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Determination of Oxygen Requirement of Trout

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Abstract

This study explores the determination of oxygen requirements in trout. Various types of water sources, which serve as the natural habitat for trout, were examined in terms of their oxygen content. A significant parameter in understanding the oxygen needs of trout, namely the dissolved oxygen level, was thoroughly analyzed, and the viewpoints of different researchers were reviewed in succession. The reason for placing strong emphasis on dissolved oxygen lies in the fact that it directly corresponds to the form of oxygen that fish require in aquatic environments—making it the fundamental focus of this analysis. Commonly referenced formulas in the literature, such as those used to estimate the amount of oxygen consumed per fish, were included, along with explanations of their respective indices. In addition to investigations into increasing the level of dissolved oxygen in water, the study also presents information on how to enhance oxygen levels in sources where oxygen availability is insufficient. By evaluating the findings of various authors, insights were provided regarding the minimum dissolved oxygen levels necessary for trout.

Keywords: *Trout, Oxygen level, Oxygen requirement, Dissolved Oxygen*

1. Introduction

Today, aquaculture has become a significant part of modern life. Activities related to fish farming in environments such as rivers, seas, lakes, and dams have been increasingly gaining importance [1].

Water is not inherently rich in oxygen content. While one liter of air contains approximately 300 mg of oxygen, one liter of water at 15°C contains only 10 mg of oxygen. The capacity of water to retain oxygen also depends on its temperature. In warm water, the ability to retain oxygen is lower, whereas it is higher in cold water. Therefore, in aquaculture, the oxygen required for fish is provided either by introducing a very high volume of water into the farm or by injecting pure oxygen into the water. To establish a trout farm, the minimum flow rate of the water source must be between 20–25 liters per second. The more this value exceeds the minimum requirement, the more stable the system becomes. The reason for such a high demand for water is the substantial oxygen requirements of trout [2].

In a study conducted by Dandy (1970), the activity levels of trout were measured at 10°C under three different oxygen concentrations. It was reported that the oxygen-related activity of fish exposed to dissolved oxygen levels ranging from 1.7 to 6 ppm peaked within the first hour [3].

In their study, Doudoroff and Shumway (1970), reported that the dissolved oxygen concentration in waters inhabited by trout should be 11 mg/L during the initial stages of life, while for other life stages, a level of 8 mg/L was considered sufficient. They also stated that the minimum dissolved oxygen concentration required for warm-water fish is 5 mg/L, whereas for cold-water species, including trout, it should not be less than 6 mg/L [4].

Downey and Klontz (1981), identified the minimum and average oxygen requirements for trout at specific water temperatures. In their research, they indicated that at a water temperature of 20°C, the minimum necessary dissolved oxygen level was 7.8 mg/L, while the average requirement was 5.90 mg/L. They also mentioned formulas that assist in calculating the oxygen consumed per fish and in managing oxygen consumption [5].

Drewett and Abel (1983), conducted a study comparing two distinct trout diseases. Their findings revealed that fish exposed to low levels of dissolved oxygen experienced tissue damage, which could only be observed under an electron microscope [6].

Weithman and Haas (1984), noted in their study that in water sources where aquaculture is widely practiced, the onset of autumn leads to oxygen depletion, making aquaculture conditions increasingly challenging. They reported that the dissolved oxygen levels in such environments ranged between 2.4 and 6.0 mg/L [7].

Raleigh et al. (1984), indicated that the optimal dissolved oxygen concentrations for rainbow trout are >7 mg/L at temperatures below 15°C, and >9 mg/L when temperatures exceed 15°C. They emphasized that the oxygen requirements of trout species are higher compared to other fish, and that available comparative data

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suggest remarkably similar dissolved oxygen needs across all trout species [8].

Chapman (1986), proposed a minimum dissolved oxygen level of 4.0 mg/L to prevent mortality, and a chronic threshold of 6.5 mg/L to safeguard natural populations from impaired reproduction [9].

Dean and Richardson (1999), conducted a study in which they kept seven species of freshwater fish in low dissolved oxygen conditions to determine their tolerance levels to dissolved oxygen. The study was conducted over a period of 48 hours at dissolved oxygen levels of 1.3 or 5 mg/L. The results showed that the fish survived at a concentration of 5 mg/L with a survival rate of 90-100%. All species were exposed to a 3 mg/L concentration for 36 hours, and it was reported that an average of 14.3% of rainbow trout died. As a result, they concluded that trout are the most sensitive species to dissolved oxygen compared to other fish [10].

Yanık et al. (2001), found in their study that the desired level of dissolved oxygen should exceed 5 mg/L, with fish surviving in the range of 1.0–5.0 mg/L but experiencing slow growth. They reported that dissolved oxygen levels in the range of 0.3–1.0 mg/L were lethal over prolonged exposure, and that in the range of 0–0.3 mg/L, small fish could survive for only a brief period [11].

Bayrak (2006), planned the oxygen content to be in the range of 9.2–11.5 mg/L for saturation, but during periods of high-water temperature, he observed that the oxygen content of the water decreased, with levels at the pond inlet ranging from 4.8 to 6.5 mg/L [12].

Güleçal (2007), conducted a study aimed at determining the efficiency level during the first 60 days of raising juvenile fish. He reported that in rainbow trout farming, the oxygen content of the water should not be less than 6 mg/L. He indicated that a lack of oxygen affects development and metabolism, and that the oxygen level of the water should be between 9–11 mg/L until the trout juveniles reach a weight of 8 grams [13].

Swales (2009), demonstrated in his study that rainbow trout prefers water temperatures below 22°C. He reported that rainbow trout are rarely found in waters where oxygen levels are significantly below 3.0 mg/L and tend to avoid dissolved oxygen concentrations below 2.5 mg/L, which can define the lower depth limit of trout distribution in lakes [14].

Frankin (2013), conducted a study on various trout species, including species native to New Zealand, by keeping them at 15°C for 48 hours in water with fixed dissolved oxygen concentrations of 1, 3, and 5 mg/L to examine their tolerance to low dissolved oxygen levels. He found that the Common Kabaday (Gobiomorphus cotidianus) and juvenile Rainbow Trout (Oncorhynchus mykiss) were the most sensitive species to low dissolved oxygen levels [15].

Sırtkaya (2013), stated in his study that the oxygen content of the water should be at least 5–6 mg/L and that the minimum oxygen requirement for maximum growth is 6 mg/L [16].

2. Material and Method

Trout are aggressive, carnivorous fish that prefer cold, clear, and fast-flowing waters. Trout, belonging to the Salmonidae family, favor environments that are clear, clean, cool, and oxygen-rich. The most used species in trout farming is the Rainbow Trout, which originates from North America [17]. Rainbow trout shows superior adaptation to farming conditions compared to other trout species, its higher tolerance to low oxygen levels and temperature, its lower need for shelter, and its greater resistance to stress, in addition to its excellent meat quality, have made this species quite popular [16]. Spring waters are suitable for the farming of many cold-water fish, including trout. Stream springs (Rheokren) are clean, clear, cold, and have minimal temperature fluctuations, but they are oxygen-poor. These springs are quite suitable for trout farming, and to enrich their oxygen content, external sources of oxygen should be introduced to the system. Lake-type springs (Limokren) are oxygen-poor sources with stable water temperatures. They are particularly suitable for fattening and juvenile trout farming, especially during incubation. Swamp-type springs (Halokren) are influenced rapidly by seasonal temperature changes. Their oxygen content is very low, and the water contains high organic matter, particularly humic acid, making the water acidic and unsuitable for trout farming. Rivers are oxygen-rich, making them suitable for trout farming. Water temperatures vary significantly depending on altitude, the region where the spring is located, meteorological conditions, and the seasons [17].

Fluctuations in water temperature are known to cause stress, which is primarily due to low oxygen concentrations at higher temperatures. If excessive oxygen is supplied, it may make the fish more susceptible to diseases [18]. At the start of spring, the water temperature in ponds is uniform from the surface to the bottom, showing little variation. However, as the weather warms up, surface waters heat up, causing a decrease in their density. In early summer, stratification occurs in the ponds, creating three primary layers: the upper layer, known as the epilimnion, which is rich in oxygen and relatively warm; the transition layer, known as the metalimnion, where sudden temperature drops occur; and the bottom layer, the hypolimnion, which is oxygen-poor and cold. These layers are shown in **Fig. 1** [11].

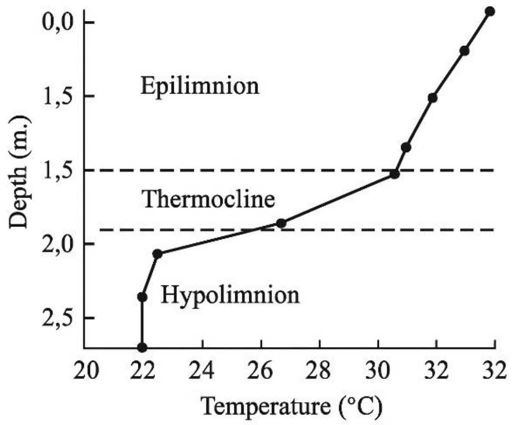

Figure 1. *Stratification occurring in summer*

2.1. Oxygen Requirement of Trout

The oxygen requirements of fish are generally expressed in terms of "ppm." This quantity refers to milligrams per liter (mg/L) depending on the oxygen pressure (1 ppm = 1 mg/L). For example, the retention of 2 mg/L of oxygen occurs at an oxygen pressure of 42 mm at 30°C and 33 mm at 15°C. The formula used to approximately estimate oxygen consumption is shown in Eq. 1 [11].

$$Y = \frac{0.001}{W * 0.82} \tag{1}$$

In this equation, Y represents oxygen consumption (g/hour), while W refers to weight in grams. In aquaculture, oxygen deficiency occurs when more oxygen is not added to the water than is consumed by organisms or if it cannot be replenished by plankton. Oxygen loss in water occurs through the respiration of plankton, fish, benthic organisms (organisms living in the mud), and diffusion (the movement of substances between areas of different densities). In the absence of an oxygen kit or an oxygen meter, oxygen deficiency can be estimated. Factors such as fish swimming near the water surface during late night or early morning hours, sticking their heads out of the water to gulp air, a sudden cessation of feeding, changes in water color, or the emission of a rotten odor from the water can make it easier to predict oxygen deficiency [11].

In a closed system, to maintain oxygen balance, the number and size of the fish must be proportional to the water volume and surface area of the closed system. Fish can survive on the dissolved oxygen in the water; however, in closed systems with a small water surface area, fish can run out of oxygen. In such cases, fish gather at the surface of the water to obtain oxygen. These issues can be addressed through aeration methods. Another method involves air injectors, which use a motor to draw water from one tank and push it into another, enriching the water with oxygen as it circulates between the tanks. Oxygen diffusers are used to increase oxygen levels in the water when necessary. They are used in fish farming ponds, live fish transport tanks, live feed production, hatcheries, adaptation ponds, and large aquariums [19].

2.2. Dissolved Oxygen

Dissolved oxygen refers to the oxygen molecules dissolved in water. Oxygen does not dissolve easily in water. Under normal conditions, oxygen can only dissolve at 12 mg per liter. Oxygen enters water from only two sources: either it dissolves by coming into contact with the atmosphere, or it is produced by plants during photosynthesis. The removal of trees and plants along the banks of rivers and streams reduces shading, leading to higher water temperatures. This indirectly causes lower dissolved oxygen concentrations because warmer water holds less oxygen. Dissolved oxygen should be measured immediately after sampling. Changes in temperature and the continued consumption of oxygen by bacteria in the water can affect the measurements. Dissolved oxygen is typically measured with a field probe or collected in a special bottle, then chemically fixed before being transported to a laboratory for analysis [23]. In aquatic environments, the oxygen content is controlled by the activities of phytoplankton and bacteria. A huge portion of the oxygen is produced by phytoplankton during photosynthesis. Excessive algal growth obstructs sunlight from penetrating the water surface, preventing photosynthesis. As a result, dead algae sink to the bottom, depleting dissolved oxygen in the benthic environment [20].

Dandy (1970), measured the locomotor activity (musculoskeletal system) of rainbow trout at three different oxygen concentrations at 10°C. He found that the oxygen-related activities of the trout peaked within the first hour at dissolved oxygen levels ranging from 1.7 to 6 mg/L and gradually decreased thereafter. Trout exposed to 1.7 mg/L of dissolved oxygen had an average survival time of 130 minutes, and their responses were more related to the absolute concentration of oxygen than its rate of decline [3].

Doudoroff and Shumway (1970), summarized studies on lethal dissolved oxygen concentrations for many species, including rainbow trout, which are generally considered the most sensitive group of freshwater fish. In their study, they reported that for rainbow trout, dissolved oxygen levels were 11 mg/L during the early stages of life and 8 mg/L during later stages. They indicated that a water source with an oxygen saturation level above 80% is considered healthy, and that the minimum dissolved oxygen concentration for warm-water fish should be at least 5 mg/L, while for cold-water fish, it should be at least 6 mg/L [4].

In their study, Downey and Klontz (1981), showed the minimum and average dissolved oxygen requirements for rainbow trout at various water temperatures. **Table 1** presents the minimum required dissolved oxygen, while **Table 2** shows the average required dissolved oxygen concentrations [5].

Table 1. *Temperature-dependent minimum dissolved oxygen requirements for trout*

Temperature (°C)	D.O. (mg/L)	% Saturation	Partial Pressure of Oxygen (mmHg)
5	9,1	71,26	113
10	8,8	78,01	123
15	8,3	82,4	129
20	7,8	85,9	133,7

Table 2. *Temperature-dependent average dissolved oxygen levels required for trout*

Temperature (°C)	D.O. (mg/L)	% Saturation	Partial Pressure of Oxygen (mmHg)
0	8,34	57	90
5	7,28	57	90
10	6,43	57	90
15	5,94	59	92
20	5,90	65	101

Drewett and Abel (1983), conducted a study comparing two different trout disorders. In this study, they reported that fish remaining at low dissolved oxygen levels suffered tissue damage, which could only be observed under an electron microscope. They noted that brown trout survived for an average of 50 minutes at 1 mg/L and 90 minutes at 1.5 mg/L [6].

Weithman and Haas (1984), established a trout farming facility in Lake Taneycomo. Through detailed examination from June 1978 to May 1980, they indicated that the success of fishing declined during the autumn as oxygen-poor waters entered the lake. They reported that the catch rate of rainbow trout during the study was 0.55 fish per hour. They also noted that the dissolved oxygen concentration ranged from 2.4 to 6.0 mg/L, and when reduced by 1 mg/L, the catch rate dropped by 0.1 fish per hour. They concluded that low dissolved oxygen concentrations would result in economic losses during production [7].

Raleigh et al. (1984), stated that for rainbow trout, dissolved oxygen levels should be at least 7 mg/L in waters with temperatures below 15°C, and at least 9 mg/L in waters above 15°C. They highlighted that trout species require higher oxygen levels than other fish species, and the comparative data available indicates that all trout species share quite similar dissolved oxygen requirements [8].

Chapman (1986), suggested that a dissolved oxygen concentration of 4.0 mg/L should be considered the lower threshold to prevent mortality in trout, and a chronic threshold of 6.5 mg/L should be maintained to protect natural trout populations from production disorders [9].

Dean and Richardson (1999), conducted a study on seven freshwater fish species, including some native to New Zealand, to determine their tolerance to low dissolved oxygen levels. The fish were kept at dissolved oxygen levels of 1.3 or 5 mg/L for 48 hours. The species used in the study included: Inanga (Galaxias maculatus), Banded Kokopu (G. fasciatus), Whitebait (Retropinna), Torrent fish (Cheimarrichthysforti), Common Galaxiid (Gobiomorphus cotidianus), Shortfinned and Longfinned Eels (Anguilla australis and A. dieffenbachii), and shrimp (Paratya curvirostris). Rainbow trout (Oncorhynchus mykiss) was tested for comparison. The results showed that the fish survived at 5 mg/L concentration with a survival rate of 90-100%. All species were exposed to a 3 mg/L concentration for 36 hours, and it was reported that an average of 14.3% of the rainbow trout died. At a 1 mg/L concentration, the mortality rates varied significantly, with Banded Kokopu, Torrent Fish, Whitebait, Galaxiid juveniles, and all trout species dying after 48 hours. The study concluded that rainbow trout were the most sensitive species to dissolved oxygen compared to others. **Table 3** shows the required dissolved oxygen levels based on the degree of acceptable deterioration in waters where trout is present or absent [10].

Table 3. *Acceptable dissolved oxygen concentrations relative to degradation levels in trout-inhabited and*

trout-absent waters (mg/L)

Acceptable Level of Degradation	Waters Inhabited by Trout		Waters Not Inhabited by Trout	
	Early Phase	Following Periods	Early Phase	Following Periods
None	11	8	6,5	6,0
Slight	9	6	5,5	5,0
Moderate	8	5	5,0	4,0
Severe	7	4	4,5	3,5
Critical Threshold	6	3	4,0	3,0

Yanık et al. (2001), addressed the relationship between oxygen solubility in water and salinity in their study. They stated that for every 9000 mg/L increase in salinity, the solubility in pure water decreases by 5%, and therefore, the effect of salinity is not considered significant in freshwater environments. They reported that cold-water species die in situations where dissolved oxygen levels are higher than those found in warm-water species. They mentioned that rainbow trout can survive for a minimum of 84 hours in a range of 1.05-1.34 mg/L dissolved oxygen. **Table 4** shows the oxygen solubility in pure water at different temperatures, and Figure 2 illustrates the dissolved oxygen levels that pond fish can tolerate [11].

Table 4. *Oxygen solubility in pure water at different temperatures*

Temperature (°C)	D.O. (mg/L)	Temperature (°C)	D.O. (mg/L)	Temperature (°C)	D.O. (mg/L)
0	14,16	12	10,43	24	8,25
1	13,77	13	10,20	25	8,11
2	13,40	14	9,98	26	7,99
3	13,05	15	9,76	27	7,86
4	12,70	16	9,56	28	7,75
5	12,37	17	9,37	29	7,64
6	12,06	18	9,18	30	7,53
7	11,76	19	9,01	31	7,42
8	11,47	20	8,84	32	7,32
9	11,19	21	8,68	33	7,22
10	10,92	22	8,53	34	7,13
11	10,67	23	8,38	35	7,04

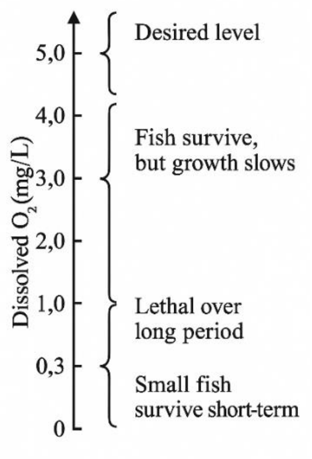

Figure 2. *The amount of dissolved oxygen that pond fish can tolerate*

Bayrak (2006), conducted a study on the reproductive performance of rainbow trout and the survival rates of larvae during the off-season egg production at a commercial trout farm during the 2004 season. The planned oxygen levels were set at 9.2-11.5 mg/L saturation, but during periods of high-water temperature, the oxygen content in the water decreased, and the values at the pond inlet were reported to be 4.8-6.5 mg/L [12].

Güleçal (2007), carried out a study aimed at determining the efficiency level during the first 60 days of trout farming. He reported that the oxygen content in water should not fall below 6 mg/L for rainbow trout farming. Oxygen deficiency affects growth and metabolism, and he emphasized that the oxygen level in water should be between 9-11 mg/L until the trout larvae reach 8 grams in weight. He also stated that the required dissolved oxygen during the growth period of trout is higher compared to other developmental stages [13].

Swales (2009), in his study indicated that rainbow trout prefer water temperatures below 22°C and are rarely found in waters where oxygen levels are below 3.0 mg/L. He stated that the upper temperature threshold for rainbow trout habitat in lakes and reservoirs is typically around 21°C, with the lower threshold for dissolved oxygen being generally around 2.5 mg/L. However, he noted that rainbow trout can tolerate conditions outside these limits for short periods, such as in shallower waters during the summer [14].

Frankin (2013), studied different trout species, including those native to New Zealand, by keeping them at fixed dissolved oxygen levels of 1, 3, and 5 mg/L for 48 hours at 15°C. The study concluded that rainbow trout is the most sensitive species to low dissolved oxygen levels among those tested. He reported that when dissolved oxygen levels fell below the tolerable limits, it contributed to changes in the community structure [15].

Sırtkaya (2013), in his study found that the water's pH should be between 6.5 and 8.5, with the optimum being around 7. He indicated that pH levels below 5.0 or above 9.2 are lethal for trout. He also noted that the oxygen content in the water should be at least 5-6 mg/L, with the minimum oxygen requirement for maximum growth being 6 mg/L. Growth stops when the oxygen level is 3 mg/L, and at oxygen levels of 0.75-1.3 mg/L, the fish die. He further stated that the necessary minimum oxygen values during farming should be >5.0 mg/L for salmonids and around 7 mg/L for salmonid eggs [16].

2.3. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Biochemical Oxygen Demand (BOD) only measures the oxygen consumed by organic matter that is broken down through biochemical processes, while Chemical Oxygen Demand (COD) measures not only the organic pollutants that are broken down biochemically but also toxic organic pollutants. Additionally, while determining the BOD requires at least five days, the COD can be determined in as little as three hours. Chemical oxidizers such as potassium dichromate or potassium permanganate give values close to the BOD for many organic pollutants. **Table 5** shows the classification of rivers based on BOD values [21].

Table 5. *Classification of water sources based on approximate biochemical oxygen demand (BOD) values*

Approximately BOD (20°C, ppm)	Definition of water
1	Excellent
2	Clean
3	Moderately Clean
5	Doubtful
10	Poor

2.4. Formulas Used to Determine Oxygen Needs of Trout

Dissolved oxygen concentrations are highest at 0°C and decrease with increasing temperature. The formula used to correct the solubility of oxygen for different atmospheric pressures is shown in Eq. 2 [11].

$$DOc = DOt * (((P0 - Pw)) / (760 - Pw)) \qquad (2)$$

In this formula, DOt represents the oxygen solubility at 760 mm pressure, DOc represents the corrected oxygen solubility, P0 represents the specified atmospheric pressure, and Pw represents the vapor pressure of water. The oxygen retention in water depends on temperature. The calculation of the oxygen concentration in fully aerated water is shown in Eq. 3 [12].

$$Cs = 468 / (31{,}6 + t\,°C)\ mg\ oxygen/liter \qquad (3)$$

Here, T represents the water temperature. Cs shows the oxygen content in water at 100% saturation and is used only for concentration measurement in fresh waters. The formula used to calculate the maximum dissolved oxygen amount at a specific temperature is shown in Eq. 4 [22].

$$Pc\ (max) = 2.07 + 3.06\ InT \qquad (4)$$

For example, at 5 °C, the maximum dissolved oxygen amount is calculated as 7.0 mg O2/L. As salinity increases, the oxygen content in water decreases exponentially. The formula used to calculate the salinity rate is shown in Eq. 5 [22].

$$Salinity = 1{,}80655 * Chlorinity \qquad (5)$$

The main parameters controlling the dissolved oxygen concentrations in rivers are widely described in scientific literature. The formula used to calculate dissolved oxygen concentration is shown in Eq. 6 [15].

$$\frac{dC}{dt} = k2(Cs - C) + (P - R) - k3x \tag{6}$$

Here, C represents the dissolved oxygen concentration, Cs represents the temperature-dependent saturation value of dissolved oxygen, k2 is the re-aeration coefficient, P is the photosynthesis rate of plants at time t, R is the respiration rate of plants at time t, and k3 is the biochemical oxygen demand (BOD) degradation coefficient.

The calculation of the oxygen consumed per fish in a fish farming facility is shown in Equation 7, and the calculation of oxygen consumption management is shown in Eq. 8 [5].

$$\frac{fish}{gpm} = \frac{(Oin - Oout)}{Yn} \tag{7}$$

Here, Oin represents the dissolved oxygen concentration in incoming water in ppm, Oout represents the dissolved oxygen concentration in water leaving the pond in ppm, and Yn represents the oxygen requirement for a fish of size "N."

$$\frac{fish}{pond} = \frac{1{,}2 * (Oin - Oout) * Rw}{K * T^{N} * W^{M}} \tag{8}$$

Also, Oin represents the dissolved oxygen in incoming water in ppm, Oout represents the dissolved oxygen in water leaving the pond in ppm, the constant 1.2, Rw is the water inflow in gpm, K is the ratio constant, T is the water temperature in Fahrenheit, N is the Temperature-Water Slope, W is the individual fish weight in pounds, and M is the weight-oxygen slope.

3. Conclusion

As a result of the research, the necessary parameters for determining the oxygen requirements of trout have been examined. When looking at the natural habitats of the fish, the most suitable sources are flowing sources such as rivers, and pond-type sources. It can be said that the oxygen obtained externally in areas where the oxygen amount is insufficient does not pose any problems in terms of production. It can be stated that a facility to be opened as an operation is more cost-effective when it is close to the source, and in facilities with elevation differences, the water should be brought to the pond in a cascading manner, if possible. Although the lower oxygen content in water compared to air is a problem, the water temperature and external oxygen supply methods seem to be the solution to this issue.

The dissolved oxygen amounts as the oxygen requirement for fish have been comprehensively studied in the conducted research, and it can be said that the values differ from author to author. The oxygen requirements for trout according to different authors are summarized in **Table 6**.

Table 6. *Minimum dissolved oxygen requirements for trout according to various authors (mg/L)*

Downey and Klontz (1981)	**7,8 at 20°C**
Raleigh et al. (1984)	7 at 15° and above 9 at 15°
Chapman 1986	6,5
Kramer 1988	2,4-6,0
Dean and Richardson 1999	8
Yanık et al. 2001	5
Bayrak 2006	9,2-11,5
Güleçal 2007	6
Swales 2009	2,5 at 21°C
Bulut 2012	6
Franklin 2013	5 at 15°
Sırtkaya 2013	5-6
Bulbul et al. 2022	5-6

4. Discussion and Future Work

In the conducted research, a comparison has been made regarding the dissolved oxygen requirements of trout according to different authors. Although there is no universal value, based on the studies reviewed, the minimum oxygen requirement for trout has been indicated as approximately 5 mg/L. This value can be considered as the minimum level required in the maturity phase, following the growth stage of trout. The dissolved oxygen values mentioned in the studies can be summarized as a general value of 5-8 mg/L for trout species. The different opinions of the authors, as well as the average of the dissolved oxygen values stated by the same authors, have been visualized on a graph and are shown in **Fig. 3**.

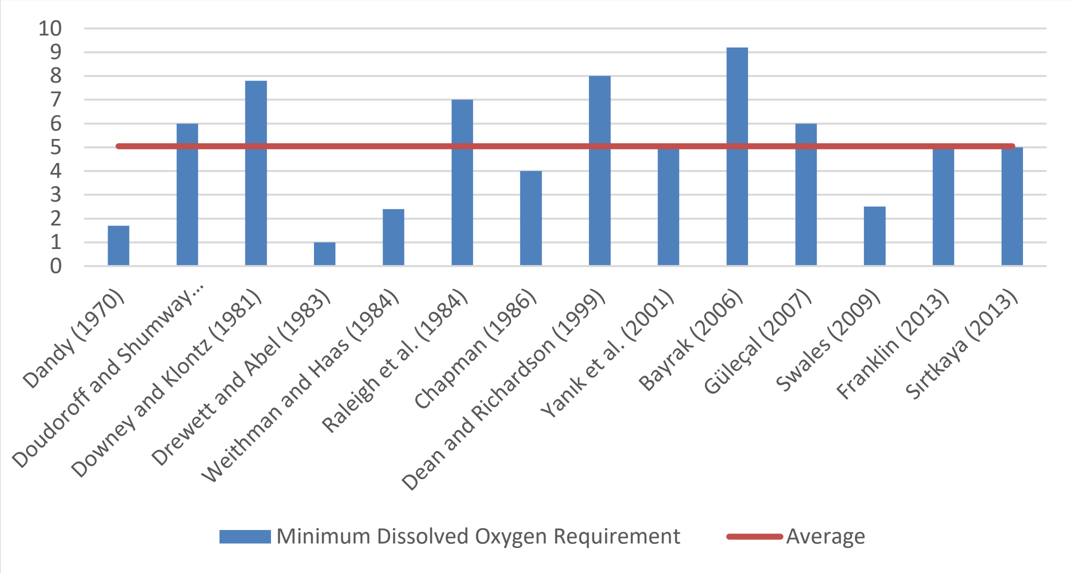

Figure 3. *Minimum and average dissolved oxygen requirements for trout according to various authors (mg/L)*

In future studies, the determination of the oxygen requirements for trout could be further developed by considering parameters such as the differences in water sources, water temperatures, various trout species, and their maturity levels. When evaluating the authors for different parameters, a separate average value can be determined for each parameter. On the other hand, by creating a database based on certain predefined parameters, a prediction method can be implemented using various types of artificial intelligence algorithms. Based on the obtained data, the required amount of dissolved oxygen can be determined with greater accuracy.

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