Investigation and Analysis of Fish Assemblages within The Berau Bay Ecosystem, West Papua, and Their Utilization Potential

Riyan Maulana[1,3,*], *Meuthia Aula* Jabbar[1], Yonvitner[2,3], *Asep* Ma'mun[3,4], *Ahmad* Zahid[3,4]

[1]Jakarta Technical University of Fisheries (Politeknik Ahli Usaha Perikanan), Jl. Aup No.1, RT.1/RW.9, Ps. Minggu, Jakarta Selatan, Jakarta, Indonesia
[2]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, 16680, Jl. Agatis, , Bogor, Indonesia
[3]Center for Coastal and Marine Resource Studies, IPB University, 16127, Jl. Pajajaran Raya, , Bogor, Indonesia a Jakarta, Indonesia
[3]Raja Ali Haji Maritime University (UMRAH), 29124, Jalan Raya Dompak - Tanjungpinang, Provinsi Kepulauan Riau, Indonesia

Abstract. Fisheries resource assessment is pivotal for grasping marine ecosystem dynamics and guiding sustainable management practices. This study focuses on exploring the fisheries resources within Berau Bay, situated in the biodiverse-rich West Papua Province, known for its significant marine biodiversity and importance to local livelihoods. Despite its importance, there is a notable absence of comprehensive assessments concerning the bay's fisheries resources and their utilization potential. This research endeavors to fill this gap by providing a detailed analysis to inform sustainable management strategies. Our findings reveal a diverse range of fish families dominating Berau Bay, with significant contributions from Carangidae and Scombridae. Moreover, acoustic surveys uncover substantial Fisheries Resource Potential (FRP) across three zones: Zone 1 at 501.555 tons, Zone 2 at 854.634 tons, and Zone 3, primarily designated as a conservation area, at 678.188 tons. The cumulative FRP potential amounts to 2.034.377 tons, encompassing various species categories, with an estimated annual utilization rate of around 1.627.502 tons. These results challenge previous assumptions regarding the bay's fisheries composition and potential, emphasizing the necessity of updated assessments. Additionally, they enhance our understanding of the region's marine biodiversity, underscoring the urgency of targeted conservation efforts for sustainable resource management. This study emphasizes the significance of holistic approaches to fisheries management, integrating ecological, socioeconomic, and conservation considerations. Such interdisciplinary efforts are paramount for safeguarding marine ecosystems and supporting the livelihoods of coastal communities worldwide.

* Corresponding Author: riyanmaulbdp@gmail.com

1 Introduction

Indonesia's marine territories account for 27.2% of the global flora and fauna species, covering a wide array including mammals (12%), amphibians (23.8%), reptiles (31.8%), fish (44.7%), mollusks (40%), and seaweed (8.6%) [1]. The waters of Berau Bay in West Papua Province harbor immense fishery potential. Pakiding [2] highlights the region's coastal conservation park as a habitat for diverse fish species, including pelagic, demersal, and coral fish, notably grouper, snapper, mackerel, and barramundi, which are the primary targets for local fishermen. Proper management strategies that adhere to sustainable utilization principles should be implemented to maximize the abundant fisheries resources in Berau Bay.

The Berau Bay area is a designated conservation area established by Minister of Marine Affairs and Fisheries Decree No. 79/KEPMEN-KP/2020 concerning the Conservation Area of Coastal Areas and Small Islands of Berau Bay and Nusalasi – Van Den Bosch Bay in West Papua Province. Consequently, fishing activities are zoned for small-scale fishermen, as specified in the utilization zoning. McConney & Charles [3] note that small-scale fishermen typically operate in nearshore waters using relatively small fishing fleets. These fishermen commonly employ traditional fishing gear such as small nets, traps, lines, spears, and hand collection methods, alongside some modified techniques [4]. As mentioned by Pakiding [2], in the Berau Bay area, 80% of fishermen utilize handline fishing gear. Additionally, a portion of the community uses other fishing gear, such as small mesh nets (9.64%), large mesh nets (8.43%), and drift nets (bottom or surface) (2.41%). These data reflect the preferences and fishing patterns within the conservation area, encompassing the use of various fishing gear by local fishermen.

Accurate knowledge about the quantity and distribution of fish resources is essential for their optimal utilization, enabling appropriate policy measures to be taken without endangering their sustainability, as noted by Kasmawati [5]. Quantitative estimation of fish population sizes is crucial for effective resource development and management [6]. Fish populations must be capable of surviving in both marine and freshwater habitats, as they often migrate between environments [7]. Only a select few species can thrive in both habitats, typically those with dominant and abundant populations [8].

Several methods can be employed to estimate fishery resource potential, one of which is the acoustic method in fishery resource estimation [9-13]. The application of acoustic methods in fish stock estimation offers several advantages, including the rapid generation of in-situ data, relatively accurate results, and non-invasiveness to the observed fishery resources. Apart from stock estimation, hydroacoustic observations can provide insights into the distribution and grouping of fishery resources within a water body [9].

2 Material and method

2.1 Sampling site

The study was conducted from May to August 2023, located in Berau Bay, Fak Fak Regency, West Papua Province (Figure 1), and at the Spatial Laboratory of the Center for Coastal and Marine Resource Studies, IPB University. The processing and analysis of acoustic data were carried out at the Faculty of Marine Science and Fisheries, Raja Ali Haji Maritime University (UMRAH) in Tanjung Pinang, Riau Islands Province.

The instruments and materials utilized during the research process include Local fishermen's fishing vessel fleet with a size of 17 GT utilized as a research platform; The SIMRAD EK-15 acoustic device, featuring a transducer frequency of 120 KHz for acquiring

acoustic data and depth measurements, coupled with Garmin GPS units (GPSmap 176C and Garmin etrex) for determining the vessel's position and survey routes for fishery resources.

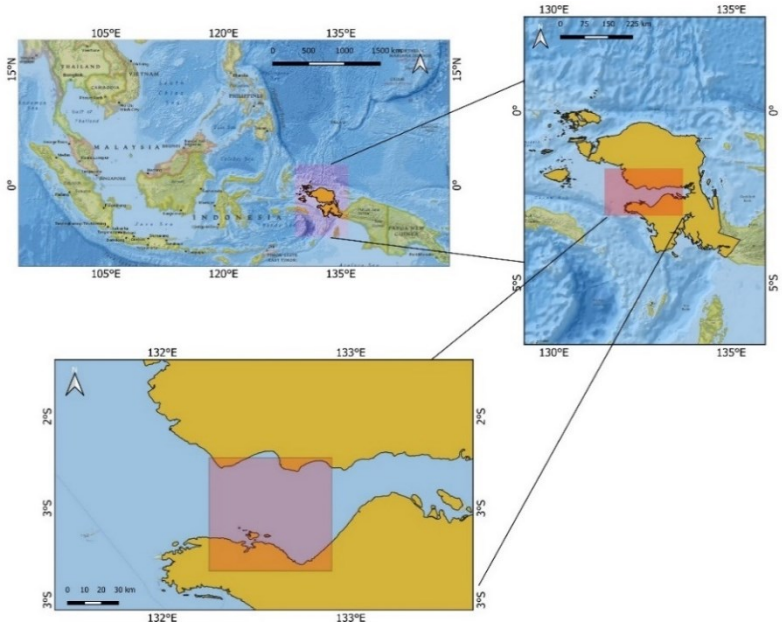

Fig. 1. Research location.

2.2 Fisheries Resources in Berau Bay Waters

Data on fishery resources (fish, crustaceans, mollusks, and others) were gathered through on-site observation and direct interviews with fishermen involved in fishing activities at the research site and fish landing locations within the study area. Fish species were identified based on the classification provided by Kailola and Trap [14]. The analysis of fishery resource characteristics in Berau Bay entailed identifying the types and species of fish landed in the vicinity of Berau Bay's landing sites, encompassing both fish and non-fishery resources.

2.3 Estimation of Fishery Resource Stock in Berau Bay Waters

The estimation of fishery resource stock is conducted using acoustic methods. Surveys are carried out along predetermined tracks divided into three zones (Figure 2). Zone delineation is based on distinct habitat characteristics. Zone 1 encompasses extensive estuarine areas with significant freshwater inputs. Zone 2 comprises open sea areas, while Zone 3 represents the conservation area of Berau Bay, characterized by numerous small islands and abundant coral reef ecosystems. This zoning also aligns with administrative boundaries, notably Zone 1 falling within the Southwest Papua Province and Zone 3 within the West Papua Province.

Acoustic surveys for estimating fishery resource potential were conducted based on the research by Manik et al. [15]. Acoustic data were collected using the SIMRAD EK-15 Scientific Echosounder transducer instrument operating at a frequency of 120 kHz, mounted on the research vessel. During the survey, data were recorded using ER60 software to generate raw data for further processing stages. Acoustic data recording was conducted

continuously throughout the day along the survey tracks, following a parallel track pattern as shown in Figure 3.

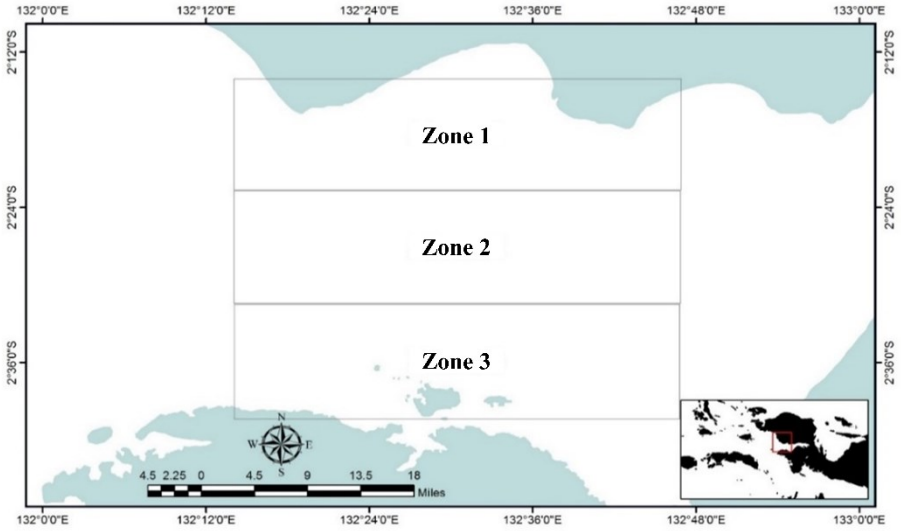

Fig. 2. The Zoning of Areas for Estimating Fishery Resource Potential.

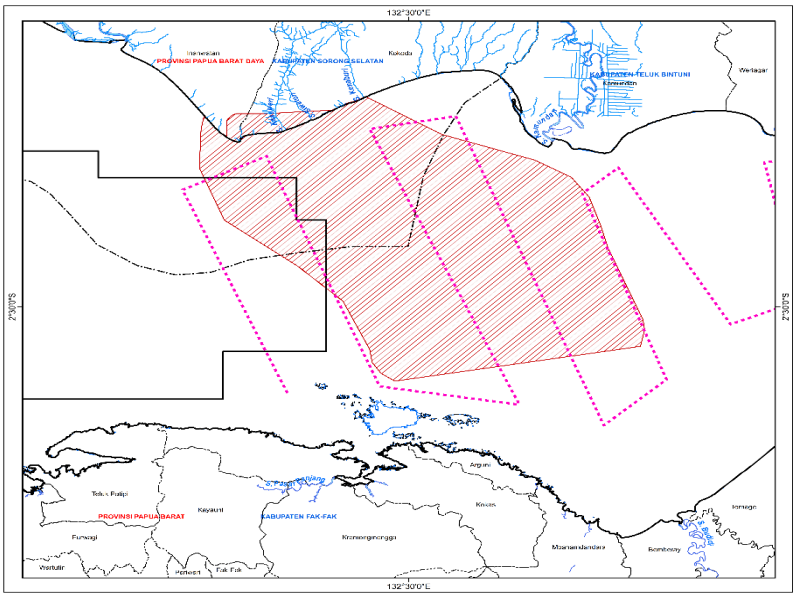

Fig. 3. Acoustic Survey Tracks for Estimating Fish Abundance.

2.4 Data Analysis

2.5.1 Fishery Resources

Information regarding fishery resources is presented in the form of a table listing the types of fish caught by local fishermen and qualitatively described through graphical representation.

2.5.2 Acoustics Survey Analysis

The transducer recording data in *.raw format is processed using Sonar Pro 5 software with a threshold range set between -70 to -24 dB, as described in the study by Manik et al. [15]. Subsequently, the data is exported to *.csv format, considering a depth range between 2 to 80 meters. The objective of this step is to gather preliminary information regarding the potential presence of fish schools at these depths, which are then targeted by local fishermen, particularly small pelagic fish. Following this, the number of individuals in the fish schools and the detected fish biomass are calculated based on depth stratification.

2.5.3 Fishery Resources Potential in Berau Bay Waters

The biomass or standing stock of fish is determined by the resource density (ρ) and the total area of the study (A), formulated according to the equation Bo = A x ρ, where ρ represents fish density [15]. Once the standing stock of a particular biota is known, the potential yield (Py) of the water body can be estimated. Potential yield is the maximum estimated catch (tons/year) of a water body without compromising the sustainability of existing resources. The equation used to calculate the Py value according to Sparre & Venema [16] is as follows:

$$P_y = B_o \times 50\% \times 80\% \quad (1)$$

3 Results

3.1 Fish Assemblages in Berau Bay Waters

Fishery resources in the Berau Bay area are divided into two categories: fishery resources and non-fishery resources. Based on field identification at the fish landing sites (TPI) in the Berau Bay area, 36 fish species belonging to 20 families were found to be landed at 4 observation points: Arguni, Ugar, Sosar, and Kokoda.

Based on the identification results, among the 20 fish families, the Carangidae and Scombridae families were the most frequently encountered, comprising 11.11% of the total with 4 species each. Other abundant families include Lutjanidae and Sciaenidae (8.33%) with 3 species each, while Serranidae, Siganidae, and Cynoglossidae are represented by 2 species each (5.56%). The remaining families collectively accounted for less than 3% of the total identified species. The research also indicated that fishermen landed sharks and rays, both of which belong to the Elasmobranchii group or cartilaginous fish, with a total percentage of 16.67% distributed across 4 families.

Table 1. List of Fish Species at The Research Sites.

No.	Family	Species	Name	Local Name
1	Carcharhinidae	*Carcharhinus macloti* (Müller & Henle, 1839)	*Hardnose shark*	Mangewang
2		*Carcharhinus sealei* (Pietschmann, 1913)	*Blackspot shark*	Mangewang
3	Rhinidae	*Rhynchobatus laevis* (Bloch & Schneider, 1801)	*Smoothnose wedgefish*	Hiu pari
4	Glaucostegidae	*Glaucostegus granulatus* (Cuvier, 1829)	*Granulated guitarfish*	Hiu pari
5	Plesiobatidae	*Plesiobatis daviesi* (Wallace, 1967)	*Deep-water stingray*	Pari
6	Dasyatidae	*Neotrygon kuhlii* (Müller & Henle, 1841)	*Blue-spotted stingray*	Pari
7	Engraulidae	*Thryssa hamiltonii* (Gray, 1835)	*Hamilton's thryssa*	Bilis
8	Clupeidae	*Escualosa thoracata* (Valenciennes, 1847)	*White sardine*	Popuri
9	Ariidae	*Nemapteryx armiger* (De Vis, 1884)	*Threadfin catfish*	Sembilang ekor dua
10		*Neoarius leptaspis* (Bleeker, 1862)	*Salmon catfish*	Sembilang ekor dua
11	Plotossidae	*Paraplotosus albilabris* (Valenciennes, 1840)	*Whitelipped eel catfish*	Sembilang ekor satu
12	Mugilidae	*Osteomugil engeli* (Bleeker, 1858)	*Kanda*	Belanak
13	Serranidae	*Epinephelus bleekeri* (Vaillant, 1878)	*Duskytail grouper*	Kerapu
14		*Epinephelus coioides* (Hamilton, 1822)	*Orange-spotted grouper*	Kerapu
15	Carangidae	*Caranx tille* Cuvier, 1833	*Tille trevally*	Bobara
16		*Alepes vari* (Cuvier, 1833)	*Herring scad*	Bobara
17		*Caranx ignobilis* (Forsskål, 1775)	*Giant trevally*	Bobara
18		*Megalaspis cordyla* (Linnaeus, 1758)	*Torpedo scad*	Taruri/Tetengkek
19	Lutjanidae	*Lutjanus malabaricus* (Bloch & Schneider, 1801)	*Malabar blood snapper*	Kakap
20		*Lutjanus argentimaculatus* (Forsskål, 1775)	*Mangrove red snapper*	Kakap
21		*Lutjanus erythropterus* Bloch, 1790	*Crimson snapper*	Kakap
22	Sciaenidae	*Johnius australis* (Günther, 1880)	*Bottlenose jewfish*	Gulamah
23		*Protonibea diacanthus* (Lacepède, 1802)	*Blackspotted croaker*	Ikan merah
24		*Nibea soldado* (Lacepède, 1802)	*Soldier croaker*	Ikan putih/Blama
25	Pomacentridae	*Neopomacentrus nemurus* (Bleeker, 1857)	*Coral demoiselle*	Betok laut
26		*Neoglyphidodon melas* (Cuvier, 1830)	*Bowtie damselfish*	Betok laut
27	Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	*Spotted scat*	Kiper
28	Siganidae	*Siganus fuscescens* (Houttuyn, 1782)	*Mottled spinefoot*	Baronang
29		*Siganus canaliculatus* (Park, 1797)	*White-spotted spinefoot*	Baronang

No.	Family	Species	Name	Local Name
30	Acanthuridae	*Acanthurus xanthopterus* Valenciennes, 1835	*Yellowfin surgeonfish*	Kulit pasir
31	Scombridae	*Scomberomorus commerson* (Lacepède, 1801)	*Narrowbarred Spanish mackerel*	Tenggiri
32		*Scomberomorus guttatus* (Bloch & Schneider, 1801)	*Indo-Pacific king mackerel*	Tenggiri
33		*Rastrelliger brachysoma* (Bleeker, 1851)	*Short mackerel*	Kembung
34		*Auxis thazard* (Lacepède, 1800)	*Frigate tuna*	Tongkol
35	Cynoglossidae	*Cynoglossus bilineatus* (Lacepède, 1802)	*Fourlined tonguesole*	Lidah
36		*Paraplagusia bilineata* (Bloch, 1787)	*Doublelined tonguesole*	Lidah

Non-fishery resources include crustaceans and mollusks. In this study, only 4 species from 3 families of crustaceans and 2 species from 2 families of mollusks were found in the research area (Table 2). Species from the Penaeidae family were the most commonly found in the research area (2 species), while the other families each had 1 species found.

Table 2. List of Non–Fish Species at The Research Sites.

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

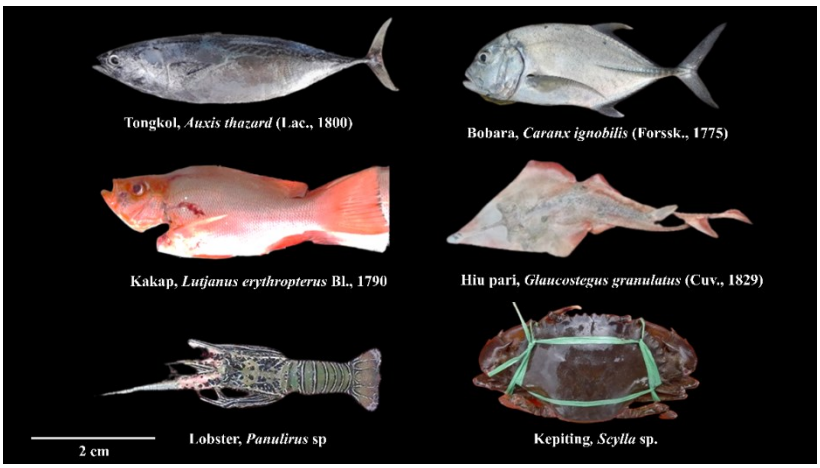

Fig. 4. Several Species of Fish and Non-Fish Caught by Fishermen in The Research Area.

3.2 The Status of Fishery Resources in Berau Bay

The conservation status of fishery and non-fishery resources recorded in the IUCN Red List data (2023) indicates that they are predominantly categorized as "Least Concern" (LC) (Table 3).

Table 3. Threat Status of Fish and Non-Fish Species Captured in The Research Area.

No.	Species	Local Name	Threat Status*	Assessment Time
Fish				
1	*Carcharhinus macloti*	Mangewang	NT	27/11/2020
2	*Carcharhinus sealei*	Mangewang	VU	19/05/2020
3	*Rhynchobatus laevis*	Hiu pari	CR	03/12/2008
4	*Glaucostegus granulatus*	Hiu pari	CR	04/04/2022
5	*Plesiobatis daviesi*	Pari	LC	13/05/2015
6	*Neotrygon kuhlii*	Pari	DD	22/06/2017
7	*Thryssa hamiltonii*	Bilis	LC	17/07/2017
8	*Escualosa thoracata*	Popuri	LC	28/02/2017
9	*Nemapteryx armiger*	Sembilang ekor dua	NE	-
10	*Neoarius leptaspis*	Sembilang ekor dua	LC	12/02/2019
11	*Paraplotosus albilabris*	Sembilang ekor satu	NE	-
12	*Osteomugil engeli*	Belanak	LC	02/07/2016
13	*Epinephelus bleekeri*	Kerapu	DD	21/11/2016
14	*Epinephelus coioides*	Kerapu	LC	21/11/2016
15	*Caranx tille*	Bobara	LC	09/03/2015
16	*Alepes vari*	Bobara	LC	04/02/2009
17	*Caranx ignobilis*	Bobara	LC	09/03/2015
18	*Megalaspis cordyla*	Taruri/Tetengkek	LC	10/03/2015
19	*Lutjanus malabaricus*	Kakap	LC	28/06/2018
20	*Lutjanus argentimaculatus*	Kakap	LC	04/03/2015
21	*Lutjanus erythropterus*	Kakap	LC	28/06/2018
22	*Johnius australis*	Gulamah	LC	27/09/2018
23	*Protonibea diacanthus*	Ikan Merah	NT	30/07/2018
24	*Nibea soldado*	Ikan putih/Blama	LC	29/06/2016
25	*Neopomacentrus nemurus*	Betok laut	LC	23/09/2021
26	*Neoglyphidodon melas*	Betok laut	LC	23/09/2021
27	*Scatophagus argus*	Kiper	LC	04/02/2009
28	*Siganus fuscescens*	Baronang	LC	10/03/2015
29	*Siganus canaliculatus*	Baronang	LC	10/03/2015
30	*Acanthurus xanthopterus*	Kulit pasir	LC	04/05/2010
31	*Scomberomorus commerson*	Tenggiri	NT	05/12/2009

No.	Species	Local Name	Threat Status*	Assessment Time
32	*Scomberomorus guttatus*	Tenggiri	DD	04/12/2009
33	*Rastrelliger brachysoma*	Kembung	DD	10/12/2009
34	*Auxis thazard*	Tongkol	LC	14/09/2010
35	*Cynoglossus bilineatus*	Lidah	LC	14/08/2019
36	*Paraplagusia bilineata*	Lidah	LC	16/11/2020
Non – Fish				
37	*Scylla* sp.	Kepiting	NE	-
38	*Penaeus monodon*	Udang windu	NE	-
39	*Penaeus indicus*	Udang putih	NE	-
40	*Panulirus versicolor*	Lobster	LC	03/12/2009
41	*Tridacna* sp.	Siput	*)	-
42	*Uroteuthis chinensis*	Cumi-cumi	DD	01/07/2015

*Threat Status : NE: Not Evaluated; DD: Data Deficient; LC: Least COncern; NT: Near Threatened; VU: Vulnerable; CR: Critically Endangered; *): Evaluated for species in that genus.
Source: IUCN 2023

Among these fish and non-fish species, the guitarfish (R. laevis and G. granulatus) are classified as "Critically Endangered" (CR), one species of mangrove jack (C. sealei) is categorized as "Vulnerable" (VU), and another mangrove jack species (C. macloti) falls under the "Near Threatened" (NT) category. As for non-fish species, only two types have their status recorded in the IUCN Red List data (2023): Panulirus versicolor is classified as "Least Concern" (LC), and Uroteuthis chinensis is listed as "Data Deficient" (DD). One non-fish species, Tridacna sp., is categorized as "Vulnerable" for the T. gigas and T. derasa species, both of which can be found in Indonesian waters according to the IUCN Red List data (2023).

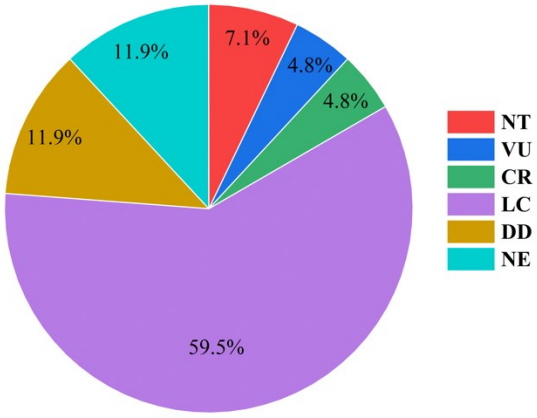

Fig. 5. The number and percentage of fish species landed in Berau Bay, Indonesia, based on the conservation status categories by the International Union for Conservation of Nature (IUCN, 2023) are as follows: CR — Critically Endangered, VU — Vulnerable, NT — Near Threatened, DD — Data Deficient, LC — Least Concern, NE — Not Evaluated.

3.3 The Potential of Fishery Resources

The fishery resource potential varies across zones, with Zone 1 covering 295.683 km^2 and offering a potential of 501.555 tons, Zone 2 spanning 299.244 km2 with a potential of 854.634 tons, and Zone 3 encompassing 311.375 km^2 with a potential of 678.188 tons (Tables 4; 5; 6). Throughout all zones, large pelagic fish consistently dominate over small pelagic species, except for demersal fish, notably in Zone 1, where extensive mangrove and estuarine areas provide habitat for various fish species. Estimations of harvestable catches are based on 80% of the fishery resource potential, allowing 20% of the resources to support growth and reproduction.

The distribution of fish varies significantly with depth (Figure 6). In the 2-10 meter depth range, small pelagic fish dominate, with large pelagic fish also present. In the 10-20 meter range, large pelagic fish prevail, influenced by the presence of small pelagic fish. From 20-30 meters, large pelagic fish dominate again, with a decreasing trend in density observed in deeper strata. By 60-80 meters, fish schools have significantly reduced, with demersal fish prevalent across all zones, particularly in Zones 1 and 2.

Table 4. Fishery Resource Potential and Estimated Catch in Each Depth Stratum in Zone 1.

Depth (m)	Area (km^2)	Density (ton/ km^2)	Fishery Resource Potential (ton)			Estimated Catch (ton/year)		
			Large Pelagic	Small Pelagic	Demersal	Large Pelagic	Small Pelagic	Demersal
2 – 10	41.645	0,331	3.098	4.878		2.478	3.902	-
10 – 20	41.645	0,407	19.758	13.999		15.807	11.199	-
20 – 30	41.645	0,067	46.132	2.685		36.905	2.148	-
30 – 40	41.645	0,008	13.606	163		10.885	130	-
40 – 50	29.152	0,002	282	10		226	8	-
50 – 60	24.987	0,759	73.039	10.933		58.431	8.746	-
60 – 70	20.823	0,548	31.165	16.691		24.932	13.353	-
70 – 80	12.494	0,000	-	-		-	-	-
Demersal	41.645	0,975	-	-	265.117	-	-	212.093
Total	**295.683**		**187.079**	**49.359**	**265.117**	**149.664**	**39.487**	**212.093**

4 Discussions

Fish are the fauna with the largest number of species in aquatic environments. There are recorded more than 33,000 species of fish worldwide, consisting of Elasmobranchii, Teleostei, and Agnatha, inhabiting freshwater, marine, and estuarine environments [17]. In this study, the Carangidae family is the dominant fish family found in the Berau Bay area (11.11% of total fish species), followed by Lutjanidae and Sciaenidae (8.33%). Findings from this research align with other studies in the Pusong Bay area, Lhokseumawe [18], and the Coastal Island of Rio de Janeiro [19]. Conversely, the results tend to differ from other areas, such as the Chiapas waters in Mexico, which are dominated by the Sciaenidae family[20], while the Persian Gulf is dominated by the Gobiidae family [21]. Meanwhile, the Eastern Coast Bay of the Novaya Zemlya Islands is dominated by the Zoarcidae family [22].

The distribution of non-fish fauna in the Berau Bay area is dominated by the class Crustacea, such as *Scylla* sp., *P. monodon*, and *P. indicus,* which are crustacean species commonly found in estuarine habitats, although they are also encountered in marine environments. This ability is influenced by the life stages of each organism. Typically, the juvenile stages of shrimp inhabit estuaries, while adults are found in the sea. Additionally, the abundance of a species of aquatic organism can be influenced by environmental factors. Paulangan et al. [22] mentioned that changes in abundance, distribution, and species composition in a habitat can be attributed to major factors such as tidal currents and environmental conditions.

Table 5. Fishery Resource Potential and Estimated Catch in Each Depth Stratum in Zone 2.

Depth (m)	Area (km^2)	Density (ton/ km^2)	Fishery Resource Potential (ton)			Estimated Catch (ton/year)		
			Large Pelagic	Small Pelagic	Demersal	Large Pelagic	Small Pelagic	Demersal
2 – 10	40.438	1,030	103.497	7.045		82.798	5.636	-
10 – 20	40.438	0,718	29.115	22.807		23.292	18.246	-
20 – 30	40.438	0,320	140.728	13.833		112.583	11.066	-
30 – 40	40.438	0,101	162.714	1.949		130.172	1.559	-
40 – 50	24.263	0,035	30.384	360		24.307	288	-
50 – 60	32.351	0,004	2.545	99		2.036	80	-
60 – 70	28.307	0,004	1.348	112		1.079	90	-
70 – 80	12.132	0,000	1.304	-		1.044	-	-
Demersal	40.438	1,247	-	-	336.790	-	-	269.432
Total	**299.244**		**471.638**	**46.206**	**336.790**	**377.310**	**36.965**	**269.432**

Table 6. Fishery Resource Potential and Estimated Catch in Each Depth Stratum in Zone 3.

Depth (m)	Area (km^2)	Density (ton/ km^2)	Fishery Resource Potential (ton)			Estimated Catch (ton/year)		
			Large Pelagic	Small Pelagic	Demersal	Large Pelagic	Small Pelagic	Demersal
2 – 10	40.438	0,804	117.509	8.632	-	94.007	6.906	-
10 – 20	40.438	0,432	59.645	13.719	-	47.716	10.975	-
20 – 30	40.438	0,219	219.525	7.216	-	175.620	5.773	-
30 – 40	40.438	0,028	31.533	595	-	25.227	476	-
40 – 50	40.438	0,012	19.506	285	-	15.605	228	-
50 – 60	40.438	0,003	3.477	63	-	2.781	50	-
60 – 70	16.175	0,002	861	11	-	689	9	-
70 – 80	12.131	0,001	405	8	-	324	6	-
Demersal	40.438	0,933	-	-	195.198	-	-	156.158
Total	**311.375**		**452.461**	**30.529**	**195.198**	**361.969**	**24.423**	**156.158**

This study also found other crustaceans such as lobsters, which were abundant in two areas, namely Arguni and Ugar. These two areas are surrounded by coral reef habitats, which are preferred habitats for lobsters. During the study period, lobster fishing was active due to the opening of a local practice known as "sasi." Sasi is a form of traditional wisdom practiced by the Papuan community to sustainably utilize their marine resources, including lobsters. Opening sasi means fishermen are allowed to catch lobsters, especially at night using traps (bubu). This situation has led to the abundance of lobsters, particularly in these two locations. Marine tenure activities are part of conservation efforts carried out in Indonesia from Sabang to Merauke, where in West Papua and Maluku regions it is known as "sasi/sasi laut" [23-27], Mane'e in North Sulawesi [28], Awig-awig in Bali and Lombok [29, 30], and Panglima Laot in Aceh and West Sumatra [31]. Each of these locally-based fisheries management systems has various forms of user rights, including differences in exclusion, access/withdrawal, management, enforcement, transferability, and resilience [32]. Thus, through the implementation of sasi practices in the Berau Bay area, the local community has made efforts towards fisheries resource management in the Berau Bay conservation area.

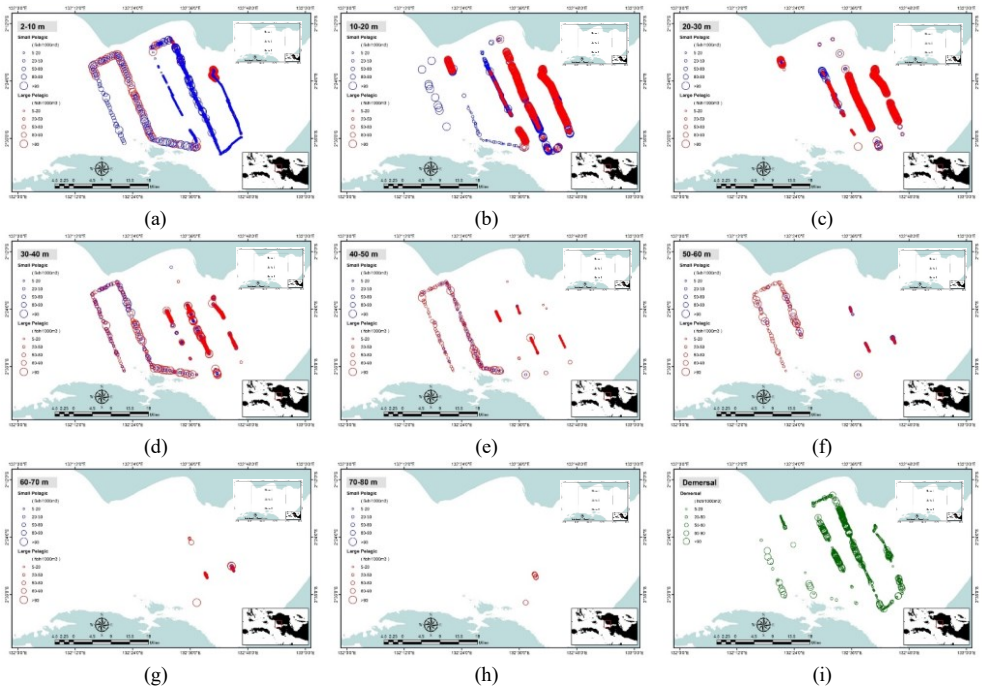

Fig. 6. Fish school distribution across various depth strata, (a) 2 – 10 m; (b) 10 – 20 m; (c) 20 – 30 m; (d) 30 – 40 m; (e) 40 – 50 m; (f) 50 – 60 m; (g) 60 – 70 m; (h) 70 – 80 m; (i) demersal.

When compared to various regions in other countries that utilize data from underwater surveys and published literature, the species count in this study is not comparable to the number of species listed in La Reunion Island in the Indian Ocean (984 species), the Cocos (Keeling) Islands (Indian Ocean, 602 species), Isla del Coco in Costa Rica (514 species), and the Marquesas Islands (495 species), both located in the Pacific Ocean [32-35]. This study employed limited survey techniques and observations with only four observation locations, resulting in a relatively smaller number of identified species. However, Indonesia possesses a high level of biodiversity; research by Allen and Erdmann [36] noted the discovery of 1511 species on the Bird's Head Peninsula in West Papua.

Based on the conservation status categories by the International Union for Conservation of Nature (IUCN, 2023), it is known that the identified fish species in the Berau Bay area consist of 4.76% classified as CR (Critically Endangered), 4.76% as VU (Vulnerable), 7.14% as NT (Near Threatened), 11.90% as DD (Data Deficient), 59.52% as LC (Least Concern), and 11.90% as NE (not evaluated). The presence of fish species classified as vulnerable or critically endangered underscores the importance of attention to the Berau Bay area, especially considering it is a designated conservation area through Ministerial Decree No. 79/KEPMEN-KP/2020 regarding the Coastal Conservation Areas and Small Islands of Berau Bay and Nusalasi – Van Den Bosch Bay in West Papua Province. Generally, global biodiversity is not evenly distributed; some countries/regions with high biodiversity often have high human populations and relatively low per capita income [37, 38] and tend to have the highest number of endangered species resources for research [39] and conservation purposes [37] and may rely more on local marine resources for their livelihoods [40, 41]

Estimation of fisheries resource potential in the Berau Bay area was conducted using acoustic methods. The use of acoustic methods in fish stock assessment has several advantages, including rapid data acquisition, in-situ implementation, relative accuracy, and

non-harmful observation of the observed fish resources [9]. Based on the transect results according to the acoustic survey track lines, the magnitude of the Fishery Resource Potential (FRP) in zone 1 is 501.555 tons with a potential utilization of 401.244 tons/year. Zone 2 has an FRP of 854.634 tons with a potential utilization of 683.707 tons/year. Zone 3, mostly comprising the Berau Bay conservation area, has an FRP of 678.188 tons with a potential utilization of 542.550 tons/year. When summed for all zones, the total FRP of the Berau Bay waters based on acoustic surveys is 2.034.377 tons with a utilization rate of 1.627.502 tons/year. This FRP potential consists of large pelagic fish, small pelagic fish, and demersal fish.

When compared to the FRP potential set by the Ministry of Marine Affairs and Fisheries through Ministerial Decree Number 19 of 2022 concerning the Estimation of Fishery Resource Potential, Allowed Fish Catch, and Fishery Resource Utilization Rate in the Waters of the Republic of Indonesia Fisheries Management Area, the Berau Bay area falls within the Fisheries Management Area of the Republic of Indonesia (WPP – NRI) 715 Waters of Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea, and Berau Bay have an estimated potential of 715.293 tons. Therefore, this study has a higher estimation value with a difference of 1.319.084 tons. The difference in potential value is influenced by various factors including the estimation method used, area coverage, season, and availability of data and information on assessments in the study area. Berau Bay is one of the areas with limited information on fisheries resource management. Luiz et al. [42] mentioned that research on small, remote, and isolated islands is still very limited, including in the Berau Bay area. Although fishing activities in this area are still low, there is a possibility of increased fishing activities in the future, highlighting the need for fisheries management attention to achieve sustainable fisheries management.

5 Conclusions

This study identified 20 fish families in Berau Bay waters, with Carangidae and Scombridae families being dominant. Fishermen catch sharks and rays, as well as non-fishery resources such as giant tiger prawn and lobster. The study evaluated the conservation status of fisheries resources, with fish species exhibiting varied statuses under the IUCN conservation status categories. The estimated potential fisheries resources in Berau Bay waters amount to 2.034.377 tons, consisting of large pelagic fish, small pelagic fish, and demersal fish. The study can serve as a basis for the development of sustainable fisheries policies and conservation strategies by identifying dominant and potential fisheries resource groups. The study recommends further research on the relationship between environmental parameters and oceanographic conditions in the Berau Bay waters, which can aid in understanding the distribution of fish and their resource potential.

This research would not have been completed without the support from the Center for Coastal and Marine Resources Studies (CCRMS), IPB University for funding project assistance and also Ministry of Marine and Fisheries Affairs for study assignment scholarship. Apart from that, the author also would like to appreciate the cooperation from the Government of Berau Bay, West Papua Province.

References

1. L. Adrianto, A. Habibi, A. Fahruddin, A. Azizy, H.A. Susanti, I. Musthofa. Modul Indikator untuk Pengelolaan Perikanan Dengan Pendekatan Ekosistem. (KKP RI, Jakarta, 2014)
2. F. Pakiding, *Socio-Economic Baseline Survey Report.* (USAID Sustainable Ecosystems Advanced (SEA) Project Report, Washington, 2018)

3. McConney, A.T. Charles, Managing Small-Scale Fisheries: Moving Towards People-Centred Perspectives (Handbook of Marine Fisheries Conservation and Management, Canada, 2008)
4. Kasmawati, Urgensi Sumber Daya Manusia Dalam Exploitasi Sumber Daya Alam. (Universitas Negeri Alauddin Press, Makassar, Indonesia, 2011)
5. F. Berkes, R. Mahon, P. McConney, R. Pollnac, R. Pomeroy, Mengelola Perikanan Skala Kecil Arah dan Metode Alternatif (International Development Researh Center. Kanada, 2008)
6. B.I. Prisantoso, B. Badrudi, Jurnal Kebijakan Perikanan Indonesia, **2,** 1, 71-78 (2017)
7. P.B. Moyle, J.J.J. Cech, Fishes. An introduction to ichthyology (5th ed.) (Englewood Cliffs, New Jersey, 2004)
8. P. Veiga, L. Vierra, C. Bexiga, R. Si, K. Erzini, Estuarine, Coastal, and Shelf Science, **70**, 1, 27–38, (2006).
9. A. Priatna, W. Wijopriono, Jurnal Penelitian Perikanan Indonesia, **17**, 1, 1-10, (2016)
10. M. Natsir, B. Sadhotomo, W. Wudianto, Jurnal Penelitian Perikanan Indonesia, **11**, 6, 101-107 (2017).
11. Z. Fahmi, Widya Riset Perikanan Tangkap, **2**, 2, 63-68 (2017)
12. A. Achmadi, T. Hestirianoto, H. Manik, Jurnal Teknologi Perikanan dan Kelautan,**5**, 2, 131-139 (2014)
13. A. Brown, P. Rengi, B. Bustari, Berkala Perikanan Terubuk, **43**, 1, 94-106, (2015)
14. G. Trap, J.P. Kailola, Trawled fishes of Southern Indonesia and Northwestern Australia National Library of Australia (The Australian Development Assistance Bureau, Canberra, 1984)
15. H.M. Manik, N.S. Tri, M. Asep, P. Asep P, Marine Fisheries **91**, 39-51 (2018)
16. P. Sparre, S.C. Venema, Introduction of Tropical Fish Stock Assessment (eManual Book, Jakarta, 1999)
17. A. Nontji, Rencana Pengembangan Puslitbang Limnologi-LIPI. Ekspose Limnologi dan Pembangunan (Puslit Limnologi-LIPI, Bogor, Indonesia, 1986)
18. A. Damora, A.S. Batubara Z. Zuhdi, Y. Restiangsih F. Amir, M. Irham N. Fadli, F. Nur R. Rizal, Eur. J. Environ., **10**, 2, 115-123 (2020)
19. C. Monteiro-Neto, A.A. Bertoncini, L.C.T. Chaves, R. Noguchi, J.P. MendonçaNeto, C.A. Rangel, Mar. Biodivers. Rec. **6,** 1, (2013).
20. A.F. González-Acosta, R. Rodiles-Hernández, A.A. González-Díaz, Mar. Biodivers. **48**, 3, 1439-1454 (2018)
21. S. Eagderi,R. Fricke,H.R. Esmaeili, P. Jalili, J. Iran, Ichthyol. **6**, 1, 1-171.
22. Y.Y. Bolshakova, D.V. Bolshakov, Oceanology **58**, 2, 228- 232 (2018)
23. Y.P. Paulangan, MM.A. Al Amin, Y. Wahyudin,, Appl. Econ. Res. on Fish. Man. and Mar. Conserv., **2**, 2 (2018)
24. A. Satria, D.S. Adhuri, Managing Coastal and Inland Waters, **4**, 31–55 (2010)
25. F.V. Benda-Beckmann, K.V. Benda-Beckman, Bijdragen tot de Taal-, Land-en Volkenkunde **167**, 195 (2011)
26. [KKP]. Kementerian Kelautan dan Perikanan, Peraturan Menteri Kelautan dan Perikanan Nomor 8/PERMEN-KP/2018 Tahun 2018 Tentang Tata Cara Penetapan Wilayah Kelola Masyarakat Hukum Adat Dalam Pemanfaatan Ruang di Wilayah Pesisir dan Pulau-Pulau Kecil, (KKP Press, Jakarta, 2018)
27. D.S. Adhuri, Selling the Sea, Fishing for Power: A Study of Conflict over Marine Tenure in Kei Islands, Eastern Indonesia. (ANU Press, Canberra, 2013)
28. L. Adrianto, M.A. Al Amin, A. Solihin, D.L. Hartoto, Konstruksi lokal pengelolaan sumberdaya perikanan di Indonesia (PT Penerbit IPB Press, Bogor, 2021)
29. A. Satria, Y. Matsuda, M. Sano,. Mar. Pol. **30**, 226–236 (2006)
30. A. Satria, D.S. Adhuri, Managing Coastal and Inland Waters, **1**, 31–55 2020)

31. P.B. Utomo, The Role of Traditional Knowledge in Fisheries Management: A Study Case of Panglima Laot (Sea Commander) in the Aceh Province of Indonesia. (The Maritime Commons: Digital Repository of the World Maritime University, Aceh, 2010)
32. J. Hobbs, S. Newman, G. Mitsopoulos, M. Travers, C. Skepper, J. Gilligan, G. Allen, G., H.J. Choat, A.M. Ayling, Raffles Bulletin of Zoology, **30**, 203-219 (2014)
33. E. Delrieu-Trottin, J.T. Williams, P. Bacchet, M. Kulbicki, J. Mourier, R. Galzin, T. Lison de Loma, G. Mou-Tham, G. Siu, S. Planes, Check List, **11**, 5, 1758 (2015)
34. M. Fourriere, J.J. Alvarado, A.A. Bocos, J. Cortes, Mar. Biodivers. **47**, 813–821, (2017)
35. R. Fricke, T. Mulochau, P. Durville, P. Chabanet, E. Tessier, Letourneur, Stuttg. Beitr. Nat. A Neue Ser. **2**, 1–168 (2009)
36. G. R. Allen, M.V. Erdmann, Check List, **5**, 3, 587–628 (2009)
37. J. Baille, C. Hilton-Taylor, S.N. Stuart, 2004 IUCN Red List of Threatened Species: A Global Species Assessment, (Cambridge Press, UK, 2006)
38. T.M. Brooks, R.A. Mittermeier, G.A.B. da Fonseca, J. Gerlach, M. Hoffmann,, J.F. Lamoreux, C.G. MittermeierJ.D. Pilgrim, A.S.L. Rodrigues, Science **313**, 58–61, (2006)
39. M. Hoffmann, C. Hilton-Taylor, C, A. Angulo, M. Bohm, T.M. Brooks, S.H. Butchart, W.R. Darwall, Science, **330**, 1503–1509 (2010)
40. L. Creel, Ripple effects: population and coastal regions (Population reference bureau, Washington DC, 2003)
41. D. Ferrol-Schulte, P. Gorris, W. Baitoningsih, D.S. Adhuri, S.C.A. Ferse, Mar. Policy **52**, 163–171, (2015)
42. O.J. Luiz, T.C. Mendes, D.R. Barneche, C.G.W. Ferreira, R. Noguchi, R. Villaça, C.E.L. Ferreira, Marine and Freshwater Research, **66**, 8, 739–749 (2015)