyze the impact of the stresses that occur in the estuary environment, which are thought to have an impact on the decline and vulnerability of populations of catfish, giant prawns and mangrove crabs.

2. Materials and methods
The study was conducted in 2016 consists of three phases of process, describing biological profile of the species, then scoring based on expert adjustment, and analyzed the expert scores using NOAA’s standard method of species vulnerability to climate change that was modified according to the needs of this study.

Water samples were taken at observation stations that representing rivers and estuaries, and the outside of the delta. Water quality data observed in this study include physical, chemical parameters and analysis methods are summarized in Table 1. The pollution index illustrated by plankton diversity were calculated following The Shannon-Wiener diversity [8].

| Parameters                          | Units | Methods                          |
|-------------------------------------|-------|----------------------------------|
| Temperature 1)                      | °C    | SNI 06.6989.23-2005              |
| Turbidity 2)                        | NTU   | Turbidity meter                  |
| Salinity 1)                         | ‰     | Hand refractometer               |
| pH 1)                               |       | SNI 06.6989.11-2004              |
| Dissolved Oxygen 1)                 | Mg/l  | SNI 06.6989.14-2004              |
| Phosphates (PO₄) 2)                 | Mg/l  | SNI 06.6989.31-2005              |
| Nitrate (NO₃) 2)                    | Mg/l  | SNI 19.6964.7-2003               |
| Manganese (Mn) 2)                   | Mg/l  | SNI 6989.5-2009                  |
| Iron (Fe) 2)                        | Mg/l  | SNI 6989.4-2009                  |
| Magnesium (Mg) 2)                   | Mg/l  | Titrimetric                      |
| Lead (Pb) 2)                        | Mg/l  | SNI 6989.46-2009                 |
| Plankton 2)                         | Ind./l| SNI 6964.8-2005                  |

Source: 1) [9]; 2) [7]

Description: SNI = Indonesian National Standard

The Design of vulnerability assessment covers two components: exposure and sensitivity. We follow terminology in [10], exposure is the level and duration of a system interacting with disruption, while sensitivity is the level of sensitivity of a species to environmental factors and anthropogenic factors. We modify the exposure and sensitivity attributes according to how a species may be affected by the
environment, with reference to the terminology by Chin et al. (2010) in [1]. The sensitivity component is divided into eleven attributes (habitat specificity, prey specificity, sensitivity to water temperature, sensitivity to salinity, stock size/status, other stressors, adult mobility, spawning cycle, complexity in reproductive strategy, larval lifecycle, survival & settlement, and population growth rate), and the exposure component is divided into five factors (estuarine temperature, salinity, water fluctuation, pollution degree).

Several stages of vulnerability study of catfish (*Pangasius* sp.) populations, giant prawns (*Macrobrachium rosenbergii*) and mangrove crabs (*Scylla serrata*) were carried out based on a modified environmental vulnerability framework in accordance with research needs, as described below:

Stage 1: identify exposure and sensitivity factors that affect the population of catfish, giant prawns, and crabs. All of those attributes obtained through direct observation, discussion with fisheries actors.

Stage 2: calculate the value of vulnerability based on two components, exposure, and sensitivity [11] through expert-based scoring. Experts assign a score based on four scoring bins (low, moderate, high, very high) for each exposure factor or sensitivity attribute assigned to them based on existing information and expert judgment [11].

Assessment is done by using a scoring system on each component, called the tally scoring system, which was originally modified into four scoring systems. Data uncertainty and expert subjectivity are summarized in scoring regarding data quality (Table 2).

| Score | Description |
|-------|-------------|
| 3     | Adequate Data. The score is based on data that have been observed, model or empirically measured for the species in question and comes from a reputable source. |
| 2     | Limited Data. The score is based on data that has a higher degree of uncertainty. The data used to score the attribute may be based on related or similar species, come from outside the study area, or the reliability of the source may be limited. |
| 1     | Expert Judgment. The attribute score reflects the expert judgment of the reviewer and is based on their general knowledge of the species, or other related species, and their relative role in the ecosystem. |
| 0     | No Data. No information to base an attribute score on. Very little is known about the species or related species and there is no basis for forming an expert opinion. |

The required experts include manager of fish landing bases, lecturer in university, fisheries managers at provincial and district and sub-district levels, water resource management authority bodies, fishermen in the Mahakam upstream and downstream, also fish collectors.

Stage 3: calculating the average score of the exposure and sensitivity factors to get the attribute score, using the following formula:

\[
\frac{(L \times 1) + (M \times 2) + (H \times 3) + (VH \times 4)}{(L + M + H + VH)} = \text{attribute} \tag{1}
\]

Where:
L = sum of tallies in ‘low’ scoring  
M = sum of tallies in ‘medium’ scoring  
H = sum of tallies in ‘high’ scoring  
VH = sum of tallies in ‘very high’ scoring
Component scores for exposure and sensitivity attributes are calculated using a logic model. The assessment is carried out by following conditions:

- **Very high**, if 3 or more attribute/factor scores $\geq 3.5$
- **High**, if 2 or more attribute/factor scores $\geq 3.0$
- **Moderate**, if 2 or more attribute/factor scores $\geq 2.5$
- **Low**, if less than 2 or more attribute/factor scores $\geq 2.5$

Additional exposure factors used in mangrove crab vulnerability analysis, includes tides, degree of pollution, mangrove coverage, and fishing. While other (giant prawn and catfish) only need three exposure factor, they are water level, degree of pollution and fishing.

Stage 4: determine the overall vulnerability rank by multiplying exposure and sensitivity. Low, moderate, high and very high component scores are assigned 1, 2, 3, and 4 respectively. The product is then classified were 1-3 results in a low vulnerability rank, 4-6 a moderate vulnerability rank, 8-9 a high vulnerability rank, and 12-16 a very high vulnerability rank. Results can be displayed visually using a vulnerability matrix, to show final ranks as well as component scores (Rubrik matrix). For the most part, the overall vulnerability rank ends up being the lesser of the sensitivity or exposure scores as mentioned by Chin et al. (2010) in [11].

In this study, large portion of data used are secondary data, so weighting in vulnerability analysis cannot be avoided from the subjectivity of respondents. Improvement of the data collection system is needed in the use of primary data so that it might cover the real conditions.

3. Results and discussion

3.1. Tides and water level fluctuation

East Kalimantan Province has a tropical climate pattern with a dry season that occurs in May to September, and rainy season in October to April [12], with peak rainfall in December and May [13]. Data records from the Kotabangun (upstream part of Mahakam) meteorological station show variations in daily temperature between 24 and 29 °C, relative humidity between 73-99% and an average annual rainfall estimated at 2300 mm. During the El Nino-Southern Oscillation (ENSO) years (in 1997), rainfall reached the lowest rate up to half of its annual average [13]. Rainfall trend models in the Mahakam watershed area show high rainfall throughout 2014, beginning at middle of 2013 and 2016. While in 2015 only occurred at the beginning and end of the year (as normal conditions), although in 2015 this rainfall occurred which is very low in the 5 year cycle (2012-2016) [7].

![Figure 1](https://giovanni.gsfc.nasa.gov)  
**Figure 1.** Rainfall (average value) in Mahakam Watershed.
Trend of water level fluctuated monthly (Figure 2). High water conditions occurred in February to April and begin to rise towards December. Conversely, the low level conditions occurred from June to October (Figures 1, 2).

3.2. Pollution in Mahakam Region

Observation of water quality in the river and Mahakam Estuary shows that there is high turbidity in the estuary region. Water pH which is classified as critical or below the threshold was found in the Mahakam tributary (downstream of Mahakam), namely the Sanga-Sanga River. Dissolved oxygen shows a positive relationship with an increase in turbidity that occurs. Low dissolved oxygen was found at observation stations in the estuary region. Salinity shows the natural conditions of river and estuary waters. Organic pollution in the form of an increase in the element phosphate occurred in Sanga-Sanga River to the Mahakam River. The phosphate element of 1.30-1.34 mg / L has exceeded the requirements for river and estuary waters (0.2-1 mg / L and 0.05-1.4 mg / L) (Government Regulation No. 82/2001 on management of water quality and pollution control; State Minister of Environment Decree No. 51/2004 on standard criteria of sea water). The opposite condition is seen in nitrate values which are far below the threshold, and occurred in almost all observation stations, with a range of values of 0.1-5.35 mg / L. Iron (Fe) content was detected at main estuary of the Mahakam River. Likewise, manganese (Mn) was detected in the Mahakam tributary (Sanga-Sanga River). Magnesium (Mg) and lead (Pb) contents were detected in almost all observation stations. The pollution index illustrated by plankton diversity shows that the percentage of species diversity is relatively low with high ecological pressure (H’<1.5). Evenness index shows that the plankton community in all observation stations is categorized as a community that is experiencing pressure (0<E<0.5). Dominance index shows that there are species that dominate other species or in other words the unstable community structure due to ecological pressure (D ≤ 1) [7].

3.3. Mangrove coverage

Ecological pressures occurred in Mahakam Estuary include 2 major causes, namely habitat degradation and mining. Habitat degradation includes: i) the reduction in mangrove area reaches to 86.6% of the total area of 58 thousand ha in 1980 (Figure 3) [14]; ii) the level of criticality of the Mahakam watershed so that it is determined as first priority which must be managed as stipulated through the Decree of the Minister of Forestry of the Republic of Indonesia number: SK. 328 / Menhut-II / 2009 concerning the determination of priority watersheds in the context of the 2010-2014 medium-term development plan (Rencana Pembangunan Jangka Menengah, RPJM).
3.4. The vulnerability of catfish

Exposure factors of the catfish populations declining include water level conditions, degree of pollution and fishing. The water level is related to the spawning season of catfish that occurred at the beginning of the high water cycle. Pollution is related to the susceptibility of catfish to pollutants. Overfishing is related to community preferences for certain types of catfish and non-selective fishing activities such as trawl in downstream of Mahakam which also caught the juvenile of catfish (Table 3).

Table 3. Attribute score of catfish exposure factor.

| No | Exposure          | Low | Medium | High | Very High | Attribute Score |
|----|-------------------|-----|--------|------|-----------|-----------------|
| 1  | Water level       | 2   | 2      | 4    | 4         |                 |
| 2  | Degree of pollution | 1   | 7      | 4    | 4         |                 |
| 3  | Fishing           | 3   | 9      | 10   | 0         | Low             |

The sensitivity factors consists of several attributes such as habitat specifications, etc., indicate that the high score comes from the status attribute or size of the stock, other forms of stress received by catfish and spawning cycles (Table 4). These three attributes indicate that the catfish stock condition that has decreased means that it is vulnerable on a high scale, as well as other forms of pressure and spawning cycles as described in Table 2. Low component scores on the habitat specification attribute and other attributes with the same component scores indicate that the fish catfish is classified as vulnerable on a medium scale, which means that although various forms of conditions lead to the vulnerability of catfish populations, these factors does not have a big impact.
| No | Attribute                              | Quality of data | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Score | Component score |
|----|----------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|
| 1  | Habitat specification                   | 2               | Large river and calm water, in estuaries and lakes. In general, inhabiting certain habitats in river sections, such as deep pits [15][16]. Moves into deeper and protected waters in the dry season. Spawning habitats consist of rocky sand dunes with canals and basins. Eggs are attached to the roots and trees spread [17][18].                                                                                     | 2     | Medium          |
| 2  | Predation specification                 | 2               | The position of catfish as the second or third consumer in the food chain makes the catfish vulnerable to pollutants. In addition, the increasing number of predatory fish such as giant snakehead is thought to have contributed to changes in the composition of the catch fish [7].                                                                                                           | 2     | Medium          |
| 3  | Sensitivity to water temperature        | 2               | Catfish is prefers to live in waters that have low temperature fluctuations. The activity of catfish is stopped in waters where the temperature is below 6 °C or above 42 °C [16].                                                                                                                                                                                                 | 2     | Medium          |
| 4  | Sensitivity to salinity                 | 1               | Catfish (especially Flathead Catfish) is a bento-pelagic type which has a Potamodromous migration pattern (fish originating from upstream of a freshwater habitat, then in the juvenile phase migrating to downstream but still in freshwater to adulthood, then back upstream to spawn [16]. Some of Pangasiid catfish only occurs in the middle part of river, some in inhabits estuaries and lower reaches [19]. In this study also found in estuaries of Mahakam [7]. [19] stated that some species of Pangasiid in Mahakam River live in brackish water in the delta of the river *(Pangasius Mahakamensis, P. kunyit, P. rheophilus)*. | 2     | Medium          |
| 5  | Status/stock size                       | 3               | Catfish production in general is decreased from 2007 to 2016 [7]. Some species of catfish has significantly decreased and is no longer caught.                                                                                                                                                                                                                                                                                                                                 | 3     | High            |
| 6  | Other stressor                          | 3               | Exploited in upstream to downstream areas; being a bycatch of trawls; caught in a small size range (≤ 15 cm); Transportation activities along the Mahakam are suspected to disrupt the migration route [7].                                                                                                                                                                                                                                                    | 3     | High            |
| No | Attribute                  | Quality of Data | Description                                                                                                                                                                                                 | Score | component score |
|----|----------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|
| 7  | Adult mobility             | 1               | Originating from upstream of a freshwater habitat, then in the juvenile phase migrating to downstream but still in freshwater to adulthood, then back upstream to spawn [21]. Based in specimen found in Mahakam River, the small sized of *P. Mahakamensis* (15 mm) is in brackish water in the delta of river, and the large size were found in the upper part [19]. | 2     | Medium          |
| 8  | Spawning cycle             |                 | Spawning occurs at the beginning of the high water cycle (flood), which is in May-June [7]. *Pangasius polyuranodon* that inhabits estuaries and lower reaches also observed in upper during rainy season to spawn [19]. | 3     | High            |
| 9  | Reproductive strategy      | 2               | Sexual maturity in females is generally achieved at the age of 3 years, while males mature first or at the age of 2 years. Adult female catfish reaches to 10 kg and fecundity of more than 1 million eggs [16]. In *Pangasius nasutus*, absolute fecundity ranges from 39,273-145,989 eggs in the female weighing 1.2-3.0 kg [20]. Relative fecundity varied between species, *P. nasutus* has 26-67 eggs per gram body weight of fish, higher than that of *P. djambal*, but lower than that of *P. hypophthalmus* [20]. | 1     | Low             |
| 10 | Early life cycle           | 0               | Larvae stage stays in the upstream then juvenile stage in downstream. Upstream exploitation is in the form of fishing gear with small mesh size or spawning conditions that are not supportive due to habitat degradation [7]. Based in specimen found in Mahakam River, the small sized of *P. Mahakamensis* (15 mm) is in brackish water in the delta of river, and the large size were found in the upper part [19]. | 1     | Low             |
| 11 | Growth rate                | 0               | Catfish can survive in waters that are in poor condition and will grow normally in ideal waters as their natural habitat [15]. This is also the case with ovarian development of *P. nasutus*, which is more fully developed in its habitat than in restricted environments such as aquaculture area [20]. | 1     | Low             |
|    |                            | 1.6             | Quality of data is low                                                                                                                                  | 2.0   | Low             |
Catfish susceptibility level are obtained from factors of catfish exposure to water level, degree of pollution and fishing are classified as moderate, while the sensitivity factor to habitat specifications, predation specifications, sensitivity to water temperature, sensitivity to salinity, status/size of stock, others stressor, adult mobility, spawning cycles, Reproduction strategy, Early life cycle and growth rates are categorized as ‘low’. Refers to the 2 factors mentioned before, it shows that catfish are in a low level of vulnerability (Figure 4).

![Figure 4. Matrix of catfish vulnerability rank.](image)

3.5. Vulnerability of mangrove crabs
Exposure factors of the mangrove crab populations declining include tides, pollution, sedimentation rates, mangrove coverage and fishing pressures (Table 5). Tides are related to life cycle and sensitivity to temperature and salinity for the benefit of metabolism. Pollution is related to behavior when molting. The rate of sedimentation is related to silting of lagoon waters which results in delays in the circulation of seawater and fresh water which are urgently needed by the mangrove forest ecosystem. This situation is to be one of the causes of the decline in mangrove crab production. Overfishing is due to an increase in the number of fishery households due to the collapse of the coal mining business [7].

| No. | Exposure            | Scoring         | Attribute Score |
|-----|---------------------|-----------------|-----------------|
| 1   | Tides               | 2 High 3 Very High | 7 High         |
| 2   | Degree of pollution | 2 3             | 7 High         |
| 3   | Mangrove coverage   |                 | 7 High         |
| 4   | Fishing             | 3 3             | 7 High         |
| 5   | Sedimentation rate  | 1 1             | 7 High         |

The sensitivity factors indicate that the component score ‘very high’ comes from the attributes of habitat specifications, stock status or size, other pressures and growth rates. Classified as very high because of mangrove crabs have a special habitat only in the mangrove environment so they are considered to be vulnerable. The stock condition also has declined respectively, both in East Kalimantan and other regions has been depleted. Other forms of pressure other than fishing are described as the level of vulnerability associated with critical phases such as molting in the life cycle of mangrove crabs, as well as the rate of growth which is considered slow. A description of low component scores can be seen in Table 6.
Table 6. Sensitivity attribute scores and component scores of mangrove crab (*Scylla serrata*).

| No  | Attribute                          | Quality of Data | Description                                                                                                                                                                                                                                                                                                                                 | Score | Component Score |
|-----|------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|
| 1   | Habitat specification              | 3               | Habitat is specific. Mangrove crab is directly associated with the mangrove area [22][23]. Mangrove crabs are commonly found in coastal area, estuary and mangrove area in river and estuary.                                                                                                                                   | 4     | Very high       |
| 2   | Predation specification            | 1               | Other critical phases besides moulting [24], cannibalism characteristic also become a major problem in aquaculture activities. The availability of sufficient food and stocking that is not too dense is an important factor that must be considered in aquaculture activities [25]. When food is not available and high in individual density will trigger cannibalism among mangrove crabs. | 2     | medium          |
| 3   | Sensitivity to water temperature   | 2               | Temperature affects appetite and mangrove crab activities. Water temperature below 20 °C will cause the decrease of activity and appetite of mangrove crabs dramatically [24][26].                                                                                                                                         | 3     | high            |
| 4   | Sensitivity to salinity            | 2               | Mangrove crabs like other intertidal organisms has important responses to environmental factors such as temperature and salinity [24]. These two parameters affect the metabolic functions such as respiration, excretion, and efforts to maintain the balance of homeostasis and its moulting cycle. | 3     | high            |
| 5   | Status/stock size                  | 3               | Demand for crabs in world and domestic trade continues to increase. The trend of increasing world mangrove crab production has been drastic since 1950-1968 to 1968-2014 [27][28]. The contribution range of mangrove crabs from natural catches is 77% and 23% from aquaculture [28]. | 4     | Very high       |
| 6   | Other stressor                     | 1               | The critical phase in the life cycle of mangrove crabs occurs during moulting. The moulting process is very important because it plays a role in the process of growth and reproduction. The body of the crab becomes soft and is very susceptible to predation from predatory animals and other mangrove crabs. | 4     | Very high       |
| No | Attribute                   | Quality of Data | Description                                                                                                                                                                                                 | Score | Component Score |
|----|------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|
| 7  | Adult mobility               | 2               | Megalopa usually chooses structurally complex habitats that can provide protection and food [29]. The portunid mud crab, *Scylla serrata*, is commonly found in muddy estuaries after reach > 40 mm of carapace width [29]. | 3     | high            |
| 8  | Spawning cycle               | 2               | The egg content of female crabs (170-208 g) are maintained for 10-12 days reaches 900,000 - 2,000,000 eggs [30]. F female crab begins to mature in the gonad at a width of carapace 64.2-75.0 mm precisely at the size of the carapace width of 72.8 mm. Meanwhile, the male crab was first matured in a gonad size of 71.2 mm (64.2-75.0 mm) [31]. | 2     | medium          |
| 9  | Reproduction strategy        | 2               | Mangrove crab fecundity in 3\textsuperscript{rd} mature stage ranged from 345.923-1.046.272 eggs, while in 4\textsuperscript{th} mature stage ranged between 352.152-1.472.639 eggs [31]. Mangrove crab fecundity can reach hundreds of thousands to millions so that mangrove crabs can produce eggs and larvae that are quite large. | 2     | high            |
| 10 | Early life cycle             | 1               | The life cycle of mangrove crabs starts from eggs that hatch into planktonic larvae known as zoea. Then the first larvae level (Zoea I) continuously changing their skins, while carried by the currents of coastal waters, the 5th stage of Zoea then change the skin again into megalopa whose body shape is similar to adult crabs but still has a long tail [32]. | 3     | high            |
| 11 | Growth rate                  | 2               | The growth of mangrove crabs depends on the moultung process. The growth of mangrove crabs is reach to 150 mm carapace width, and might has moultung experience until 15 times [24]. Mangrove crab growth is relatively fast at the age of one year and tends to be slow when the crab reaches the age of two to three years. The growth will continue until maximum carapace width in favorable ecological conditions. Meanwhile, at the age of 12-14 months, crabs are considered adults and mature. | 4     | Very high       |
| 2  | Quality of data is medium    |                 | 3.2  Very high                                                   |       |                 |
The vulnerability of mangrove crabs are obtained from exposure factors and sensitivity attributes which indicate that mangrove crabs are in a very high or very vulnerable (Figure 5).

![Matrix of mangrove crab vulnerability rank.](image)

**Figure 5.** Matrix of mangrove crab vulnerability rank.

### 3.6. Vulnerability of giant prawn

Environmental factors that potentially influence giant prawn populations are water level, pollution and fishing pressure (Table 7). Fluctuations in water level are related to the life cycle of giant prawn in brackish waters (salinity 5-20 ppt) and freshwater (salinity 0 ppt). In the larval to juvenile phases inhabiting brackish habitats, the juvenile to adult phases inhabit in freshwater habitats, optimum growth occurs at low salinity. Pollution is related to water quality conditions that affect the growth rate. Fishing pressure shows by the increase in number of fishing households after the collapse of several mining companies.

| No. | Exposure          | Scoring | Attribute Score |
|-----|-------------------|---------|-----------------|
| 1   | Water level       | Low: 1  | Medium: 1 High: 7 Very High: 7 |
| 2   | Degree of pollution | Low: 2 Medium: 4 High: 6 | Very High: 6 |
| 3   | Fishing           | Low: 3 Medium: 4 High: 2 Very High: 8 |

| No. | Exposure          | Scoring | Attribute Score |
|-----|-------------------|---------|-----------------|
| 1   | Water level       | Low: 1  | Medium: 1 High: 7 Very High: 7 |
| 2   | Degree of pollution | Low: 2 Medium: 4 High: 6 | Very High: 6 |
| 3   | Fishing           | Low: 3 Medium: 4 High: 2 Very High: 8 |

The sensitivity factor of giant prawn shows that the component score is high. Very high and high sensitivity comes from status or stock size attributes, other forms of pressure, adult mobility, spawning cycles, early life history including temperature and salinity sensitivity and habitat specifications (Table 8). Brackish and freshwater phases in giant pawns are considered vulnerable related to the location of the Mahakam River, because the extreme water level fluctuations that occurred can reach to the delta. These conditions are closely related to temperature and salinity fluctuations that are directly related to the spawning phase, the larval life phase including the adaptation of food habits and the type of food consumed.
Table 8. Sensitivity attribute scores and component scores of giant prawn (*Macrobrachium rosenbergii*).

| No. | Attribute                          | Quality of data | Description                                                                 | Score | Component Score |
|-----|-----------------------------------|-----------------|-----------------------------------------------------------------------------|-------|-----------------|
| 1   | Habitat specification             | 2               | Giant prawns live in two habitats, namely brackish (5-20 ppt) and freshwater (0 ppt) [33]. | 3     | High            |
| 2   | Predation specification           | 1               | A common characteristic that is also found in shrimp is natural cannibalism. This characteristic often arises when shrimp are in good condition, not in molting phase. | 2     | Medium          |
| 3   | Sensitivity to water temperature  | 1               | Larval growth is strongly influenced by temperature factors, habitat/media for growing, food type, light intensity and water quality [34]. | 3     | High            |
| 4   | Sensitivity to salinity           | 2               | Different levels of salinity can influence body weight and cause mortality; Giant prawn grows optimally in low salinity condition [35]. | 2     | Medium          |
| 5   | Status/stock size                 | 3               | The trend of production have decreased. The reduction in catch of giant prawns has also been complained by fishermen in downstream part of Mahakam since the last 3-5 years [7]. | 4     | Very high       |
| 6   | Other stressor                    | 3               | Giant prawns are exploited from upstream to downstream of the Mahakam river. Prawn fishing is using trapped gear, in lake, small rivers in Mahakam Delta or downstream of the Mahakam [7]. | 4     | Very high       |
| 7   | Adult mobility                    | 3               | Adult giant prawns lives in freshwater, and migrate to brackish waters for spawning [33]. | 4     | Very high       |
| 8   | Spawning cycle                    | 1               | Naturally, giant prawns can spawn in a freshwater area at a distance of 100 km from the estuary, then the larvae are carried by the river to the sea. Larvae that hatch from eggs at the latest 3-5 days must get brackish water [36]. Giant prawns with a body length of 15.5 cm have been able to do spawning [37]. | 4     | Very high       |
| No. | Attribute               | Quality of data | Description                                                                                                                                                                                                                                                                 | Score | Component Score |
|-----|-------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------|
| 9   | Reproduction strategy   | Medium          | Prawn spawn throughout the year, with unspecified period of marriage. Spawning usually occurs at night, although it can spawn during the day. Prawns that are ready to spawn can be seen from the gonads with a red orange colour that spreads throughout the gonad to cephalothorax. Before spawning female shrimp first shed their skin. When changing the skin, the shrimp is weak. After recovering, spawning occurs again. | 2     | Medium          |
| 10  | Early life cycle        | High            | Egg incubation occurs along 19-21 days before the next stage (larvae). Then developed through 11 stages of larval development, before reaching the seed stage. The larval phase requires brackish water, and the seed phase in freshwater conditions. | 3     | High            |
| 11  | Growth rate             | Medium          | Shrimp growth was influenced by several internal and external factors including sex, age, parasite and disease (internal factors), food and water quality (external factors).                                                                                           | 2     | Medium          |
|     |                         |                 | Quality of data is medium                                                                                                                                                                                                                                           | 3.0   | High            |
The vulnerability of giant prawn are obtained from exposure factors and sensitivity attributes which indicate that giant prawn are in a high or high vulnerable (Figure 6).

Figure 6. Matrix of giant prawn vulnerability rank.

4. Conclusion
Vulnerability analysis of catfish, giant prawn and mangrove crab shows that catfish are in a low level of susceptibility, mangrove crabs in a very high or very susceptible level, giant prawns in a high level of vulnerability. Additional exposure factors used in mangrove crab vulnerability analysis, includes tides, degree of pollution, mangrove coverage, and fishing. While other (giant prawn and catfish) only need three exposure factor, they are water level, degree of pollution and fishing.

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