



RESEARCH ARTICLE

WATER QUALITY AND TROPHIC STATUS IN WIDAS RESERVOIR, EAST JAVA, INDONESIA

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ARTICLE DETAILS

Article History:

Received 23 August 2024
Revised 18 September 2024
Accepted 18 October 2024
Available online 21 October 2024

ABSTRACT

Widas Reservoir is a multifunctional resource with potential for fisheries, but its water quality can be significantly affected by various activities. This research aims to determine the status of trophic levels and water quality, which is crucial for water resource management and conservation. The study involved a comprehensive field survey with sampling at various points, considering the inlets, outlets, and conservation zones. The research found that the average water depth was 10.9 meters, transparency was 511 centimeters, CO₂ concentration ranged from 0.0 to 17.6 mg/L, DO ranged from 0.1 to 8.2 mg/L, and temperature ranged from 25 to 31.1°C. In addition, temperature and DO decrease with depth, in contrast to CO₂, which tends to increase with depth. The average conductivity was 150.3 µmhos/cm, total alkalinity was 103.1 mg/L, turbidity was 63 NTU, pH ranged from 6 to 8, and phosphate (PO₄) concentration averaged 28.74 µg/L. TP average was 33.39 µg/L, and Chlorophyll-a averaged 21.75 µg/L. The Trophic Status Index (TSI) showed a high fertility (eutrophic) level with an average index value of 63.8. The potential for fish production was high at 626.6 kg/ha/year.

KEYWORDS

Trophic Status Index, Water Quality, Widas Reservoir.

1. INTRODUCTION

Widas Reservoir covers an area of 500 ha in East Java, Indonesia and it has multipurpose for agriculture, fisheries, hydropower, recreation, flood control, and others. Fishery activities in the reservoir include aquaculture in floating net cages and fishing activities. The water quality in reservoirs is influenced by anthropogenic activities in the reservoir and the surrounding environment (Ummenhofer and Meehl, 2017; Aida et al., 2022). Widas Reservoir is essential for supporting the fish stock and can contribute to the local community's economy. The average catch is about 283 tons/year, consisting of the following fish species: *Cyprinus carpio*, *Barbonymus gonionotus*, *Oreochromis niloticus*, *Pangasianodon hypophthalmus*, *Notopterus notopterus*, *Osteochilus vittatus*, and *Rasbora* spp. Concerning fish sustainability, the water quality in the Widas Reservoir needs to be further controlled (Aida et al., 2022).

Several activities that affect water quality in reservoirs include residential activities, recreation, land use in water catchment areas, floating net cages, aquaculture, and sedimentation. Household waste from residential areas and floating net cages for fish culture entering reservoir waters can deteriorate water quality and induce eutrophication. Sediment supply entering the reservoir can cause siltation and increase water turbidity (Cunha et al., 2021; Schleiss et al., 2016; Aida et al., 2023). Monitoring water quality is vital for future management because current conditions and emerging problems can be detected early, and water benefits can be protected. Fish and their habitats are very dependent on the conditions of the aquatic environment (Stela et al., 2010; Rocha et al., 2015).

Water physicochemical parameters, such as pH, temperature, turbidity, dissolved oxygen, total phosphorus, and phosphate, are commonly used to determine water quality (Xiao et al., 2016; Huang et al., 2015). Assessing the status of water conditions aims to overcome several environmental problems, such as water pollution, habitat degradation, and ecological changes (Prabhakaran et al., 2017; Aida et al., 2022; Umi Wahidah et al., 2020). On the other hand, organic material pollution can cause eutrophication (EPA 2000 in Tas, 2012; Ayoade et al., 2019). The level of eutrophication can be assessed through physical, chemical, and biological examination of water (Carlson, 1977; Sivaranjani et al., 2015). This research aims to assess water quality criteria, trophic state index (TSI), and the production potential of Widas Reservoir to manage its fish resources sustainably. The information obtained guides strategies to control eutrophication and sustainable fishery resources.

2. MATERIALS AND METHODS

2.1 Study Site And Sampling Time

This research was conducted in Widas Reservoir, Madiun Regency, East Java Province, Indonesia (Figure 1) from March, May and September 2021. Sampling was carried out at locations that represent habitat types: Observation stations are "Centre" (Station 1), representing the habitat in the middle of the reservoir; "Conservation area" (Station 2), representing the conservation habitat, "Muara Petung" (Station 3) and "Muara" (Station 4) are the inlet habitat, "Pintu Air" (Station 5) representing the outlet habitat and "Kali Bening" (Station 6) representing the inlet habitat.

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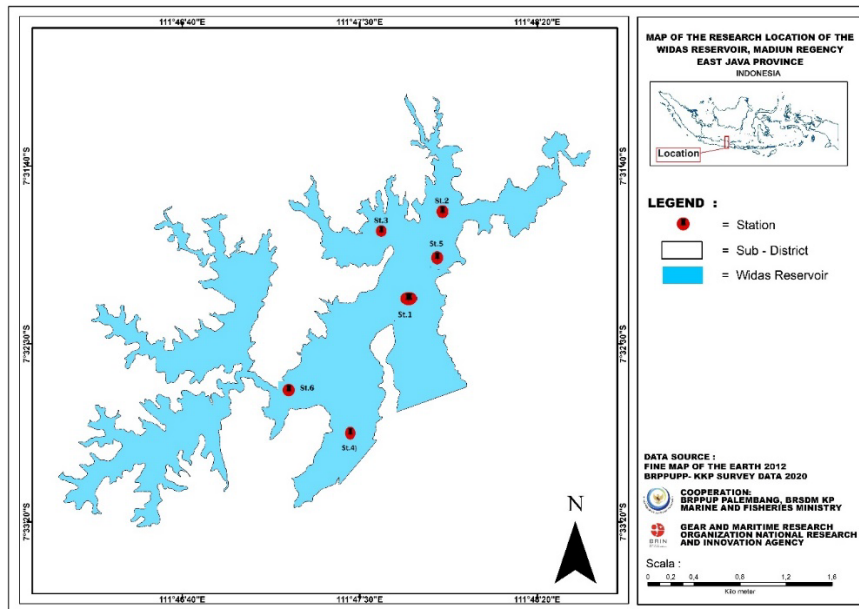


Figure 1: Study Site And Sampling Stations

2.2 Water Quality Parameters and Analysis

Water quality parameters measured in situ include transparency (cm), carbon dioxide (CO₂), dissolved oxygen/DO (mg/L), temperature (°C), conductivity (µS/cm), total alkalinity (mg/L), turbidity (NTU), and pH. The parameters analyzed in the laboratory are orthophosphate (mg/L), total phosphate (mg/L), and chlorophyll-a (mg/m³) (Table 1).

Water transparency is an indicator of the status of water fertility levels. The transparency value depends on the weather conditions, measurement time, watercolor, turbidity, and suspended solids in the water (Effendi, 2003). On the other hand, the determination of the trophic state of the waters is based on physical (transparency measured by Secchi disk depth), chemical (total phosphorous), and biological conditions (chlorophyll-a).

Water quality parameters were analyzed using a descriptive method using tables and graphs based on sampling locations and water depths, so that differences in water quality can be identified based on location and depth.

Table 1: Parameters and methods of water sample analysis adapted from APHA (2012)

Parameters	Unit	Methods	Process
Depth	Meter	Depth Sounder	<i>In situ</i>
Transparency	Cm	Secchi Disk	<i>In situ</i>
Carbon Dioxide (CO ₂)	mg/L	Titrimetric	<i>In situ</i>
Dissolved Oxygen (DO)	mg/L	DO Meter	<i>In situ</i>
Temperature	°C	Termometer	<i>In situ</i>
Electric conductivity (EC)	µS/ cm	SCT meter	<i>In situ</i>
pH	-	pH indicator	<i>In situ</i>
Ortophosphate (PO ₄ ⁻³)	µg/L	Spectrophotometric	ammonium molybdate
Total phosphorus	µg/L	Spectrophotometric	Ascorbic Acid
Chlorophyll-a	µg/L	Spectrophotometric	Colourimetry

2.3 Trophogenic Layer

Trophogenic layer estimation uses transparency parameters, and the brightness value seen on the Secchi disk instrument means that only 10 % of sunlight enters the water. Meanwhile, phytoplankton can still assimilate at the level of 1% of sunlight entering the waters, so the estimation of the depth of the photic layer based on (Williams and Mann, 2024) is as follows:

$$S_n = (P_s + 0.495)/0.117 \quad (1)$$

where:

S_n = Depth of photic layer (cm)

P_s = Brightness value on the Secchi Disk tool (cm)

2.4 Trophic Status Analysis

The trophic state of the waters was analyzed by calculating the value of the trophic state index (TSI) formulated by (Carlson, 1977):

$$TSI (SD) = 60 - 14.41 \ln (SD) \quad (2)$$

$$TSI (Chl - a) = 30.6 + 9.81 \ln (Chl - a) \quad (3)$$

$$TSI (TP) = 4.15 + 14.42 \ln (TP) \quad (4)$$

$$TSI_{average} = (TSI (SD) + TSI (Chl - a) + TSI (TP))/3 \quad (5)$$

where:

TSI = the trophic state index

SD = transparency (m)

$Chl - a$ = chlorophyll-a (µg/liter).

TP = Total phosphorus (µg/liter).

Based on the TSI value, the trophic state of lake/reservoir waters is classified into four levels: Oligotrophic (low eutrophication), mesotrophic (moderate eutrophication), eutrophic (high eutrophication), and hypereutrophic (very high eutrophication) (Table 2).

Table 2: Trophic State Categories based on TSI

TSI	SD (m)	TP (µg/L)	Chl-a (µg/L)	Status
< 30 - 40	>8 - 4	6 - 12	0.94 - 2.6	Oligotrophic
40 - 50	4 - 2	12 - 24	2.6 - 6.4	Mesotrophic
50 - 70	2 - 0.5	24 - 96	6.4 - 56	Eutrophic
70 - 100	0.5 - 0.062	96 - 768	56 - 1.183	Hyper-eutrophic

2.5 Fish Production Potential

Fish production potential is the ability of a water body to produce fish. The estimation of fish production potential is estimated using the chlorophyll-a content parameter in the waters, using the formula from Almazan and Boyd in Boyd (1990):

$$Y = 1.43 + 24.48X_c - 0.15X_c^2 \quad (6)$$

Where:

Y = Potential fish production (kg/ha/year)

X_c = Chlorophyll-a (mg/m³)

3. RESULTS

3.1 Water Quality

Based on the results of water depth measurements with a depth sounder, the water depth of the Widas Reservoir ranges from 2 to 23 m, with an average of 10.72 m. The most profound depth is at the station around the

outlet and the shallowest part is at the inlet. Based on water transparency measurements using a Secchi disk, the transparency of the Widas Reservoir water ranges from 0.49 m to 0.57 m with an average of 0.511 m (Figure 2; Table 3). The transparency value of the Widas Reservoir is low, with an average of only 0.511 m, explicitly indicating eutrophic water condition.

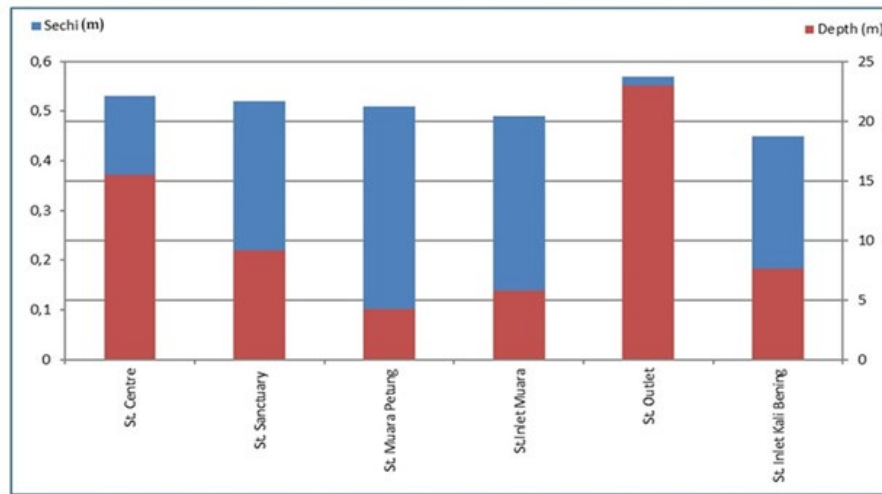


Figure 2: Transparency and Depth in Widas Reservoir

Location	Transparency (m)	Depth (m)	Photic (m)	Aphotic (m)
	A	B	C	D
Station 1 (Centre)	0.53	15.5	8.76068	6.7393
Station 2 (Conservation area)	0.52	9.2	8.67521	0.5248
Station 3 (Inlet Muara Petung)	0.51	4.3	8.58974	None. All Photic
Station 4 (Inlet Muara)	0.49	5.8	8.41880	None. All Photic
Station 5 (Outlet)	0.57	23	9.10256	13.8974
Station 6 (Inlet Kali Bening)	0.45	7.6	8.07692	None. All Photic
Average	0.511	10.9	8.60	3.5

$$\text{Photic (C)} = (A + 0.495) / 0.117$$

$$\text{Aphotic (D)} = B - C$$

Figure 3 shows the pattern of CO₂ and DO concentrations in the waters of the Widas Reservoir. The concentration of free CO₂ ranged from 0.0 to 17.6 mg/L. The range of free CO₂ at the surface (0 m) was between 0.0-0.79 mg/L, and at a depth of 3 m to near the bottom of the water ranged from 6.16 to 17.6 mg/L. Free CO₂ at Central Station (Station 1) ranged from 0.74 - 6.16 mg/L, at Widas Sanctuary (Station 2) ranged from 0.44-7.04 mg/L, at Stations 3 and 4 in the Inlet Muara Petung ranged from 0.74-6.16 mg/L, at the Outlet and Inlet Kali Bening (stations 5 and 6) ranged from 0.53-8.8 mg/L.

On the other hand, the range value (DO) at the surface (0 m) was between 5.1-8.2 mg/L on average 6.79 mg/L. at the 1 m depth, it ranged from 3.6-7 mg/L, on average 5.87 mg/L; at 3 m depth, it ranged from 3.12-6.8 mg/L, on average 5.0 mg/L; at the 5 m depth, it ranged from 0.2-6.0 mg/L on average 2.67 mg/L, and at the bottom waters it ranged from 0.1-1.5 mg/L on average 0.47 mg/L.

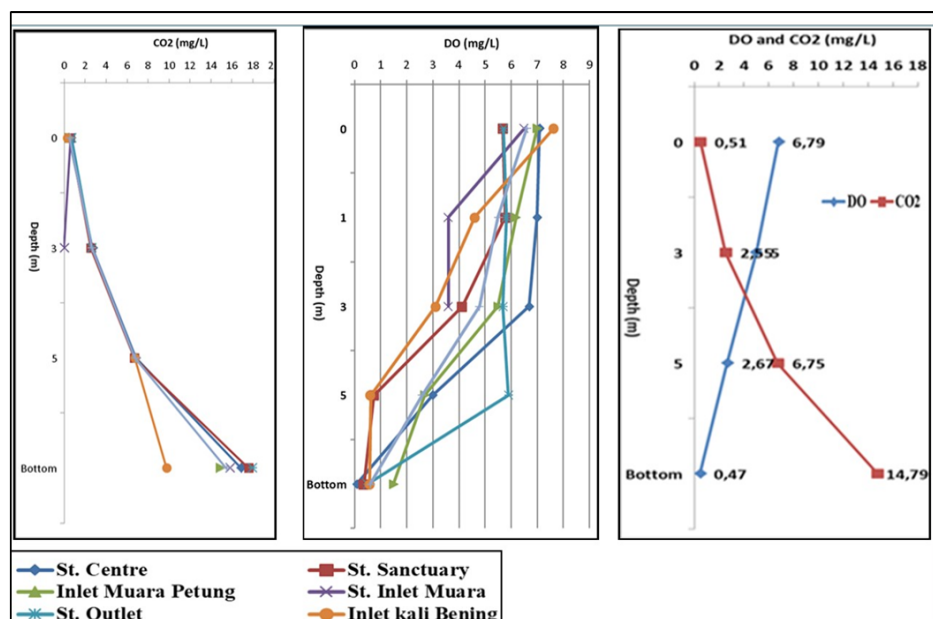


Figure 3: CO₂ and DO in Widas Reservoir

The water temperature of Widas Reservoir ranged from 25 - 31.1°C. The temperature range at the surface (0 m) was between 28.1 - 31.1°C, on average 29.83°C and at the 1m depth ranged from 27.9 - 30.8°C, on average 29.74°C; at the 3 m depth between 27-30.6°C, on average 28.63°C; at the 5 m depth, it ranged from 25-30.0°C, on average 27.51°C, at the bottom waters, it ranged from 25-29°C on average 26.99°C (Figure 4). The temperature in the waters of Widas Reservoir decreased with an increasing depth of about 2.1 °C in March, 3.2 °C in May, and 3.45 °C in September.

Figure 5 shows the electric conductivity (EC) measurements results in

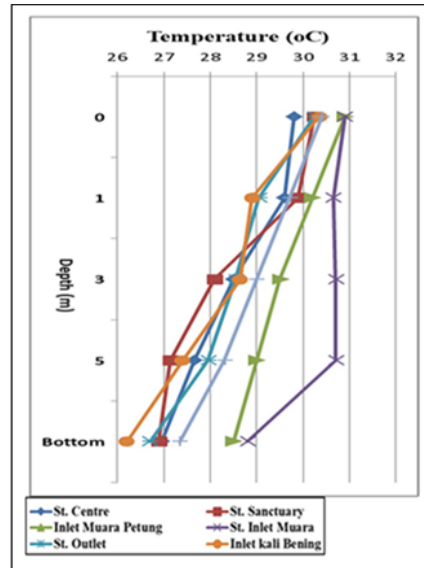


Figure 4: Temperature in Widas Reservoir

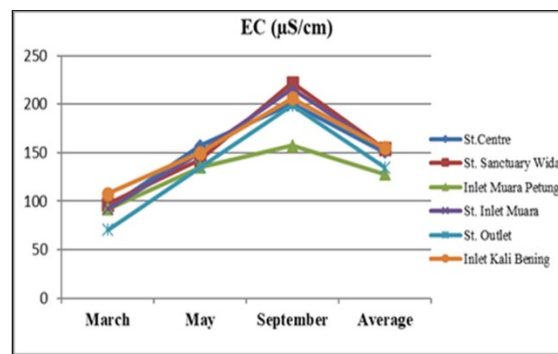


Figure 5: Electrical conductivity in Widas Reservoir

Table 4: Water Quality Parameters in Widas Reservoir

Station	PO ₄ (µg/L)		TP (µg/L)		Chl-a (µg/L)		pH	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Station 1 (Centre)	14.27	53.36	26.1	132.3	29.80	8.82	7.83	7
Station 2 (Conservation area)	6.59	18.03	29.98	38.81	19.49	2.39	7.50	6.8
Station 3 (Inlet Muara Petung)	5.25	10.38	35.67	59.86	59.93	16.34	7.33	6
Station 4 (Inlet Muara)	13.85	62.44	35.29	150.27	23.36	9.52	7.50	6.5
Station 5 (Outlet)	23.35	62.96	38.46	66.33	36.61	10.20	8.00	6.5
Station 6 (Inlet Kali Bening)	12.72	57.48	34.84	68.54	32.26	12.31	7.50	6.5
Average	12.67	44.1	33.84	86.01	33.57	9.93	7.61	6.55

3.2 Trophogenic Layer

The transparency value of each sampling location did not differ much between 0.45 m and 0.57 m. However, the depth of each sampling location varied from 4.3 m to 23 m. The shallowest depth was at the inlet of Muara Petung (Station 3). The deepest one was at the outlet (Station 5). The photic and aphotic layers differed at each location (Table 3). The photic layer reaches the bottom of the waters. There is no aphotic layer, namely Station 3 (Muara Petung), Station 4 (Muara Inlet), and Station 6 (Kali Bening). At the same time, Station 5 (outlet) is the location that has the thickest aphotic layer (13.89 m); in the aphotic layer, sunlight cannot enter, and it is dark).

Widas Reservoir waters ranging from 61-266.7 µS/cm with an average of 150.3 µS/cm. In March, it ranged from 70.5-108 µS/cm; in May, it ranged from 135-157.1 µS/cm; in September, it ranged from 157-221.1 µS/cm.

The consistent pH distribution was almost the same in the vertical water column. The pH value at the bottom of the water ranged from 6-6.8. The pH value in surface waters ranged from 7.3-8. (Table 4). Fluctuations in the pH of the Widas Reservoir waters between observation times and sampling points at various depths did not change too much. Furthermore, the pH of the water tended to be low or acidic as the depth increased.

3.3 Trophic status in Widas Reservoir

The nutrient concentrations determined for Widas Reservoir are presented in Table 4. The PO₄³⁻ concentration varied from 5.25–62.96 µg/L and averaged 28.39 µg/L (mesotrophic). The minor average at the surface was 5.25 (µg/L) at Station 1 (Muara Petung), and the highest at the bottom was 62.96 (µg/L) at Station 5 (Outlet). The phosphate content at the bottom of the water was higher than on the surface. The concentration of total phosphor (TP) on the surface ranged from 26.1–38.46 µg/L with an average of 33.84 µg/L and at the bottom of the waters ranged from 38.81–150.27 µg/L with an average of 86.02 µg/L (eutrophic). The total phosphor (TP) content at the bottom of the water was higher than on the surface

(Table 4). The total chlorophyll-a content in the surface ranged from 19.49 to 59.93 µg/L with an average value of 33.57µg/L (eutrophic) (Table 4). The Chlorophyll-a content in the surface layer was higher than at the bottom of the water.

The Trophic State Index (Table 5) value from the measurement of Secchi

disk, Chlorophyll-a concentration, and total phosphorus (TP) of Widas Reservoir is 60.2-67.4. The average TSI value of 63.76 indicates that the status index of water is eutrophic. TSI in Widas Reservoir is as follows: Station 1 (Center) = 63; St.5 (Outlet) = 63.2; Station 2 (Conservation) = 60.2; Station 3 (Inlet Muara) = 61.6; Station 4 (Inlet Muara) = 67.2; and Station 6 (Kali Bening) = 67.4.

Table 5: Trophic State Index of Widas Reservoir							
Research Location	SD (m)	TP (µg/l)	Chl-a (µg/l)	TSI -TP	TSI-SD	TSI-Chl.	TSI Average
St.1 (Centre)	0.53	79.2	29.8	57.52	69.18	62.79	63.17
St. 2 (Conservation area)	0.52	34.39	19.49	51.61	69.55	59.34	60.17
St. 3 (Inlet Muara Petung)	0.51	47.76	59.93	63.77	69.74	60.09	67.20
St. 4 (Inlet Muara)	0.49	92.78	23.36	54.76	70.36	59.65	61.57
St.5 (Outlet)	0.57	52.38	36.61	55.06	68.11	65.86	63.00
St.6 (Inlet Kali Bening)	0.45	51.69	32.26	66.78	71.47	64.02	67.42
Average	0.51	59.70	33.58	58.25	69.74	61.96	63.76

3.4 Fish Production Potential

Fish production potential is calculated based on the chlorophyll content in the waters. The higher the chlorophyll content, the higher the potential value of fish production. The potential value of fisheries production in Widas Reservoir is relatively high, ranging from 421.56 to 929.7 kg/ha/year, with an average value of 628.6 kg/ha/year. The highest is Station 3 (Muara Petung), and the lowest is Station 2 (conservation area) (Table 6).

Table 6: Fish production potential in Widas Reservoir.		
Research Location	Xc (µg/l)	Y (kg/ha/year)
St.1 (Centre)	29.8	597.73
St.2 (Conservation area)	19.49	421.57
St.3 (Inlet Muara Petung)	59.93	929.78
St. 4 (Inlet Muara)	23.36	491.43
St.5 (Outlet)	36.61	696.60
St.6 (Inlet Kali Bening)	32.26	635.05
Average	33.575	628.69

4. DISCUSSION

4.1 Water Quality Status and Trophogenic Layer in Widas Reservoir

Based on its depth and breadth, Widas Reservoir has excellent potential for fishing (Aida et al., 2023). The reservoir has a wide littoral area, and water level fluctuations are large, so the littoral area has natural food sources such as benthos and water insects. Therefore, environmental management of reservoir waters is critical (Noori et al., 2018; Woldeab et al., 2023). Water transparency is an indicator of water fertility status. The water transparency ranged from 0.45 to 0.57 m, on average 51 cm (Table 3). Low transparency is included in the category of eutrophic waters.

Transparency highly depends on turbidity and suspended solids in the water (Effendi, 2003). Waters with high sedimentation tend to have low transparency. For example, the Gadjah Mungkur Reservoir has a transparency range of 7-54 cm (Utomo, 2013). Reservoir waters generally have low transparency below 100 cm. For example, Rawa Pening has a water transparency value range of 60-80 cm (Aida and Utomo, 2016), and Bukit Merah Reservoir, Malaysia has a transparency value range of 18 - 87 cm (Zakeyuddin et al., 2016).

Transparency is a physical parameter closely related to photosynthesis in an aquatic ecosystem. High transparency indicates the penetrating power of sunlight far into the water, the part of the light transmitted into the water and expressed in (%), the possibility of assimilation processes in water (Brezonik et al., 2019). Clearwater is suitable for aquatic life, including fish. Therefore, the transparency value of Widas Reservoir is still suitable for fish life.

CO₂ concentration in waters depends on various factors, including assimilation, decomposition processes, and respiration of plants, animals, and aerobic and anaerobic bacteria (Aida & Utomo, 2016; Wetzel, 2001) due to the processes of respiration and photosynthesis. The content of CO₂ and DO in the water will generally be inversely proportional during the day in the surface layer of reservoir waters. CO₂ is very low and can reach 0.0

mg/L, while DO is high. Conversely, at night and deeper in the water, The CO₂ levels are relatively higher. The oxygen content will decrease more in the bottom layer of the water because sunlight decreases in the bottom layer, so the photosynthesis process will also decrease, and oxygen production will also decrease.

On the other hand, the carbon dioxide content on the water's surface is smaller than in the bottom layer (Figure 3) because carbon dioxide on the water's surface is widely used in photosynthesis. At the bottom of the water, the photosynthesis is minimal. Much organic material decomposes at the bottom of the water, producing carbon dioxide.

Oxygen concentration will be higher during the day and at the surface. Likewise, according to the results of other studies, the deeper the water, the lower the oxygen concentration, such as in Pondok Reservoir, ranging between 6.72-9.52 mg/L (Aida and Utomo, 2016). In Gadjah Mungkur Reservoir, it ranges from 7.9-3.74 mg/L (Utomo, 2013); in Angereb Reservoir, Ethiopia, it ranges from 5.1-6.18 mg/L (Gobeze et al., 2023). CO₂ and DO are directly related to the life of aquatic biota, even becoming a limiting factor. Water DO values close to 0.0 mg/L and high CO₂ at the bottom of the water can cause fish death. The carbon dioxide and oxygen content in the photic layer in Widas Reservoir is still suitable for fish life.

Figure 4 shows a decrease in temperature with increasing depth because the heat energy received by deeper waters is getting smaller. The decrease in water temperature based on water depth has not shown apparent symptoms of stratification. However, it is necessary to be aware if there is prolonged heavy rain so that the surface temperature is lower than the bottom of the water. At low temperatures, the water will have a higher specific gravity so that the surface water will fall to the bottom, and the water at the bottom will rise. The vertical water mass transfer is well-known as upwelling.

Widas Reservoir water temperature is still good enough to support fish life. Temperature measurements down to the bottom layer of water at a depth of 15 meters, despite a decrease in temperature, are still typical for fish life. The temperature value is still in the optimum temperature range for the growth of biota in the waters, which is between 20 to 30°C and is a typical freshwater surface temperature in the tropics. Temperature can affect organisms' metabolic activity, so organisms' distribution in the water relies on the temperature of the water (WHO, 2017).

Conductivity is the ability of water to transmit electric current—the more the dissolved salts, minerals, and ions, the greater the conductivity value. Natural waters generally have a conductivity content ranging from 20 to 1500 µS/cm. Sea water usually has higher conductivity because it has a higher salt content. The conductivity value of Widas Reservoir ranges between 75 to 250 µS/cm (Figure 5). The highest is observed in the dry season (September) when the lower water volume occurs, so the dissolved minerals and ions are more concentrated. The EC value in Widas Reservoir is still suitable for fish life.

The conductivity in Gadjah Mungkur Reservoir, Indonesia, is above 250 µS/cm (Aida et al., 2022). The electrical conductivity value at the Ketiwon River estuary ranges from 516 µS/cm to more than 1999 µS/cm. The highest is at high tide because it is greatly influenced by seawater, and the lowest is at low tide due to the influence of fresh water from the river (Lisa et al., 2023). Conductivity in Rudrasagar Lake Tripuya-India ranges between 60 µS/cm at the surface and 80 µS/cm at a depth of 4 m. The lake is oligotrophic with poor nutrients (Mihir et al., 2015). Compared to the EC

value of Gajah Mungkur Reservoir, which is above 250 $\mu\text{S}/\text{cm}$ (Aida et al., 2022). Conductivity in industrial waste can reach 10.000 $\mu\text{S}/\text{cm}$ (Apha, 2012). High EC values may also be related to extensive agricultural activities around the area and improper sewage discharge (Gobeze et al., 2023). The EC value in this study still ranges between 200 to 800 $\mu\text{S}/\text{cm}$, which is permitted for drinking water (WHO, 2017).

The pH in the bottom layer of water tends to be low or acidic compared to the surface due to the influence of the decomposition of organic material at the bottom of the water, which will produce gases such as CO_2 and H_2S , which can lower the pH. In line with other reservoir waters, namely: pH in Pondok Reservoir 7–8 (Aida et al., 2021), Gajah Mungkur Reservoir 6–8 (Utomo, 2013), Sempor Reservoir 6.3–8.4 (Shaleh et al., 2014), Bukit Merah Reservoir 6.2–6.7 (Zakeyuddin et al., 2016), Gilgel Reservoir Ethiopia 7.2–8.1 (Woldeab et al., 2023). In Angereb Reservoir Ethiopia 7.32–8.00 (Gobeze et al., 2023). Overall, the pH value is neutral-alkaline, indicating hydrolysis of HCO_3^- and CO_2 and production of OH^- (Boyd, 2015). However, the pH value in the study area is within safe limits up to the limits set by WHO (2017) and Regulations Government No. 22 of 2021 (PP 22/2021).

The Photic layer is where sunlight still penetrates so that the process of photosynthesis still occurs. Therefore, in this layer, the biota still has a lot of dissolved oxygen that the biota can utilize. The aphotic layer is a layer where very little sunlight enters. Therefore, photosynthesis does not occur in the aphotic layer; it is poor in oxygen, and there are many toxic materials at the bottom of the waters, such as carbon dioxide and ammonia (Wetzel, 2001). Water with a thick aphotic layer will one day cause environmental problems if there is a water reversal from the upper layer down to the bottom and from the lower layer up (upwelling). Then, rotten organic matter and toxins at the bottom of the water will be lifted to the top and cause mass fish deaths, especially fish in floating net cages (Utomo, 2013; Utomo et al., 2019). Upwelling occurs when there is heavy rain at night so that the surface temperature of the water is frigid and the specific gravity of the water will be greater so that the surface layer will drop down and the bottom layer of the water will rise (Odum, 1996).

4.2 Trophic Status and Fish Production in Widas Reservoir

The phosphate content at the bottom of the water is higher than on the surface due to much precipitation at the bottom of the water. Based on this phosphate concentration, the waters are classified as mesotrophic (Wetzel, 2001). The phosphate content in Angereb Reservoir Ethiopia 14.8–26.75 $\mu\text{g}/\text{L}$ (Gobeze et al., 2023), Bukit Merah Reservoir 0.025–0.72 mg/L (Zakeyuddin et al., 2016), Sempor Reservoir 0.2–21 $\mu\text{g}/\text{L}$ (Shaleh et al., 2014), In Gajah Mungkur Reservoir 5.2 – 115 $\mu\text{g}/\text{L}$ (Utomo, 2013), Taizhou Reservoirs, East China 0.01–0.05 mg/L (Yin et al., 2021). Bukit Merah Reservoir 0.04–0.109 mg/L (Zakeyuddin et al., 2016), Pondok Reservoir 11–56.7 $\mu\text{g}/\text{L}$ (Aida et al., 2022).

The presence of phosphorus in natural waters is relatively small and quickly settles to the bottom, so it is a limiting factor for algae growth. The presence of high phosphorus is an indicator of organic material pollution (Novotony and Olem, 1994). The large amount of organic material that settles at the bottom of the water will cause the layer at the bottom to become more acidic than at the surface. The average value of total phosphorus shows that the water status of the Widas Reservoir is eutrophic (Carlson, 1977). The concentration of Widas Reservoir TP is still suitable for aquatic life, especially fish. The TP content of the Widas Reservoir enters through the runoff of the Inlet Muara Petung and Inlet Kali Bening. The catchment area contains a lot of intensive agriculture and waste from fish farming and other activities in the reservoir. Because the Widas Reservoir is also a source of drinking water, it must be processed first before being used so that it is suitable for drinking water.

The chlorophyll-a content in the surface layer is higher than at the bottom of the water because sunlight does not reach the bottom. Dark waters with little sunlight will be poor in algae, whereas chlorophyll is found in algae. Based on the average value of chlorophyll-a in Widas Reservoir, in general, the status of these waters is eutrophic (Carlson, 1977; Wetzel, 2001). This state is due to the enrichment of nutrients (eutrophication), especially phosphorus and nitrate elements in the waters. Chlorophyll-a also indicates high eutrophication processes and algae growth in water bodies. According to Novotony and Olem (1994) oligotrophic waters if the chlorophyll content is $<4 \mu\text{g}/\text{L}$ mesotrophic if the chlorophyll content is between 4–10 $\mu\text{g}/\text{L}$ and eutrophic if the chlorophyll content is $>10 \mu\text{g}/\text{L}$. In Gajah Mungkur Reservoir, the chlorophyll-a value ranges between 3.57 – 83.3 $\mu\text{g}/\text{L}$ with an average value of 21.31 $\mu\text{g}/\text{L}$ (Utomo, 2013). The Angereb reservoir, Ethiopia, ranges from chlorophyll-a concentrations of 3.89–6.01 $\mu\text{g}/\text{L}$ (Gobeze et al., 2023). Bukit Merah Reservoir chlorophyll-a 0.085–0.39 $\mu\text{g}/\text{L}$ (Zakeyuddin et al., 2016).

The average TSI value is 63.6, indicating that the status index of water is eutrophic. Reservoirs are characterized as inland waters, open access, and lentic water, so their activities greatly influence water quality: the catchment area and activities in the waters themselves. Reservoirs are stagnant waters (lentic) whose water quality status is influenced by the activities around them. The catchment area and the activities in the waters themselves (Klippel et al., 2020;). Eutrophic status indicates that the waters have received a lot of organic material input from the surrounding environment (Wetzel et al., 2021; Wiegand et al., 2021). Since the reservoir waters are eutrophic in developing fish farming in reservoirs, it is recommended not to use artificial feed (pellets). It is better to use natural feed (water plants that fish and maggots can eat) (Utomo et al., 2019).

Fish production potential is 626.6 $\text{kg}/\text{ha}/\text{year}$ due to the high concentration of chlorophyll. High chlorophyll indicates that the waters have a lot of phytoplankton, which is a natural fish food. Based on the analysis, the maximum sustainable yield (MSY) value of fish in the Widas Reservoir is 542.4 $\text{kg}/\text{ha}/\text{year}$; thus, the sustainable potential of fish in the utilization of fish resources in Widas Reservoir could be increased to 626.6 $\text{kg}/\text{ha}/\text{year}$ by spreading/restocking phytoplankton-eating fish, thereby increasing the fishermen's catches.

5. CONCLUSION

Based on the Trophic Status Index (TSI) Widas Reservoir is categorized into eutrophic water with an average index of 63.6. Several water quality parameters that decrease towards the bottom of the water are temperature, oxygen, and pH. Meanwhile, the parameters that increase towards the bottom of the waters are carbon dioxide and turbidity. Overall, the water quality of the Widas Reservoir waters is still suitable for the life of freshwater fish. Because of the eutrophic water state, so the use of reservoir water for drinking water should be undergoing such treatments before it can be consumed by local society. Likewise, the use of natural foods for fish farming could also reduce the rapid growth of algae due to the impact of eutrophication. Therefore, fisheries activities are prioritized for the stocking of algae-feeder fish. The potential for fish production is relatively high at 626.6 $\text{kg}/\text{ha}/\text{year}$, with the potential to increase the production of fishermen's catches by stocking plankton-feeder fish.

ACKNOWLEDGMENT

The author would like to thank: Research Institute for Inland Fisheries and Fisheries Extension Palembang for funding this research activities. Gratitude is also given to the research team for writing this manuscript and to fellow researcher and technicians who have helped a lot during the implementation of this research from the field survey up to the laboratory analysis.

CONFLICTS OF INTEREST

Authors declare no conflict of interest

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