Jurnal Teknologi Perikanan dan Kelautan Vol. 16 No. 1 February 2025: 22-32 *ISSN 2087-4871*
DOI: https://doi.org/10.24319/jtpk.16.22-32 *EISSN 2549-3841*

DOMAIN ASSESSMENT OF BALI SARDINELLA RESOURCES THROUGH ECOSYSTEM APPROACH AT ARCHIPELAGO FISHING PORT (PPN) PENGAMBENGAN

PENILAIAN DOMAIN SUMBER DAYA IKAN LEMURU MELALUI PENDEKATAN EKOSISTEM DI PELABUHAN PERIKANAN NUSANTARA (PPN) PENGAMBENGAN

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(Received February 28, 2024; Revised November 13, 2024; Accepted December 29, 2024)

ABSTRACT

Bali sardinella is a fish species that contributes greatly to the Archipelago Fishing Port (PPN) Pengambengan. The potential of Bali sardinella fishery resources is abundant and of high economic value. The purpose of this study was to assess the performance of fish resource domain status with an ecosystem approach. The research was conducted for seven months from January to July 2023. Data collection was done through observation and interviews. The data analysis used was a multi-criteria analysis approach with assessment and visualization of the composite index with a flag model. Six indicators in the fish resources (SDI) domain were studied, namely standardized CPUE trends, Bali sardinella size, proportion of juveniles caught, species composition of the catch, range collapse of fish resources, and endangered, threatened, and protected species (ETP). Indicators in the fish resources domain indicate that the trend of standardized CPUE is decreasing, the trend of Bali sardinella size is relatively fixed, the proportion of juveniles caught is 53%, the species composition of the catch is a higher proportion of target fish, the range collapse of fish resources for fishing grounds is relatively fixed depending on the target species, and for ETP species caught but released. The final result of the assessment of the status of Bali sardinella fish resources based at PPN Pengambengan received a composite score of 70, so it is in a good category.

Keywords: ecosystem approach, lemuru, PPN Pengambengan

ABSTRAK

Lemuru adalah salah satu jenis ikan yang memberikan kontribusi besar di Pelabuhan Perikanan Nusantara (PPN) Pengambengan. Potensi sumber daya perikanan lemuru melimpah dan bernilai ekonomis tinggi. Tujuan dari penelitian ini adalah untuk menilai performa status domain sumber daya ikan dengan pendekatan ekosistem. Penelitian dilaksanakan selama tujuh bulan terhitung dari bulan Januari sampai Juli 2023. Pengumpulan data dilakukan dengan observasi dan wawancara. Analisis data yang digunakan yakni pendekatan analisis multi kriteria dengan penilaian dan visualisasi indeks komposit dengan model bendera. Enam indikator pada domain sumber daya ikan (SDI) yang diteliti yakni tren CPUE baku, ukuran ikan lemuru, proporsi *juvenile* yang ditangkap, komposisi spesies hasil tangkapan, *range collapse* sumber daya ikan, dan spesies *endangered*, *threatened*, and *protected* (ETP). Indikator pada domain SDI menandakan bahwa tren CPUE baku menurun, tren ukuran ikan lemuru relatif tetap, proporsi ikan yuwana yang tertangkap 53%, komposisi spesies hasil tangkapan yakni proporsi ikan target lebih banyak, *range collapse* sumber daya ikan untuk daerah penangkapan ikan relatif tetap tergantung spesies target, dan untuk spesies ETP tertangkap namun dilepas. Hasil akhir penilaian status sumber daya ikan lemuru yang berbasis di PPN Pengambengan mendapatkan nilai komposit sebesar 70 sehingga masuk dalam kategori baik.

Kata kunci: lemuru, pendekatan ekosistem, PPN Pengambengan

INTRODUCTION

The Bali Strait waters have abundant potential for lemuru fishery resources (*Sardinella lemuru*) and have high economic value (Simbolon *et al.* 2011). From 2004 to 2014, the average lemuru fish production reached 64,961 tons. Based on data from the Jembrana Regency Government in 2015, the waters of West Bali have a sustainable potential for marine fishery resources of 56,947 tons per year. Local fishermen make lemuru fish a catch that provides a large contribution from the purse seine fishing gear.

One of the centers of Bali sardinella fisheries in the Bali Strait is in the Pengambengan area, with a fishing base at PPN Pengambengan. Based on the 2022 PPN Pengambengan annual report, the dominant fish species landed were Bali sardinella fish at 90% compared to other species. The potential for Bali sardinella fisheries in Pengambengan is an opportunity for the surrounding community as a source of livelihood. The high production of Bali sardinella fish is one of the factors that causes fishermen to catch fish continuously and pay less attention to environmental aspects. When fishing efforts reach excessive levels, resources and production will decline. Therefore, a management plan is needed to ensure the sustainability of Bali sardinella resources; this is in line with Ministerial Decree Number 68/KEPMEN-KP/2016 (Ministry of Marine Affairs and Fisheries) concerning the Bali Sardinella Fish Fisheries Management Plan in the Fisheries Management Area of the Republic of Indonesia.

The preparation of the Fisheries Management Plan (RPP) has been based on the development mission of the Ministry of Marine Affairs and Fisheries (KKP) through the principle of fisheries management through an ecosystem approach (Ecosystem Approach to Fisheries Management (EAFM)). Through the EAFM approach, it is hoped that the balance between social and economic objectives related to fisheries management can be identified based on considerations of scientific aspects and uncertainties of biotic, abiotic, and human components and their interactions in aquatic ecosystems through integrated, comprehensive, and sustainable fisheries management. EAFM has six domains, including the fish resources domain, aquatic habitat and ecosystem, fishing techniques, economic, social, and institutional (NWG EAFM 2014). Meanwhile, to realize sustainable lemuru fisheries, a comprehensive approach is needed (Putra *et al.* 2020). Based on the description above, integrated fisheries management through an ecosystem approach is very much needed. EAFM is one model that supports sustainable management through an ecosystem approach. This EAFM is designed to assess the performance of a management area through indicators in six interrelated domains in fisheries. Through this study, it is expected to provide an overview of the condition of Bali sardinella fish resources based on the status of the ecosystem approach. It is hoped that the results of this study can be the basis for determining policies that will be implemented for Bali sardinella fisheries based on PPN Pengambengan.

METHODS

The research was conducted at the Archipelago Fishing Port (PPN) Pengambengan, Jembrana, Bali (Figure 1). The research was conducted from January to July 2023. The data collection method in the fish resources domain was guided by the EAFM Module, 2014 edition (NWG EAFM 2014). Details of the data collection method can be seen in Table 1.

The tools used during the study included stationery (books, pens/pencils) and rulers/measuring boards with a total of 817 Bali sardinella fish samples. The research methods used were surveys and interviews. Interviews were conducted with 15 respondents from "slerek" boat fishermen. Measurement of catches focused on the type of Bali sardinella fish obtained from purse seine fishing gear based at PPN Pengambengan.

Data analysis

Catch per unit effort (CPUE) baku

The raw CPUE data analysis was conducted using time series trends. The formula used to calculate CPUE is based on Noija *et al.* (2014) as follows:

$$CPUE = \frac{Catch}{Effort}$$

Description:
CPUE = Catch per fishing effort (tons/trip)
Catch = All catches (ton)
Effort = All catch efforts (trip)

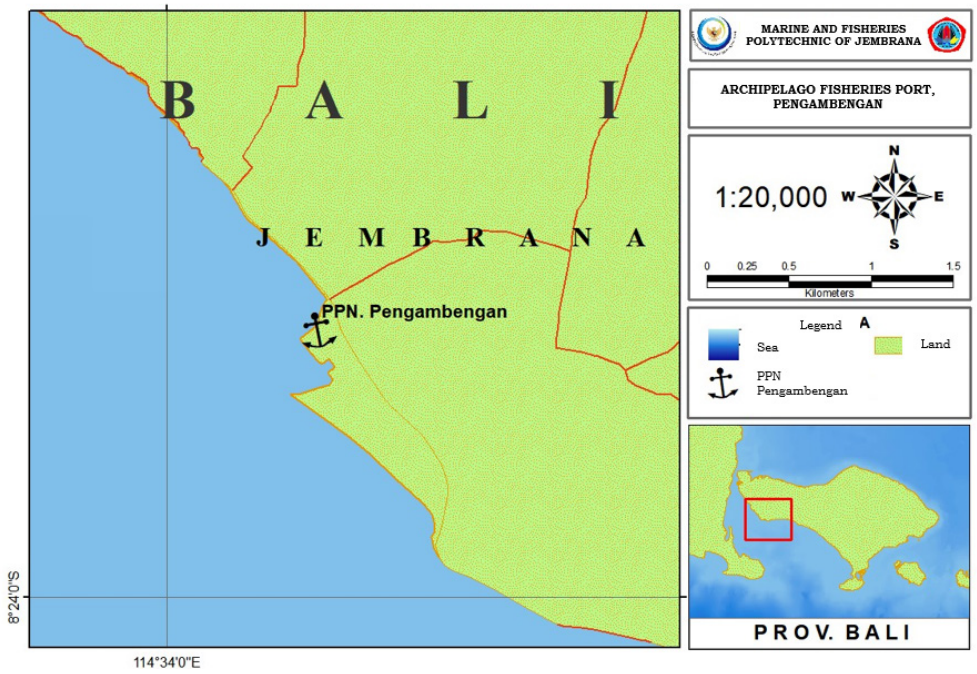

Figure 1. Map of research locations at the Archipelago Fishing Port (PPN) Pengambengan.

Table 1. Types and sources of research data at the Archipelago Fishing Port (PPN) Pengambengan.

No	Data Parameters	Data Type and Source	Description
1	Catch per unit effort (CPUE) standard	Secondary data of PPN Pengambengan	Bali sardinella production Data in 2013-2022
2	Fish size	Primary data	Direct observation
3	Proportion of juvenile fish caught	Primary data	Observation and interview to Fishermen
4	Species composition	Primary data	Observation and interview to fishermen
5	Species ETP (endangered, threatened, and protected species)	Primary data	Interview to fishermen
6	"Range collapse" fish resources	Primary data	Interview to fishermen

Fish size

The purpose of collecting data on the total length of fish in this study was to determine the length of Bali sardinella fish, which is useful as a length frequency analysis. The calculation of the distribution of length size frequency is based on Sudjana (2002), namely as follows:

$$K = 1 + 3{,}3\log(n)$$

$$C = \frac{W}{K}$$

Description:
K = Class number
C = Interval
W = Interval length
(P maximum - P minimum)
N = Data number

Proportion of juvenile fish caught

The calculation of juveniles caught is used to determine the proportion of juveniles caught on a particular fishing gear. The unit of measurement for this indicator is percent (%). Based on the NWG EAFM Module (2014), the proportion of juveniles caught can be calculated by:

$$PCy = \frac{Cyi}{Ctot} \times 100\%$$

Description:
PCy = Proportion of juveniles caught (%)
Cyi = Juveniles caught (i) in fishing gear (ton)
Ctot = All catches on fishing gear i (ton)

Species composition of the catch

The purpose of this indicator is to determine the composition of fish and non-fish species that are the target of fishing and those that are not included in the target of fishing (bycatch). The calculation of the composition of the catch species can use the following formula:

$$Ks = \frac{n_i}{N} \, x \, 100\%$$

Description:
Ks = Species composition of the catch (%)
ni = Number of individuals per species
N = Number of individuals of all fish species

Endangered, threatened, and protected species (ETP)

The purpose of this indicator is to observe the effect of catching ETP species with certain fishing gear in a water area. For ETP species indicators, direct observations of catches and interviews with fishermen in the field are carried out.

Range collapse fish resources

Information related to the range collapse indicator of fish resources is used to see the impacts that arise on fish resources due to the impact of fishing pressure. Data obtained related to determining the range collapse can be seen from the condition of the Bali sardinella fishing area, whether there are indications that fishermen are having difficulty finding fishing areas or not. The data was obtained based on interviews with fishermen.

EAFM assessment analysis

There are several stages that must be carried out in the analysis of the fish resources domain in EAFM, namely:

1. Conduct an assessment of each indicator based on a Likert scale score of 1, 2, and 3 according to the evaluation criteria for each indicator.
2. Calculating the index value using the formula

$$Cat\text{-}i = Sat\text{-}i \times Wat\text{-}i$$

Description:
Cat-i = Attribute/indicator index value i
Sat-i = Attribute/indicator score i
Wat-i = Weight of attribute/indicator i

3. Perform composite value calculations using the formula

$$NK = (Cat\text{-}i/Cat\text{-}max) \times 100$$

Description:
NK = Composite value
Cat-i = Total index value of all attributes/indicators i
Cat-max = The maximum total index value of all attributes/ indicators i

4. The resulting composite values are then visualized in the form of a flag model analysis, as shown in Table 2.

RESULTS AND DISCUSSION

Results

CPUE standard

Catch per unit effort (CPUE) is obtained by calculating catch data with a fishing effort at PPN Pengambengan for a period of 10 years, namely in 2013-2022. The calculation of CPUE Bali sardinella can be seen in Table 3. The CPUE Bali sardinella production graph at NFP Pengambengan and the graph of the relationship between Effort and CPUE Bali sardinella can be seen in Figures 2 and 3.

Table 2. Classification of composite index values and flag models.

Composite Value Range		Flag Model	Description
Low	High		
1	20		Bad at implementing EAFM
21	40		Lack of implementation of EAFM
41	60		Moderate implementing EAFM
61	80		Good at implementing EAFM
81	100		Very good at implementing EAFM

Table 3. Bali sardinella CPUE calculation for 2013-2022.

Year	Bali Sardinella Production (ton)	Effort (trip)	CPUE (ton/trip)
2013	5,720	19,413	0.29
2014	14,146	6,301	2.25
2015	16,038	2,956	5.43
2016	7,150	3,142	2.28
2017	77	2,241	0.03
2018	1,154	6,356	0.18
2019	16,003	7,489	2.14
2020	18,101	7,316	2.47
2021	13,748	7,202	1.91
2022	11,010	8,241	1.34
Total	103,146	70,657	18.31
Average	10,315	7,066	1.83

Source: PPN Pengambengan (2023)

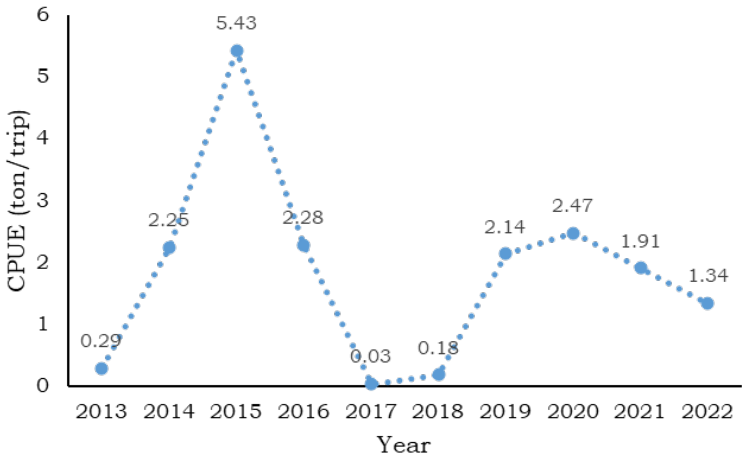

Figure 2. CPUE of Bali sardinella in PPN Pengambengan.

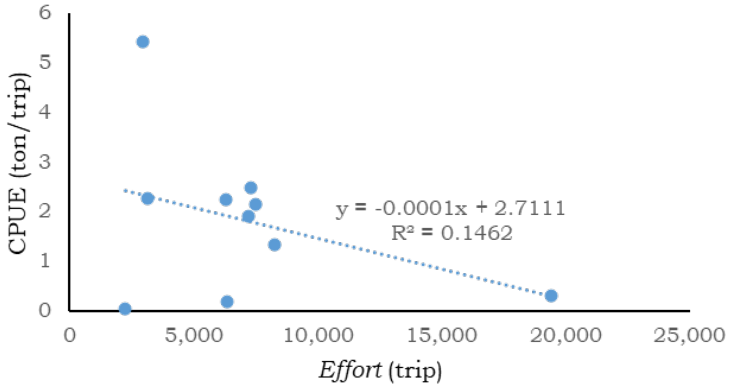

Figure 3. Relationship between effort and CPUE of Bali sardinella in PPN Pengambengan 2013–2022.

In Figure 2, it can be seen that the Bali sardinella CPUE trend from 2013 to 2022 fluctuated. In 2017, there was a sharp decline in production of 2.25 tons/trip from 2016, it increased from 2018 to 2020, and it was a decline after 2020. After seeing the results of the CPUE trend from 2013 to 2022, the assessment of the indicator on the standard CPUE is a score of 2; the standard CPUE trend has decreased slightly (average decrease <25% per year).

Trend of fish size

The total measurement results of the Bali sardinella samples landed at PPN Pengambengan were 817. Samples were collected for seven months, from January to July 2023. The Bali sardinella fish were caught at PPN Pengambengan using purse seine fishing gear with two boats, or what fishermen usually call "slerek" boats. The size of the Bali sardinella from the research results is presented in Table 4, and the documentation of the Bali sardinella can be seen in Figure 4.

Proportion of juvenile fish caught

Juvenile fish are the size of fish that have not yet entered the adult group. In this study, the results obtained for female Bali sardinella are gonad mature at a size of 157 mm TL, while male fish are 149 mm TL. Referring to Fishbase (2023), the size of gonad maturity for Bali sardinella is 143 mm SL or ranges from 140-150 mm SL. Previous research by Wujdi *et al.* (2013) stated that the size of female fish is gonad mature for the first time with a fork length of 189 mm and male fish at a fork length of 177.8 mm. The results obtained were that 84% of the fish were gonad mature and 16% were in the immature/juvenile category (Figure 5).

Reviewing the catch results, it can be seen that the percentage of fish caught before maturity is <30%; however, when viewed from the comparison of mature gonad sizes based on Fishbase (2023), 53% of Bali sardinella are not yet mature gonads, and 47% are mature gonads (Figure 6).

Table 4. Size of Bali sardinella from research at PPN Pengambengan.

Months	Total Length Average (mm)
Januari	155
Februari	131
Maret	185
April	141
Mei	182
Juni	185
Juli	161

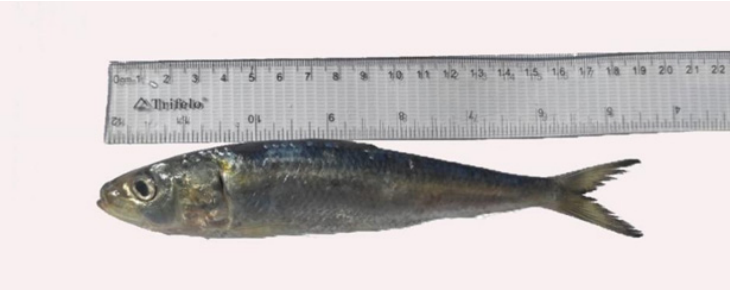

Figure 4. Documentation of the Bali sardinella (*Sardinella lemuru*).

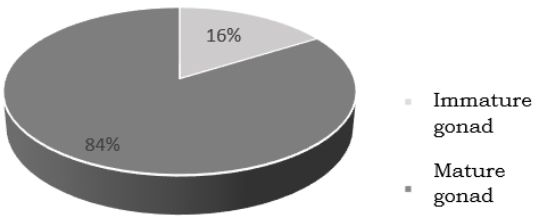

Figure 5. Percentage of mature gonad fish size from research results.

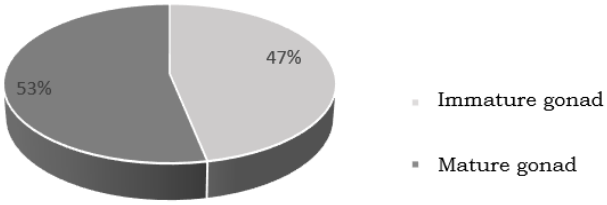

Figure 6. Percentage of mature gonad fish size based on comparison on the fishbase website.

Based on Figure 6, it can be seen that the percentage of fish size that is not yet mature gonads is more than that which is mature gonads. For this indicator, the results obtained were 53% of Bali sardinella that were not yet mature gonads, so they were given a score of 2, with a range of juveniles caught between 30-60%.

Species composition of the catch

The results of observations and interviews with fishermen obtained information that the catch of Bali sardinella (*S. lemuru*) was greater than the bycatch. The types of fish caught as bycatch at PPN Pengambengan include mackerel, fringescale sardinella, tuna, largehead hairtail, and others. Lemuru fish are caught using purse seine fishing gear. This is supported by the acquisition of production data at PPN Pengambengan, which shows that the catch of target species of Bali sardinella for 10 years from 2013 to 2022 was 72%, and for non-target species was 28%. The assessment of the indicator on the composition of the catch species obtained a score of 3 because the proportion of target fish obtained was greater. The composition of the catch species can be seen in Figure 7.

Range collapse of fish resources

The fish resources range collapse indicator is a phenomenon that occurs when fish stocks experience overfishing. The purpose of observing this indicator is to see the impacts caused to fish resources due to increased fishing pressure.

Fishermen of Pengambengan catch Bali sardinella in the area around Pekutatan, Tanah Lot, and Jimbaran, approximately 100 km from PPN Pengambengan. Through various answers from respondents in the interview, it was shown that the location of Bali sardinella fishing is relatively constant (score 2); because the Bali sardinella fishing area from year to year tends to be in the same area, there is no significant change.

Species ETP (endangered, threatened, and protected species)

Based on the results of interviews with fishermen from "slerek" boats, 67% reported that they had found ETP species caught, namely dolphins and turtles. However, the fishermen immediately released the species. Fishermen are quite aware of and understand the regulations related to the prohibition of catching fish species as stated in Government Regulation Number 7 of 1999 concerning the Preservation of Plant and Animal Species. As many as 33% stated that they had never found ETP species caught while at sea. The percentage of interview results on the ETP species indicator can be seen in Figure 8.

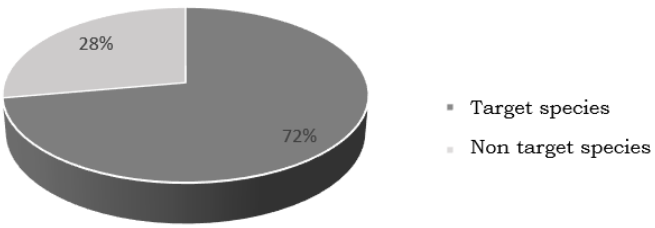

Figure 7. Composition of species caught at PPN Pengambengan.

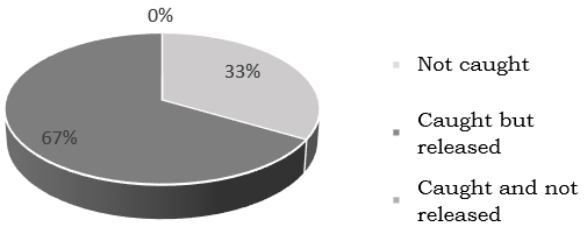

Figure 8. Percentage of results on ETP species indicators.

Bali sardinella fish were included in the IUCN Red List in 2017, listed in the category of near-threatened species. This category has begun to enter a worrying stage and does not rule out the possibility of extinction because many fishermen are overfishing, which could potentially lead to overfishing. The catch at PPN Pengambengan shows that there are ETP species that are caught but released, so the score for this indicator is 2.

The results of the EAFM assessment in the fish resources domain obtained an average score of 2.2 and a composite value of 70, as can be seen in Table 5.

Discussion

The trend of the CPUE value of Bali sardinella is assumed to decrease by 14.62% per year. However, this decrease is not followed by significant changes in fishing areas. The decrease in the trend is thought to be due to changes in climate and weather, such as rain and high waves. Other factors causing the decrease in CPUE are possibly due to differences in fishing seasons and continued fishing pressure, which can cause fish stocks to decline (Puansalaing *et al.* 2021). The existence of fishing pressure can be seen from the large number of fishing vessels based on data from PPN Pengambengan 2022, which is 388 vessels. This can affect fish stocks in Pengambengan.

The average size of Bali sardinella caught from January to July is 131-185 mm. There are several comparisons of the average length of fish obtained from previous researchers, which can be seen in Table 6.

Compared with several previous studies, as in Table 6, the size trend of Bali sardinella caught is still relatively constant (score 2). This is reviewed from the month of capture; the average fish caught in January to April was the small size group (11-15 cm), and in May to July, the fish size group (>15-18 cm) and fish cat-size (>18 cm). These size groups are based on the criteria of Merta *et al.* (1992).

The total length measurement of Bali sardinella caught at PPN Pengambengan varies. Based on a comparison via the Fishbase website (2023), 53% of Bali sardinella caught were categorized as immature gonads/not yet suitable for fishing. The factor causing the high percentage of juvenile fish is the use of fishing gear. Based on research by Mainnah *et al.* (2023), the size of the purse seine operated by fishermen at PPN Pengambengan is a mesh size of 0.75 inches. This is not in accordance with the calculation of the suitable size for catching Bali sardinella, because at least the mesh size used is 1.5 inches. The dominance of juvenile fish catches in the long term can affect fish populations. In addition, the high percentage of juvenile fish can be indicated as approaching overfishing conditions. This is in line with the statement of Sparre and Venema (1999) that if there are too few mature fish, the stock has experienced overfishing, and fishing pressure should be reduced.

The assessment of the species composition indicator of the catch obtained results of 72% more target fish than non-target fish. This is in line with research by Dewi and Husni (2018), which showed that the dominant type of fish caught by purse seine vessels is small pelagic fish, one of which is Bali sardinella. Based on previous research by Bubun and Mahmud (2015), the results showed that purse seine fishing gear is included in the category of environmentally friendly tools. The level of friendliness of this purse seine can be reviewed from several criteria, namely fishing gear that does not damage the habitat and habitat of biota, the use of fishing gear that can cause the death of several species but does not damage the habitat, and produces dead and fresh fish.
The assessment of the range collapse indicator of fish resources is useful for

determining the potential for overfishing in nearby waters. Fishermen who landed fish at PPN Pengambengan stated that the results showed that the location of Bali sardinella fishing in recent years tended to be relatively fixed. This is similar to the results of research by Suariningsih *et al.* (2021) at PPI Kedonganan, which stated that the fishing area was relatively fixed at 57%. Based on the results of interviews with fishermen around Pengambengan, in terms of finding fishing locations (fishing grounds), it is influenced by several factors, namely the fishing season and weather (wind, rain). Changes in fishing locations are influenced by the main factor of the nature of Bali sardinella, which like to migrate because the distribution of Bali sardinella is closely related to the fishing ground area (Hendiari *et al.* 2020).

Endangered, treated, and protected (ETP) species are protected species and are included in the IUCN Red List category. The reason for the capture of ETP species (dolphins and turtles) by Pengambengan fishermen because the species were accidentally caught or entangled in purse seine nets. Pengambengan fishermen always try to release the captured ETP species. The ETP species that have been caught are dolphins and turtles. This is because the waters of the Bali Strait are a turtle nesting location and a conservation area for these turtle species. In addition, the dolphin species is assumed to be migrating in Indonesian waters. Bali sardinella is included in the near-threatened category on the IUCN Red List. This is reinforced by the statement of Suariningsih et al. (2021) that the status of the Bali sardinella is endangered but is not included in the list of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Table 5. Composite analysis of fish resource domains.

Fish Resources	**1***	**2***	**3***	**4***	**5***	**6***	**Total**
Results	Average down <25% per year	Relatively fixed	53% immature	More target proportion	Relatively fixed	ETP species were caught but released	
Score	2	2	2	3	2	2	2,2
Weight	40	20	15	10	10	5	100
Value	80	40	30	30	20	10	210
Composite value	27	13	10	10	7	3	70

Description: *1) CPUE standard, 2) Tren of fish size, 3) Proportion of juveniles captured, 4) Species composition of the catch, 5) Range collapse of resources, 6) Species ETP.

Table 6. Comparison of the average length of Bali sardinella from previous studies.

No.	**Fish length average (mm)**	**Location**	**Data Collecting**	**Sources**
1	125 TL	PPN Pengambengan, Bali	July 2011	Himelda *et al.* (2011)
2	145 FL	Bali Strait waters (Muncar, Banyuwangi)	August 2010-December 2011	Wujdi *et al.* (2013)
3	137 TL	Bali Strait (Jimbaran waters)	2018	Pertami *et al.* (2019)
4	150-160,7 FL	PPN Pengambengan, Bali	October-December 2019	Annisa *et al.* (2021)
5	130 TL	Jimbaran waters, Kedonganan, Kuta, Ungasan	January-March 2021	Suariningsih *et al.* (2021)
6	149-164 FL	PPN Pengambengan	July-December 2021	Mainnah *et al.* (2023)
7	182-196 TL	PPN Pengambengan, Bali	April-July 2022	Aprianti *et al.* (2022)
8	155 TL	PPN Pengambengan, Bali	January-July 2023	This study

CONCLUSION

The performance of Bali sardinella fisheries through the fish resources domain received a composite value of 70, with a light green flag model, which means that Bali sardinella fisheries management is in the good category in implementing EAFM.

ACKNOWLEDGEMENT

We would like to express our gratitude to the academic community of Jembrana Marine and Fisheries Polytechnic, PPN Pengambengan, and Pengambengan fishermen who have provided facilities and assisted in this research.

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