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Biodiversity and Vulnerability of Fisheries Resources in Berau Bay, West Papua Province

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ABSTRACT
Berau Bay, located in West Papua Province, is one of Indonesia's marine areas rich in biodiversity. This aquatic ecosystem is a crucial habitat for various fish species that hold ecological and economic value for the local communities reliant on fisheries. However, increased human activities, including intensive fishing, pollution, and climate change, pose severe threats to the sustainability of fish resources in this region. This research aims to assess the biodiversity and vulnerability levels of fish resources in the waters of Berau Bay. The research, conducted using field survey methods, identified fish species in Berau Bay, assessed their conservation status using the IUCN Red List database, evaluated biodiversity through calculations of diversity, evenness, and dominance indices, and analyzed species diversity with the Shannon-Wiener equation and species dominance with the Simpson dominance index, with observations made at Sarulaga Island, Ugar Island, and Arguni Island. The vulnerability levels of fish resources are determined by categorizing their conservation status according to the IUCN Red List. The study results indicate that Berau Bay has a relatively high level of biodiversity with low dominance. The highest biodiversity index value in Berau Bay waters is 3.35, dominated by the families Carangidae and Scombridae. The vulnerability analysis results show that 85.71% have a low vulnerability level. However, several species exhibit high vulnerability due to excessive fishing activities, pollution, and climate change. These findings emphasize the importance of implementing effective conservation measures to ensure the sustainability of fish resources in this area. Efforts to protect habitats, manage sustainable fishing practices, and educate the local community are expected to reduce vulnerability and enhance the sustainability of the Berau Bay aquatic ecosystem.

Keywords: *Biodiversity, Fisheries Resources Vulnerability, Fisheries Conservation, West Papua, Berau Bay*

INTRODUCTION

Indonesian waters contribute 27.2% of the world's total species of flora and fauna, including 12% of mammals, 23.8% of amphibians, 31.8% of reptiles, 44.7% of fish, 40% of mollusks, and 8.6% of seaweeds. The diverse potential of fish resources includes large pelagic fish, small pelagic fish, penaeid shrimp and other crustaceans, demersal fish, mollusks and sea cucumbers, squid, commercial natural seeds, coral resources, coral reef food fish, ornamental fish, turtles, mammals, and seaweeds (Adrianto *et al.* 2014).

The Berau Bay area, located in West Papua Province, has significant fish resource potential. Pakiding (2018) mentions that this coastal park conservation area has various fish species, including pelagic, demersal, and reef fish dominated by groupers, snappers, mackerels, and jacks, which are the main targets for local fishermen. The high fish resource potential in the Berau Bay area should be optimized through management adhering to sustainable utilization principles.

Optimal utilization of fish resources can be achieved if we have accurate information on the stock quantity and distribution of these resources. With precise knowledge about the stock and distribution of fish resources, appropriate exploitation policy measures can be taken without threatening their sustainability. As stated by Kasmawati (2011), excessive exploitation of natural resources without proper planning and consideration of environmental carrying capacity can lead to depletion of natural stocks and damage the existing resource potential.

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Fishing pressure resulting from overfishing in a water area can cause resource vulnerability, impacting the balance of resource sustainability. Hidayat (2014) mentions that to maintain the sustainability of fisheries resources in nature, it is necessary to study the vulnerability levels of resources to assess the ability of natural resources to face global environmental changes, both naturally and due to human activities. Many studies have been conducted on the vulnerability of fish resources. These studies provide an approach method to assess the risks caused by fishing activities on fisheries resources. Previous studies on fish resource vulnerability include bycatch tuna fisheries (Yonvitner *et al.* 2020), tropical eel (Yonvitner *et al.* 2017), tembang fish (Puspita *et al.* 2017), small pelagic fish resources (Khatami *et al.* 2019), and a review of reference points for small pelagic fish in tropical regions (Yonvitner *et al.* 2017).

The objective of this research is to identify and analyze the biodiversity and vulnerability levels of fish resources in the waters of Berau Bay, West Papua Province. This study aims to map the species diversity of existing fish, identify threats and pressures that may affect the sustainability of fish resources, and develop effective management and conservation recommendations to maintain the sustainability of the aquatic ecosystem in Berau Bay.

METHOD

Time and Location of Research

This research was conducted from May to December 2023 and took place in the waters of Berau Bay, West Papua Province. Data collection on fishery resources was carried out by conducting surveys in four areas that serve as fish landing locations around the waters of Berau Bay, namely Arguni District and Ugar District in Fak Fak Regency, as well as Sosar District and Kokoda District within the administrative region of South Sorong Regency (Figure 1).

Research Method

The research was conducted using field survey methods. Fish resources were identified based on the reference by Tarp and Kailola (1984). The species of fish found were assessed for their conservation status. The conservation status of fish resources in the waters of Berau Bay was determined by evaluating each species based on the IUCN Red List database from the IUCN Red List (https://www.iucnredlist.org/). To assess the biodiversity levels of fish resources in the Berau Bay area, calculations of diversity index, evenness index, and dominance index were performed. The vulnerability of fish resources was determined by analyzing their conservation status and categorizing them according to their respective levels.

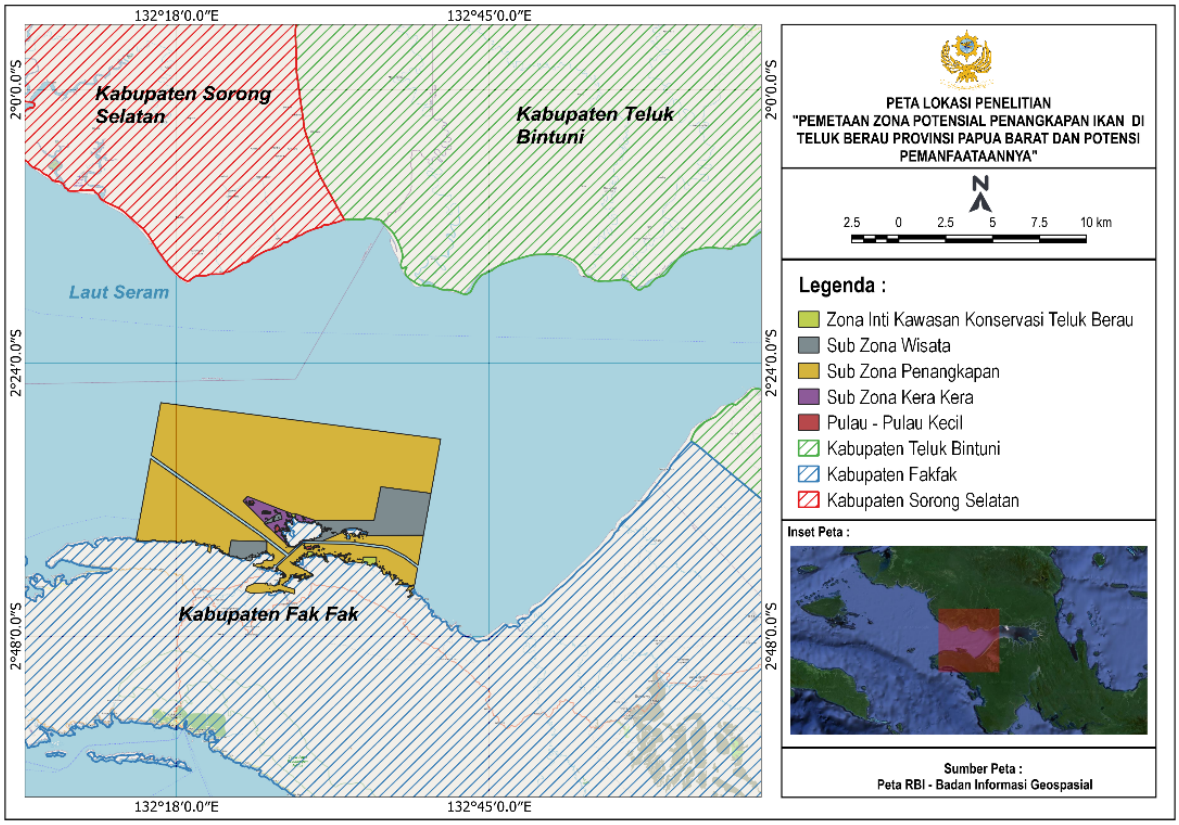

Figure 1. Location of the research.

Parameters and Data Analysis

To assess the biodiversity levels of fish resources in the Berau Bay area, calculations of the diversity index, evenness index, and dominance index were performed. Observations related to these biodiversity indices were conducted at three locations: Sarulaga Island, Ugar Island, and Arguni Island. The species diversity of fish resources was analyzed using the Shannon-Wiener equation (Odum, 1971):

$$H' = -\sum_{t=i}^{s} Pi.LnPi$$

Where :

H' = Shannon-Wiener Diversity Index
Pi = The proportion of individuals of speciesi to the total number of individuals
Ln = Natural logarithm

To assess the evenness index, calculations were performed. If the resulting evenness index value is relatively high, it indicates that the presence of each aquatic species is evenly distributed. The evenness index can be calculated using the following formula:

$$E = \frac{H'}{H'maks}$$

where:

E = Evenness Index
H' = Shannon-Wiener Diversity Index
$H'maks$ = Ln S (S is the number of genera)

To determine the presence or absence of dominance by a particular species, the Simpson dominance index (Odum, 1971) can be analyzed and calculated using the following equation:

$$D = \sum_{i=1}^{s} (Pi^2)$$

where:

D = Dominance index
S = Total number of species
Pi = The proportion of individuals of species i to the total number of individuals

RESULTS AND DISCUSSIONS

Results

Fishery Resource Groups in Berau Bay

Fishery resources in Berau Bay are divided into two categories: fish resources and non-fish resources. Based on field observations at four fish landing sites (TPI) in Berau Bay–Arguni, Ugar, Sosar, and Kokoda—36 fish species belonging to 20 families were found. From the identification of the 20 fish families shown in Table 1 and Figure 2, it was found that the families Carangidae and Scombridae were the most frequently encountered, each comprising 11.11% of the total, with 4 species each. Other commonly found families were Lutjanidae and Sciaenidae (8.33%), each consisting of 3 species. Serranidae, Siganidae, and Cynoglossidae were each represented by 2 species (5.56%). The other families contributed less than 3% of the total identified species. The study also indicated that fishermen catch sharks and rays, which belong to the Elasmobranchii group or cartilaginous fish, with a total percentage of 16.67% and distributed across 5 families.

Table 1. Families and number of species landed in the research area.

No.	Famili	Amount of Species	Percentage
1	Carcharhinidae	2	5,56%
2	Rhinidae	1	2,78%
3	Glaucostegidae	1	2,78%
4	Plesiobatidae	1	2,78%
5	Dasyatidae	1	2,78%
6	Engraulidae	1	2,78%
7	Clupeidae	1	2,78%
8	Ariidae	2	5,56%
9	Plotossidae	1	2,78%
10	Mugilidae	1	2,78%
11	Serranidae	2	5,56%
12	Carangidae	4	11,11%
13	Lutjanidae	3	8,33%
14	Sciaenidae	3	8,33%
15	Pomacentridae	2	5,56%
16	Scatophagidae	1	2,78%
17	Siganidae	2	5,56%
18	Acanthuridae	1	2,78%
19	Scombridae	4	11,11%
20	Cynoglossidae	2	5,56%
Total		**36**	**100,00%**

Source : Field Survei

Non-fish resources include crustaceans and mollusks. In this study, 4 species from 3 families of crustaceans and 2 species from 2 families of mollusks were found in the research area (Table 2). The Penaeidae family was the most frequently encountered in the research area, with 2 species, while the other families were each represented by only 1 species.

Biodiversity Index of Berau Bay Waters

The results of the biodiversity index analysis of fish resources in the waters of Berau Bay are shown in Table 3. The biodiversity index values are divided into three parameters: diversity index, evenness index, and dominance index. Observations related to these biodiversity indices were conducted at three locations: Sarulaga Island, Ugar Island, and Arguni Island.

The analysis results indicate that Sarilaga Island has a very high fish biodiversity index. Additionally, the fish community in the Sarilaga coral reef ecosystem is stable, as shown by its high evenness index value. This stability is due to the absence of dominant reef fish species. The low dominance index (C) at Sarilaga Island (Table 3) indicates the presence of few reef fish species with low abundance. At Ugar Island, the fish resource diversity has a value of 2.15, which is considered moderate (Table 2). The fish community at this location shows high evenness (0.98) and low dominance (0.12). At Arguni Island, the fish resource community has a moderate diversity level with a value of 2.56, high evenness of 0.82, and a dominance index of 0.13 (Table 3). This indicates good conditions within the fish community at this location.

Conservation Status and Vulnerability Levels of Fish Resources in Berau Bay

The conservation status of fish resources in the waters of Berau Bay was determined by evaluating each species based on the IUCN Red List database (https://www.iucnredlist.org/).

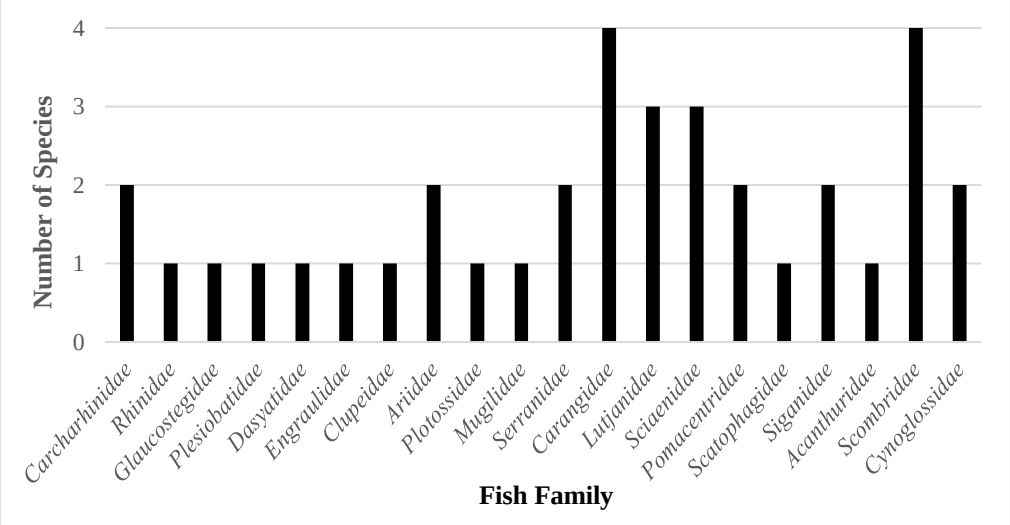

Figure 2. Frequency of species and families identified in the Berau Bay Area

Table 2. List of non-fish fauna found in the research area

No.	Famili	Species	Common Name	Local Name
1	Portunidae	*Scylla* sp.	*Mud crab*	Kepiting
2	Penaeidae	*Penaeus monodon* Fabricius, 1798	*Tiger shrimp*	Udang windu
		Penaeus indicus H. Milne Edwards, 1837	*White shrimp*	Udang putih
3	Palinuridae	*Panulirus versicolor* (Latreille, 1804)	*Painted Spiny Lobster*	Lobster
4	Cardiidae	*Tridacna* sp.	*Clam*	Siput
5	Loliginidae	*Uroteuthis chinensis* (Gray, 1849)	*Mitre squid*	Cumi-cumi

Source : Field Survei

Table 3. Biodiversity Index of Fisheries Resources in Berau Bay

No.	Biodiversity Index	Location					
		Sarulaga Island		Ugar Island		Arguni Island	
		Value	Class	Value	Class	Value	Class
1.	H (Diversity Index)	3.35	High	2.15	Moderate	2.56	Moderate
2.	E (Evenness Index)	0.87	High	0.98	High	0.82	High
3.	D (Dominance Index)	0.06	Low	0.12	Low	0.13	Low

Among the identified fish and non-fish species, sharks and rays (*R. laevis* and *G. granulatus*) are categorized as "Critically Endangered" (CR), one type of mangrove fish (*C. sealei*) is categorized as "Vulnerable" (VU), and another mangrove fish (*C. macloti*) is categorized as "Near Threatened" (NT). Among non-fish species, only two species have their status recorded in the IUCN Red List data (2023): *Panulirus versicolor* (LC) and *Uroteuthis chinensis* (DD). One non-fish species, *Tridacna* sp., according to the IUCN Red List data (2023), is categorized as "Vulnerable" for the species *T. gigas* and *T. derasa*, both of which can be found in Indonesian waters.

Table 4. Conservation status and vulnerability levels of fish resources in Berau Bay.

No.	Species	Local Name	Conservation Status (IUCN, 2023)	Vulnerability Levels
1.	*Carcharhinus macloti* (Müller & Henle, 1839)	Mangewang	NT	Moderate
2.	*Protonibea diacanthus* (Lacepède, 1802)	Ikan merah	NT	Moderate
3.	*Scomberomorus commerson* (Lacepède, 1801)	Tenggiri	NT	Moderate
4.	*Carcharhinus sealei* (Pietschmann, 1913)	Mangewang	VU	High
5.	*Rhynchobatus laevis* (Bloch & Schneider, 1801)	Hiu pari	CR	High
6.	*Glaucostegus granulatus* (Cuvier, 1829)	Hiu pari	CR	High
7.	*Nemapteryx armiger* (De Vis, 1884)	Sembilang ekor dua	NE	Low
8.	*Paraplotosus albilabris* (Valenciennes, 1840)	Sembilang ekor satu	NE	Low
9.	*Scylla* sp.	Kepiting	NE	Low
10.	*Penaeus monodon* Fabricius, 1798	Udang windu	NE	Low
11.	*Penaeus indicus* H. Milne Edwards, 1837	Udang putih	NE	Low
12.	*Neotrygon kuhlii* (Müller & Henle, 1841)	Pari	DD	Low
13.	*Epinephelus bleekeri* (Vaillant, 1878)	Kerapu	DD	Low
14.	*Rastrelliger brachysoma* (Bleeker, 1851)	Kembung	DD	Low
15.	*Tridacna* sp.	Siput	DD	Low
16.	*Uroteuthis chinensis* (Gray, 1849)	Cumi-cumi	DD	Low
17.	*Scomberomorus guttatus* (Bloch & Schneider, 1801)	Tenggiri	DD	Low
18.	*Osteomugil engeli* (Bleeker, 1858)	Belanak	LC	Low
19.	*Plesiobatis daviesi* (Wallace, 1967)	Pari	LC	Low
20.	*Auxis thazard* (Lacepède, 1800)	Tongkol	LC	Low
21.	*Panulirus versicolor* (Latreille, 1804)	Lobster	LC	Low
22.	*Neoarius leptaspis* (Bleeker, 1862)	Sembilang ekor dua	LC	Low
23.	*Epinephelus coioides* (Hamilton, 1822)	Kerapu	LC	Low
24.	*Lutjanus malabaricus* (Bloch & Schneider, 1801)	Kakap	LC	Low
25.	*Lutjanus argentimaculatus* (Forsskål, 1775)	Kakap	LC	Low
26.	*Lutjanus erythropterus* Bloch, 1790	Kakap	LC	Low
27.	*Johnius australis* (Günther, 1880)	Gulamah	LC	Low
28.	*Nibea soldado* (Lacepède, 1802)	Ikan putih/Blama	LC	Low
29.	*Neopomacentrus nemurus* (Bleeker, 1857)	Betok laut	LC	Low
30.	*Neoglyphidodon melas* (Cuvier, 1830)	Betok laut	LC	Low
31.	*Scatophagus argus* (Linnaeus, 1766)	Kiper	LC	Low
32.	*Siganus fuscescens* (Houttuyn, 1782)	Baronang	LC	Low
33.	*Siganus canaliculatus* (Park, 1797)	Baronang	LC	Low
34.	*Acanthurus xanthopterus* Valenciennes, 1835	Kulit pasir	LC	Low
35.	*Cynoglossus bilineatus* (Lacepède, 1802)	Lidah	LC	Low
36.	*Paraplagusia bilineata* (Bloch, 1787)	Lidah	LC	Low
37.	*Thryssa hamiltonii* (Gray, 1835)	Cangkang/Puri	LC	Low
38.	*Escualosa thoracata* (Valenciennes, 1847)	Popuri	LC	Low
39.	*Caranx tille* Cuvier, 1833	Bobara	LC	Low
40.	*Alepes vari* (Cuvier, 1833)	Bobara	LC	Low
41.	*Caranx ignoCangkang* (Forsskål, 1775)	Bobara	LC	Low
42.	*Megalaspis cordyla* (Linnaeus, 1758)	Tarur/Tetengkek	LC	Low

Note: NE: Not Evaluated; DD: Data Deficient; LC: Least Concern; NT: Near Threatend; VU: Vulnerability; CR: Critically Endangered. Source : IUCN 2023

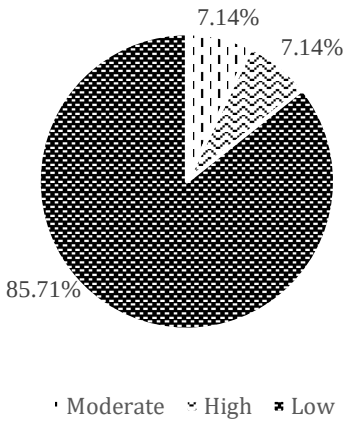

Figure 3. Percentage of vulnerability level of fish resources in the waters of Berau Bay.

The analysis results indicate that fish resources in Berau Bay are primarily characterized by a low level of vulnerability, accounting for 85.71% or 36 species. Both high and medium levels of vulnerability each account for 7.14% with 3 species falling into each category.

Discussions

Fish are the most diverse group of fauna in the world's waters, with over 33,000 species identified, including Elasmobranchii, Teleostei, and Agnatha. They can be found in fresh waters, oceans, and estuaries (Nontji, 2007). Compared to previous research, a large number of fish species were discovered during this study. Mote (2015) found 13 fish species in several small river estuaries on the Payum coast, Merauke Regency, while Weliken (2013) reported 17 fish species in the lower reaches of the Maro River. In contrast, Simanjuntak (2011) discovered 106 fish species in Bintuni Bay, and Zahid (2011) reported 105 fish species in the Mayangan estuary ecosystem, West Java. This research identified 42 fish species from 25 families. The diversity and structure of fish communities in a given body of water provide insights into the characteristics and life cycles of the species, which in turn are related to changes in environmental conditions (Winemiller *et al.* 2008).

The Berau Bay area's non-fish population is mainly comprised of crustaceans such as Scylla sp., P. monodon, and P. indicus. These types of crustaceans are typically found in estuary habitats, but are also commonly found in the sea. The biota's stage influences this ability, with the juvenile stage of shrimp typically found in estuaries and the adult stage in the sea. Additionally, environmental factors can contribute to the abundance of a species of aquatic organism. According to Arshad (2010), changes in abundance, distribution, and species in a habitat can be influenced by factors such as tidal currents and environmental conditions.

Based on the biodiversity index analysis in Berau Bay, Sarilaga Island has a very high fish diversity index and a stable fish community. Ugar Island shows moderate fish diversity (2.15) with high uniformity (0.98) and low dominance (0.12). Similarly, Arguni Island also displays moderate diversity (2.56), high uniformity (0.82), and low dominance (0.13), indicating a healthy fish community. Preniti (2019) suggested that the diversity and abundance of fish is influenced by the characteristics of the aquatic habitat. Additionally, Akhrianti (2017) explained that the number of fish species at a location depends on environmental parameters such as water quality, vegetation, weather conditions, as well as the techniques and tools used, leading to differences in the composition of fish species caught in different locations.

According to the International Union for Conservation of Nature (IUCN, 2023), the fish species in the Berau Bay area are classified as follows: 4.76% are Critically Endangered, 4.76% are Vulnerable, 7.14% are Near Threatened, 11.90% are Data Deficient, 59.52% are of Least Concern, and 11.90% have not been evaluated. The presence of fish with vulnerable to highly threatened status highlights the need for special attention in the Berau Bay area, especially as it has been designated as a conservation area under the Minister of Marine and Fisheries Affairs Decree No. 79/KEPMEN-KP/2020, which concerns Coastal and Small Island Conservation Areas in Berau Bay and Nusalasi Bay – Van Den Bosch in West Papua Province. Globally, biodiversity is not evenly distributed. Some countries and regions with high levels of biodiversity also have high human populations and relatively low per capita income (Baille *et al.* 2004; Brooks *et al.* 2006). These areas also tend to have the highest number of endangered species (Hoffmann *et al.* 2010; Baille *et al.* 2004). Additionally, countries with high human populations and biodiversity often lack financial resources for research and conservation (Baille *et al.* 2004) and may depend more on local marine resources for their livelihoods (Creel, 2003; Ferrol-Schulte *et al.* 2015).

The results from the IUCN conservation status categorize the levels of vulnerability for various species. 85.70% or 36 species have low vulnerability, while six other species each have a medium and high level of vulnerability at 7.14%. High vulnerability indicates pressure from fishing activities that exceeds sustainable potential, emphasizing the need for efforts to maintain natural

fisheries resources and balance. Fishing carried out in areas of high exploitation will result in a decline in the population. These fishing activities will influence the exploitation of large fish with high vulnerability towards species with low vulnerability (Pauly, 1998 in Cheung, 2007). Fish with high vulnerability will have their populations reduced more quickly and experience overexploitation (Cheung *et al.* 2005 in Cheung 2007). Factors that influence the vulnerability of a species are the fishing gear used (Patrick *et al.* 2009) and climate (Belhabib *et al.* 2016). Operating fishing gear that is less selective will affect ecosystem quality and potentially cause overfishing in the short and long term (Yonvitner *et al.* 2017).

CONCLUSIONS

The Biodiversity Index in the waters of Berau Bay, West Papua Province, was observed at three different locations. Sarilaga Island displayed a very high fish diversity index and a stable fish community, characterized by a uniformity index and low species dominance. At the observation station on Ugar Island, the fish diversity was moderate (2.15), with high uniformity (0.98) and low dominance (0.12). Similarly, the observation station on Arguni Island also showed moderate diversity (2.56), high uniformity (0.82), and low dominance (0.13). The analysis revealed that the waters of Berau Bay have a relatively high level of biodiversity in fish resources with low dominance between species. Furthermore, the vulnerability level of fish resources in the waters of Berau Bay is relatively low, as per the IUCN conservation status categorization, with a percentage of 85.70%.

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