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Water Pollution and Its Effects on Aquatic Animal Life

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Abstract

Polluted water places sustained pressure on animals living in rivers, lakes, estuaries and seas. Their survival depends on fairly steady water conditions, especially enough dissolved oxygen, moderate nutrient levels, suitable pH, clear water and limited exposure to toxins. This paper discusses the effects of sewage, farm runoff, industrial discharge, metals, pesticides, oil, plastics and microplastics, pharmaceuticals and endocrine-active compounds on fish, crustaceans, molluscs, plankton, bottom-dwelling organisms, marine mammals and other aquatic fauna. The review shows that organic wastes raise biochemical oxygen demand and draw down dissolved oxygen, whereas excess nutrients promote eutrophication, algal blooms, hypoxia and fish mortality. Chemical contaminants can injure gills, liver, kidneys, nervous tissue, DNA and reproductive organs. Long-lived pollutants, especially methylmercury, build up in organisms and become more concentrated along food chains. Microplastics can be swallowed and may carry harmful chemicals, while oil pollution can smother animals, harm early life stages and contaminate habitats. Evidence from the Gulf hypoxic zone, Minamata mercury contamination, the Deepwater Horizon spill and polluted river stretches in India shows that pollution can cause sudden deaths as well as gradual biodiversity loss. The paper concludes that protection of aquatic animals depends on better wastewater treatment, nutrient control, industrial regulation, plastic-waste reduction, enforcement of environmental laws and restoration of damaged habitats.

Keywords: Water Pollution; Aquatic Animals; Dissolved Oxygen; Eutrophication; Bioaccumulation; Hypoxia; Microplastics; Aquatic Biodiversity.

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Introduction

1.1 Concept of Water Pollution

Water pollution is the deterioration of rivers, lakes, wetlands, aquifers, estuaries and oceans when physical, chemical, biological or heat-related contaminants change normal water conditions and weaken ecosystem functioning. In water bodies, pollution is not limited to obvious materials such as plastic debris, sewage scum or oil slicks. It may also appear as less visible shifts in dissolved oxygen, pH, nutrient levels, salinity, conductivity, temperature, turbidity and toxic chemical concentration. Such shifts matter for aquatic animals because many species take in substances through their gills, skin, feeding structures, eggs, larvae and sediment-contacting tissues.

Standard indicators are often used to judge ambient water quality. SDG Indicator 6.3.2 records the share of rivers, lakes and groundwater bodies that meet the category of good ambient water quality. Under this indicator, water is considered good when it does not harm ecosystem functioning or human health, based on parameter groups such as oxygen, nitrogen, phosphorus, salinity and acidification (United Nations Environment Programme [UNEP], 2024). UNEP's 2024 update reported a small decline in the monitored global share of good-quality water bodies, from 57% in 2017 to 56% in 2023, indicating that water-quality pressure continues (UNEP, 2024).

1.2 Importance of the Study

Aquatic systems have high biological value. Freshwater systems are particularly important because they cover only a limited part of the planet's surface but contain a large proportion of biodiversity. Fresh waters support more than 10% of known species and roughly half of all fish species (Dudgeon et al., 2006; Sayer et al., 2025). Broader assessments also show that rivers are affected by several pressures at the same time, including pollution, altered flows, water withdrawal, habitat damage and invasive species (Vörösmarty et al., 2010; Reid et al., 2019).

Recent biodiversity findings show why aquatic pollution is a conservation concern. In an assessment of 23,496 freshwater decapods, fishes and odonates, Sayer et al. (2025) found that about one-fourth were threatened with extinction. Pollution was reported as a common threat, affecting 54% of the threatened species in those groups (Sayer et al., 2025). This evidence places water pollution beyond a narrow water-quality problem and links it to faunal decline and ecosystem instability.

1.3 Research Objective

This paper aims to examine how water pollution affects aquatic animal life from environmental and ecological perspectives. It describes major pollution types and sources, explains the processes by which pollutants harm aquatic fauna, defines important terms such as eutrophication, dissolved oxygen, bioaccumulation and biomagnification, discusses selected case examples, reviews relevant legal and environmental frameworks and identifies preventive measures for protecting aquatic fauna.

Types and Sources of Water Pollution

Pollutants reach aquatic ecosystems through both point and non-point routes. Point sources are specific, traceable outlets, such as sewage pipes, industrial drains, wastewater-treatment discharges and spill sites. Non-point sources are more scattered and include farm runoff, road runoff, urban stormwater, atmospheric deposition, mining leachate and dispersed plastic waste. These diffuse sources are harder to manage because contaminants enter water bodies across wide areas and often vary with season and rainfall.

Farms and cities are important sources of nitrogen and phosphorus inputs. Carpenter et al. (1998) identified diffuse phosphorus and nitrogen inputs as a major reason for surface-water deterioration, and Smith et al. (1999) explained that excess nutrients can change the structure of freshwater, marine and terrestrial ecosystems. Howarth (2008) also linked coastal nitrogen pollution closely with agricultural intensification and wastewater discharge.

2.1 Domestic and Municipal Sources

Municipal sewage contains organic material, suspended particles, nutrients, pathogens, detergents, pharmaceuticals, hormones and personal-care chemicals. If sewage is untreated or only partly treated before entering a river, lake or coastal water, microbes break down the organic matter and use up oxygen, thereby raising biochemical oxygen demand and lowering dissolved oxygen. Kolpin et al. (2002) also reported organic wastewater contaminants such as pharmaceuticals and hormones in streams, which is significant because some of these compounds may affect aquatic organisms even at low levels.

2.2 Agricultural Sources

Runoff from agricultural land can carry fertilisers, pesticides, herbicides, animal manure and soil particles into nearby water bodies. Nitrogen and phosphorus encourage eutrophication, while pesticides can be toxic to fish, amphibians, zooplankton and macroinvertebrates. Relyea (2005) found that common insecticides and herbicides can lower biodiversity and productivity in aquatic communities, and Beketov et al. (2013) reported declines in stream invertebrate biodiversity associated with pesticide exposure.

2.3 Industrial Sources

Industrial contamination may come from mining, electroplating, tanneries, textile production, chemical manufacturing, refineries, battery production and untreated effluent discharge. Such activities can release heavy metals, acids, alkalis, dyes, petroleum residues, solvents and persistent organic pollutants. Metals are especially problematic because they can remain in aquatic environments, build up in animal tissues and disrupt physiological functions (Rainbow, 2007; Javed et al., 2017).

2.4 Plastic and Microplastic Sources

Plastic waste enters aquatic systems through packaging, fishing gear, textile fibres, tyre wear, urban litter and weak solid-waste management. Large plastic items gradually break into microplastics and nanoplastics, which may be swallowed by zooplankton, mussels, crustaceans and fish. Cole et al. (2013) documented microplastic ingestion in zooplankton, and Browne et al. (2008) showed that microscopic plastic particles can move from the gut into the circulatory system of mussels.

2.5 Oil and Petroleum Sources

Oil contamination can result from offshore drilling, tanker accidents, routine shipping, refinery leaks and coastal industry. Petroleum hydrocarbons and polycyclic aromatic hydrocarbons may coat animals, injure organs, affect embryos and pollute sediments. The Deepwater Horizon event released about 134 million gallons of oil across 87 days and affected large areas of marine habitat, including habitat used by marine mammals and sea turtles (National Oceanic and Atmospheric Administration [NOAA], 2017). Table 1 summarises the main pollution types, sources and ecological effects.

Table 1: Main Pollution Sources and Effects on Aquatic Animals

Pollution category	Common sources	Indicators	Animal effects	Key citations
Organic waste	Sewage, animal waste and food-processing discharge	High BOD, low DO and pathogens	Oxygen loss, disease exposure, fish stress and death	USEPA (2026); Kolpin et al. (2002)

Pollution category	Common sources	Indicators	Animal effects	Key citations
Nutrient pollution	Fertilisers, detergents, sewage and livestock waste	Nitrogen and phosphorus	Eutrophication, algal blooms, hypoxia and fish mortality	Carpenter et al. (1998); Smith et al. (1999); Conley et al. (2009)
Industrial waste	Mines, tanneries, electroplating and chemical industries	Metals, dyes, solvents and acids	Gill injury, oxidative stress, DNA damage and mortality	Rainbow (2007); Javed et al. (2017)
Pesticides	Farm runoff and pest-control use	Insecticides, herbicides and fungicides	Invertebrate decline, neurotoxicity and reproductive stress	Relyea (2005); Beketov et al. (2013)
Plastic waste	Packaging, fishing gear, textiles and tyre particles	Microplastic and nanoplastic particles	Ingestion, tissue stress, chemical transfer and food-web movement	Browne et al. (2008); Cole et al. (2013); Rochman et al. (2013); Lu et al. (2016)
Oil pollution	Drilling, tankers, refineries and shipping	Petroleum hydrocarbons and PAHs	Smothering, embryo toxicity, habitat contamination and death	NOAA (2017); Incardona et al. (2014); White et al. (2012)
Sediment load	Construction, mining, forest loss and dredging	Suspended solids and turbidity	Gill blockage, egg burial and reduced feeding	Newcombe & Jensen (1996); Bilotta & Brazier (2008)
Thermal pollution	Power plants and industrial cooling water	Raised water temperature	Reduced oxygen solubility, metabolic stress and reproductive changes	Pörtner & Farrell (2008); Breitburg et al. (2018)

Impact on Aquatic Animal Life

3.1 Dissolved Oxygen Depletion and Respiratory Stress

Dissolved oxygen is required by fish, crustaceans, molluscs and aerobic benthic organisms. USEPA treats dissolved oxygen as a direct measure of whether an aquatic resource can support aquatic life and notes that levels below 5 mg/L are generally stressful for fish, while levels below 3 mg/L are too low for many fish species (United States Environmental Protection Agency [USEPA], 2026). Organic waste lowers oxygen because decomposer microorganisms consume oxygen while breaking down organic matter. When this demand is greater than natural reaeration and oxygen produced through photosynthesis, aquatic animals undergo respiratory stress. Fish may respond with faster gill movement, gasping at the surface, reduced feeding, slower growth or avoidance behaviour. Continued oxygen loss can result in fish kills, larval death and disappearance of sensitive benthic organisms. In marine and coastal waters, deoxygenation is also being intensified by nutrient loading and climate warming, both of which reduce oxygen availability and increase biological oxygen demand (Breitburg et al., 2018).

3.2 Eutrophication, Algal Blooms and Hypoxia

Eutrophication develops when high nitrogen and phosphorus inputs encourage rapid algal and cyanobacterial growth. Schindler's experimental lake work showed the importance of nutrients in eutrophication, and later studies argued that controlling both nitrogen and phosphorus is often necessary (Schindler, 1974; Conley et al., 2009). In coastal waters, eutrophication can lead to algal blooms, loss of submerged vegetation, altered food webs and declining oxygen levels (Cloern, 2001).

After algal material dies, bacteria decompose it and consume dissolved oxygen, producing hypoxic or anoxic conditions. Diaz and Rosenberg (2008) described the spread of coastal dead zones, and Vaquer-Sunyer and Duarte (2008) showed that marine organisms differ in their tolerance of hypoxia, so biodiversity can be affected before oxygen is fully depleted. Freshwater systems are also affected; Jenny et al. (2016) linked the expansion of freshwater hypoxia to local human pressure. Rabalais et al. (2010) further showed that natural and human-caused hypoxia can change benthic habitats, food-web structure and species distribution. Warming can intensify these effects because higher temperatures reduce oxygen availability and raise animals' metabolic oxygen demand (Pörtner & Farrell, 2008; Breitburg et al., 2018).

Figure 1 illustrates how nutrient enrichment can progress toward oxygen loss and mortality of aquatic animals.

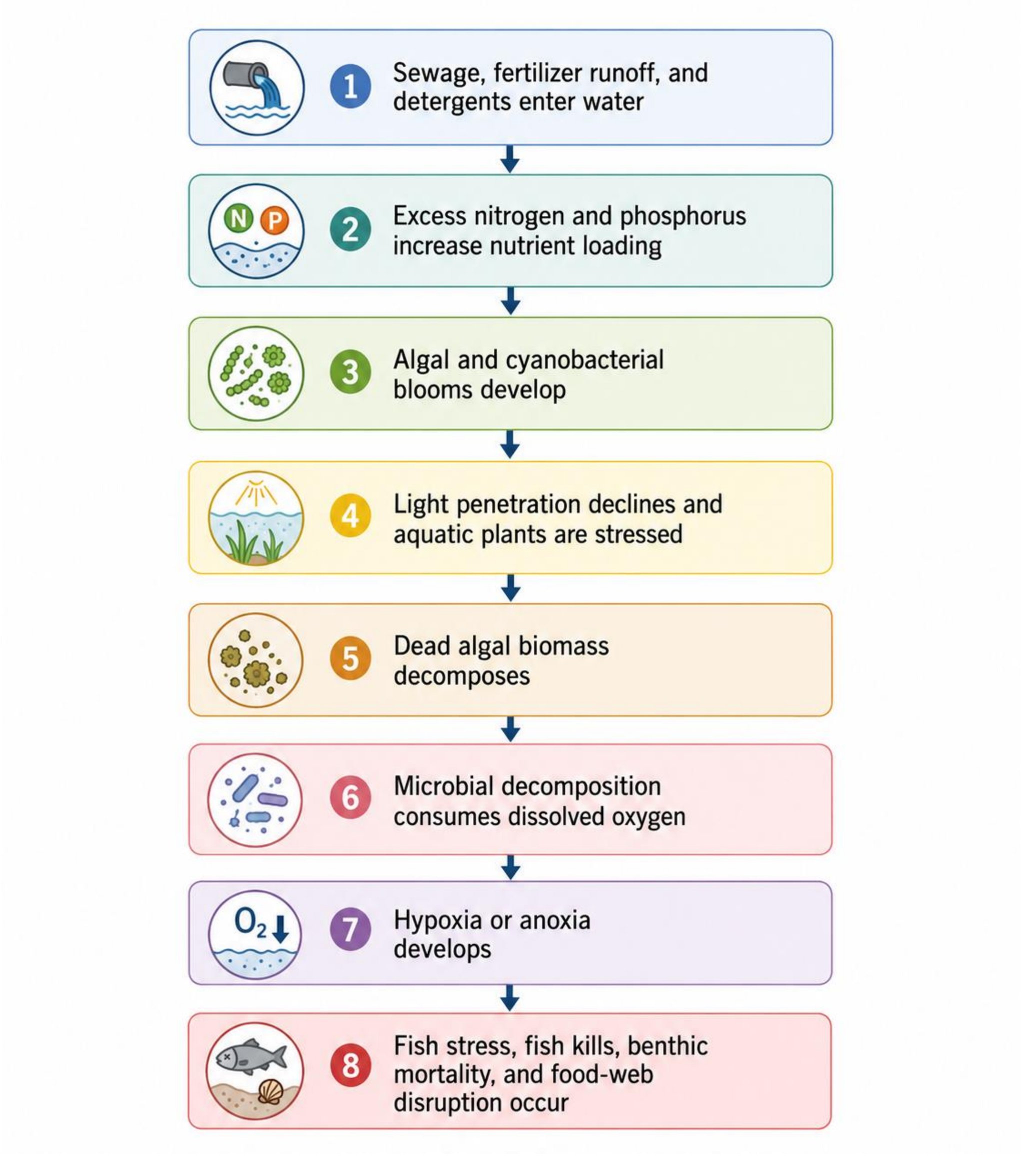

Figure 1: Eutrophication Pathway and Aquatic Animal Impacts

Source: Figure developed from Schindler (1974), Carpenter et al. (1998), Cloern (2001), Diaz and Rosenberg (2008), Conley et al. (2009) and Paerl and Otten (2013).

3.3 Heavy Metal Toxicity

Mercury, cadmium, lead, chromium, copper, nickel, zinc and arsenic can enter waters from mines, industrial wastes, urban runoff and polluted sediments. Fish may take up these metals through the gills, food or surrounding water. After uptake, the metals can collect in tissues, disturb enzyme activity, trigger oxidative stress and injure organs.

Javed et al. (2017) studied Channa punctatus exposed to wastewater containing heavy metals and observed metal build-up in the gills, liver and kidney, together with oxidative stress, genotoxicity and histopathological damage. This indicates that metal pollution can harm aquatic animals at biochemical, cellular and tissue scales. Rainbow (2007) also noted that trace-metal accumulation in aquatic invertebrates differs by species and metal, but accumulated metals may become metabolically available and toxic.

3.4 Pesticides and Endocrine-Disrupting Chemicals

Pesticides can reduce aquatic biodiversity through direct toxic effects and through indirect changes in food webs. Relyea (2005) found that commonly used insecticides and herbicides can lower both biodiversity and productivity in aquatic communities. Beketov et al. (2013) likewise reported reduced regional biodiversity of stream invertebrates in relation to pesticide exposure.

Endocrine-disrupting chemicals disturb hormonal regulation and may affect reproduction, sex differentiation, gamete formation and larval development. Jobling et al. (1998) reported sexual disruption in wild fish, and Vajda et al. (2008) found reproductive disruption downstream of estrogenic wastewater effluent. Kidd et al. (2007) showed in a whole-lake study that exposure to a synthetic estrogen could collapse a fish population, demonstrating that endocrine effects can extend to the population level.

3.5 Bioaccumulation and Biomagnification

Bioaccumulation refers to the build-up of a contaminant inside an organism when uptake is faster than elimination. Biomagnification refers to the increase in contaminant concentration from one trophic level to the next. These processes are important for methylmercury, some pesticides and persistent industrial chemicals.

Minamata disease provides a well-known example. Harada (1995) described it as methylmercury poisoning linked to eating fish and shellfish contaminated by methylmercury from industrial wastewater. The case shows how pollutants can pass from water and sediment into aquatic organisms and then into predators, including people. Mercury released to water can persist, settle in sediments and enter food chains as methylmercury (Minamata Convention Secretariat, 2023). Figure 2 depicts how persistent pollutants move through aquatic food chains by bioaccumulation and biomagnification.

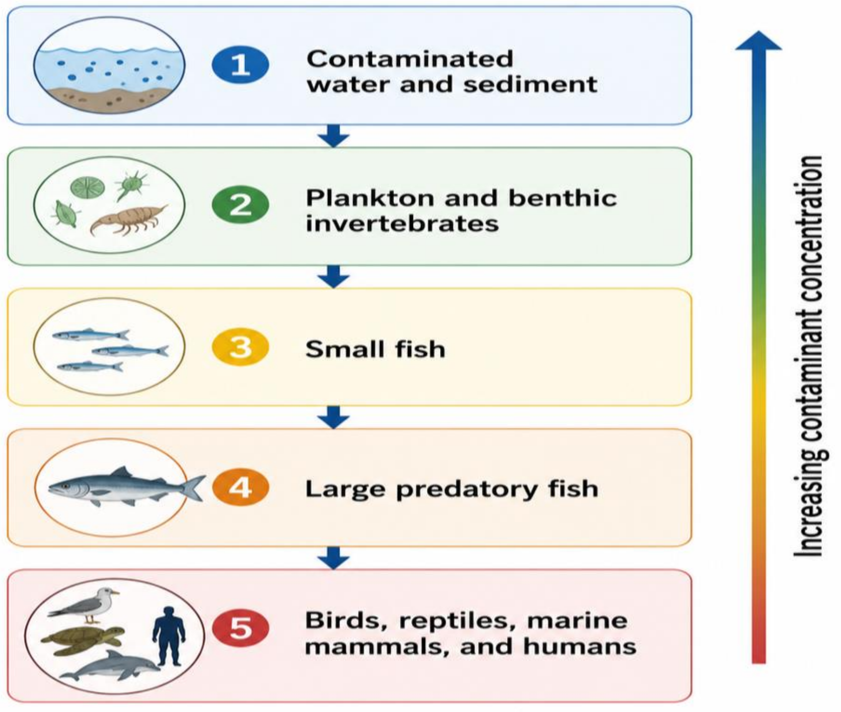

Figure 2:. Pollutant Build-up and Transfer Through Aquatic Food Chains

Source: Figure developed from Harada (1995), Rainbow (2007) and Minamata Convention Secretariat (2023).

3.6 Microplastic Ingestion and Chemical Transfer

Microplastics can harm aquatic animals when particles are swallowed, interfere with feeding, irritate the gut, move into tissues or carry chemicals. Cole et al. (2013) recorded microplastic ingestion by zooplankton, suggesting that plastics can enter food webs near their base. Browne et al. (2008) found that microscopic plastic particles can pass from the gut into the circulatory system in mussels. Microplastics may also act as carriers of hazardous chemicals. Rochman et al. (2013) found that ingested plastic moved harmful chemicals into fish and produced liver stress. Lu et al. (2016) reported uptake and accumulation of polystyrene microplastics in zebrafish, along with liver toxicity. Together, these findings indicate that microplastic pollution can be both a physical and chemical stressor.

3.7 Sedimentation, Turbidity and Habitat Degradation

Sediment pollution occurs when suspended particles from construction, farming, mining, deforestation or dredging are washed into water bodies. These particles can block fish gills, reduce feeding efficiency, bury eggs, limit light penetration and change benthic habitats. Newcombe and Jensen (1996) proposed quantitative methods for evaluating fish responses to suspended sediment exposure, and Bilotta and Brazier (2008) reviewed how suspended solids influence water quality and aquatic biota.

Habitat damage can make chemical pollution more harmful. When spawning areas, wetlands, riparian zones or benthic habitats are degraded, aquatic animals lose shelter, food resources and breeding sites. Sensitive taxa may then be replaced by organisms that tolerate pollution, reducing ecological complexity and resilience.

3.8 Oil Pollution and Marine Animal Injury

Oil harms aquatic animals by covering body surfaces, contaminating prey, damaging respiratory tissues and exposing organisms to petroleum hydrocarbons. During the Deepwater Horizon disaster, oil entered habitats used by marine mammals, sea turtles, fishes and benthic fauna. Takeshita et al. (2017) assessed marine mammal injury after the spill, while Incardona et al. (2014) found that Deepwater Horizon crude oil disrupted cardiac development in embryos of large predatory pelagic fish such as tuna and amberjack. White et al. (2012) reported effects on deep-water corals, showing that oil can damage both mobile animals and fixed benthic organisms.

Table 2 groups the main biological effects of water pollution across cellular, tissue, organism, population, community and ecosystem levels.

Table 2: Biological Responses of Aquatic Animals to Water Pollution

Biological scale	Effect of pollution	Example	Key citations
Cellular scale	Oxidative stress, DNA injury and enzyme interference	Fish tissues exposed to metals	Javed et al. (2017); Rainbow (2007)
Tissue scale	Damage to gills, liver, kidneys and reproductive organs	Histopathological damage and liver stress	Javed et al. (2017); Rochman et al. (2013); Lu et al. (2016)
Whole-organism scale	Lower feeding, respiration, growth and immunity	Surface gasping, slow growth and stress behaviour	USEPA (2026); Vaquer-Sunyer & Duarte (2008)
Reproductive scale	Hormonal disruption and lower fertility	Intersex fish and population collapse	Jobling et al. (1998); Kidd et al. (2007); Vajda et al. (2008)
Population scale	Lower recruitment and higher mortality	Loss of sensitive fish and invertebrates	Beketov et al. (2013); Sayer et al. (2025)
Community scale	Species replacement	Dominance by pollution-tolerant taxa	Dudgeon et al. (2006); Reid et al. (2019)
Ecosystem scale	Food-web disturbance and biodiversity loss	Dead zones, eutrophication and habitat degradation	Diaz & Rosenberg (2008); Breitburg et al. (2018)

Key Concepts

4.1 Dissolved Oxygen in Water

Dissolved oxygen is the oxygen present in water that aquatic organisms use for respiration. Fish and aerobic invertebrates need adequate oxygen for metabolism, movement, growth and reproduction. Low oxygen can trigger stress, movement away from affected areas, reduced feeding and death. USEPA's guidance notes that DO below 5 mg/L is generally stressful for fish, and DO below 3 mg/L cannot support many fish species (USEPA, 2026).

4.2 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is the amount of oxygen microorganisms need to break down organic matter in water. A high BOD value signals strong organic pollution. As BOD rises, dissolved oxygen falls, which can stress aquatic animals. For that reason, BOD is an important measure in river-pollution evaluation and wastewater management.

4.3 Eutrophication

Eutrophication is the enrichment of water with nutrients, mainly nitrogen and phosphorus. It can produce algal blooms, cyanobacterial dominance, reduced light penetration, oxygen loss and food-web changes. Limiting nutrient inputs is widely accepted as a key approach to controlling eutrophication (Schindler, 1974; Smith et al., 1999; Conley et al., 2009).

4.4 Hypoxia and Anoxia

Hypoxia refers to low dissolved oxygen, while anoxia refers to the absence or near absence of oxygen. Hypoxia can shrink usable habitat and kill bottom-dwelling organisms. For the Gulf hypoxic zone, NOAA identifies hypoxic seafloor areas using oxygen levels of 2 mg/L or lower (NOAA, 2025).

4.5 Bioaccumulation and Biomagnification

Bioaccumulation takes place inside an individual organism over time, whereas biomagnification occurs as contaminants move through feeding levels. These processes explain why predatory fish, birds, reptiles and marine mammals may contain high pollutant concentrations even when the surrounding water contains only low levels.

4.6 Endocrine Disruption

Endocrine disruption occurs when chemicals disturb hormone systems. In aquatic animals, such disturbance may affect sex differentiation, fertility, spawning behaviour and recruitment. Kidd et al.'s (2007) whole-lake estrogen experiment, which led to fish-population collapse, shows the ecological seriousness of this type of disruption. Table 3 defines the main concepts used to explain pollution effects on aquatic life.

Table 3: Core Concepts Used in Aquatic Pollution Analysis

Term	Meaning	Aquatic-life relevance	Key citations
Dissolved oxygen	Respirable oxygen present in water	Supports survival of fish and aerobic invertebrates	USEPA (2026)
BOD	Oxygen consumed during microbial decomposition	High BOD lowers DO and causes respiratory stress	USEPA (2026); PIB (2026)
Eutrophication	Excessive nutrient enrichment	Produces algal blooms and oxygen loss	Schindler (1974); Carpenter et al. (1998); Smith et al. (1999)
Hypoxia	Low-oxygen condition	Shrinks habitat and stresses fish and benthic fauna	Diaz & Rosenberg (2008); Vaquer-Sunyer & Duarte (2008)
Anoxia	No or almost no oxygen	Often fatal for aerobic organisms	Breitburg et al. (2018)
Bioaccumulation	Build-up of pollutants within organisms	Leads to chronic toxicity and tissue contamination	Rainbow (2007); Harada (1995)

Term	Meaning	Aquatic-life relevance	Key citations
Biomagnification	Increase of pollutants along food chains	Endangers predators and higher consumers	Harada (1995)
Endocrine disruption	Interference with hormones	Can reduce reproduction and population stability	Jobling et al. (1998); Kidd et al. (2007)
Microplastic translocation	Particle movement beyond the gut	Can create tissue-level physical and chemical stress	Browne et al. (2008); Lu et al. (2016)
Sediment stress	Suspended particles in water	Can block gills and bury eggs	Newcombe & Jensen (1996); Bilotta & Brazier (2008)

Case Studies / Examples

5.1 Gulf Hypoxic Zone

The Gulf hypoxic zone is a clear example of nutrient-driven oxygen loss. NOAA reported that in 2025 the zone covered 4,402 square miles of seafloor, using 2 mg/L or lower as the low-oxygen threshold (NOAA, 2025). Such conditions reduce available habitat for fish, shrimp and benthic organisms. Mobile animals may leave the area, but less mobile species can suffer stress or die.

5.2 Minamata Mercury Contamination

Minamata disease in Japan illustrates the danger of industrial mercury contamination. Methylmercury discharged into water entered fish and shellfish and then moved through the food chain. Harada (1995) identified the disease as methylmercury poisoning from eating contaminated aquatic products. The example shows how persistent pollutants can bioaccumulate and biomagnify.

5.3 Deepwater Horizon Spill

The Deepwater Horizon spill released about 134 million gallons of oil over 87 days and affected large areas of marine habitat (NOAA, 2017). Scientific assessments reported injuries involving marine mammals, sea turtles, fish embryos and deep-water corals. Incardona et al. (2014) reported developmental heart effects in pelagic fish embryos exposed to the crude oil, White et al. (2012) documented damage in a deep-water coral community, and Takeshita et al. (2017) assessed marine mammal injuries, showing why organised post-spill assessment is ecologically and legally important.

5.4 Polluted River Stretches in Indian River Systems

India's Central Pollution Control Board tracks river water quality through national monitoring programmes. A 2026 Government of India release stated that CPCB's 2025 report, using 2022 and 2023 water-quality data, identified 296 polluted stretches on 271 rivers. It also reported a decrease from 351 polluted stretches in 2018 to 296 in 2025 (Press Information Bureau, 2026). The figures show continuing pressure on river habitats despite some reported improvement.

Table 4 summarises selected cases that show different pollution types and their ecological importance.

Table 4: Case Studies of Aquatic Pollution Impacts

Example	Pollution form	Verified evidence	Ecological significance	Key citations
Gulf hypoxic zone	Nutrient enrichment and hypoxia	4,402 square miles of low-oxygen seafloor in 2025	Less habitat for fish, shrimp and benthic organisms	NOAA (2025); Diaz & Rosenberg (2008)
Minamata, Japan	Methylmercury contamination	Fish and shellfish contamination led to methylmercury poisoning	Shows bioaccumulation and biomagnification	Harada (1995); Minamata Convention Secretariat (2023)

Example	Pollution form	Verified evidence	Ecological significance	Key citations
Deepwater Horizon	Oil contamination	134 million gallons of oil released during 87 days	Harm to marine mammals, turtles, fish embryos and corals	NOAA (2017); Incardona et al. (2014); White et al. (2012); Takeshita et al. (2017)
Indian rivers	Organic and mixed contamination	296 polluted stretches across 271 rivers in CPCB's 2025 report	Indicates continuing river-quality pressure and need for monitoring	PIB (2026); CPCB water-quality criteria

Legal and Environmental Framework

6.1 Indian Legal Framework

India's main law on water pollution is the Water (Prevention and Control of Pollution) Act, 1974. The Act is intended to prevent and control water pollution and to maintain or restore the wholesomeness of water. It also creates the Central and State Pollution Control Boards and assigns them functions connected with water-pollution control (Government of India, 1974).

The Environment (Protection) Act, 1986 gives a wider environmental basis for regulation. It treats the environment as including water, air and land, together with their relationships with people, living creatures, plants, microorganisms and property. It also defines environmental pollutants as substances present at levels that may harm the environment (Government of India, 1986).

The Water (Prevention and Control of Pollution) Amendment Act, 2024 is relevant because it changes selected provisions of the 1974 Act and updates parts of the water-pollution-control system (Government of India, 2024). CPCB's designated-best-use categories also provide benchmarks relevant to aquatic life. For Class D water, meant for wildlife and fisheries, the criteria include pH 6.5-8.5, dissolved oxygen of at least 4 mg/L and free ammonia as nitrogen not above 1.2 mg/L (Central Pollution Control Board, 2008).

6.2 International Environmental Framework

Internationally, SDG Target 6.3 focuses on improving water quality by reducing pollution, ending dumping, minimising hazardous chemical releases, cutting untreated wastewater and expanding safe reuse. SDG Indicator 6.3.2 monitors ambient water quality in rivers, lakes and groundwater (UNEP, 2024).

The Kunming-Montreal Global Biodiversity Framework is also relevant. Its Target 7 calls for pollution risks and negative impacts from all sources to be reduced by 2030 to levels that are not harmful to biodiversity and ecosystem functions. It specifically refers to excess nutrient loss, pesticide risk and plastic pollution (Convention on Biological Diversity, 2022). For marine pollution, MARPOL is the main international agreement dealing with ship-based pollution from operational or accidental causes (International Maritime Organization, 1973/1978). Table 5 summarises the main frameworks linked to water-pollution control and aquatic animal protection.

Table 5: Frameworks Relevant to Water-Pollution Control and Aquatic Fauna

Framework	Year	Relevance for water-pollution control and aquatic life
Water Act, India	1974	Aims to prevent and control water pollution and restore water wholesomeness
Environment Protection Act, India	1986	Regulates pollutants that may harm water and living organisms
Water Amendment Act, India	2024	Revises selected provisions of the Water Act

Framework	Year	Relevance for water-pollution control and aquatic life
CPCB water-quality criteria	Ongoing	Provides designated-use criteria, including DO and pH benchmarks for wildlife and fisheries
SDG Target 6.3 / Indicator 6.3.2	2015 onward	Monitors ambient water quality in rivers, lakes and groundwater
Kunming-Montreal GBF Target 7	2022	Calls for pollution reduction to levels that do not harm biodiversity
MARPOL	1973/1978	Regulates ship-source marine pollution, including oil, sewage and garbage
Minamata Convention	2013	Targets mercury pollution and its environmental-health impacts

Source: Framework details compiled from the Water Act, 1974; Environment Protection Act, 1986; Water Amendment Act, 2024; UNEP SDG 6.3.2 materials; CBD Target 7; IMO MARPOL documentation; and the Minamata Convention framework.

Preventive Measures and Solutions

7.1 Wastewater Treatment and Sewage Control

Sewage should not be discharged into rivers, lakes or coastal waters without treatment. Secondary treatment lowers organic matter and BOD, while tertiary treatment can reduce nutrients such as nitrogen and phosphorus. This matters because sewage-related organic loading directly lowers dissolved oxygen and raises disease pressure.

7.2 Nutrient-Load Reduction

Controlling nutrient loads is necessary to prevent eutrophication. Useful measures include precise fertiliser use, manure management, riparian buffer strips, constructed wetlands, stormwater control and reduced nutrient inputs from detergents and sewage. Although nutrient restriction is central to eutrophication control, recovery varies with ecosystem type, stored nutrients in sediments and hydrological conditions (Carpenter et al., 1998; Smith et al., 1999; Conley et al., 2009).

7.3 Industrial Effluent Control

Industries should rely on effluent-treatment plants, cleaner production, replacement of hazardous chemicals and continuous discharge monitoring. Regulation should give priority to heavy metals, persistent organic pollutants, acids, dyes, solvents and petroleum residues. Since metals can accumulate in fish tissues and produce oxidative stress, genotoxicity and histopathological injury, controlling discharge at the source is more effective than trying to restore contaminated systems later (Rainbow, 2007; Javed et al., 2017).

7.4 Pesticide and Pharmaceutical Control

Pesticide use in agriculture should be lowered through integrated pest management, buffer zones and restrictions near water bodies. Wastewater systems should also be improved to reduce hormones, pharmaceuticals and endocrine-active compounds. Evidence of pesticide-related invertebrate biodiversity loss and estrogen-related reproductive disruption in fish supports stricter ecological risk assessment for chemical discharges (Beketov et al., 2013; Kidd et al., 2007; Vajda et al., 2008).

7.5 Plastic and Microplastic Prevention

Preventing plastic pollution requires less single-use plastic, better waste collection, recycling, storm-drain filtration, recovery of fishing gear and microfibre filtration in wastewater systems. Because microplastics can be eaten by zooplankton, mussels and fish and may carry hazardous chemicals, controlling plastic at the source is more practical than removing it after it has spread through the environment (Browne et al., 2008; Cole et al., 2013; Rochman et al., 2013; Lu et al., 2016).

7.6 Oil-Spill Prevention and Emergency Response

Oil-spill prevention depends on strict offshore drilling standards, ship-safety rules, tanker monitoring, emergency-response systems and restoration planning. After a spill, response measures should include wildlife rescue, habitat rehabilitation, sediment assessment and long-term monitoring. Evidence from Deepwater Horizon shows that oil can affect marine mammals, turtles, fish embryos and corals across different habitats (NOAA, 2017; Incardona et al., 2014; White et al., 2012; Takeshita et al., 2017).

7.7 Biological Monitoring and Habitat Restoration

Chemical monitoring should be supported by biological monitoring. Measures such as fish diversity, macroinvertebrate indices, plankton composition, tissue contaminant levels, reproductive biomarkers and larval survival can show ecological stress more directly than chemical readings alone. Restoration should cover wetlands, riparian vegetation, spawning grounds, floodplain connectivity and ecological flows because aquatic animals need functional habitats as well as clean water. Table 6 lists preventive measures and their expected benefits.

Table 6: Pollution Prevention Measures and Expected Benefits

Pollution issue	Preventive action	Expected aquatic-life benefit
Untreated sewage	Secondary and tertiary sewage treatment	Lower BOD, improved DO and reduced pathogen exposure
Nutrient runoff	Controlled fertiliser use, manure management, riparian buffers and wetlands	Fewer algal blooms, eutrophication events and hypoxic zones
Industrial discharge	Effluent treatment, cleaner production and real-time monitoring	Reduced toxic exposure and organ damage
Heavy metals	Source control, sediment management and hazardous-waste regulation	Less bioaccumulation and food-chain contamination
Pesticides	Integrated pest management and buffer areas	Better protection for fish, amphibians and invertebrates
Pharmaceuticals	Advanced treatment and source reduction	Lower endocrine and behavioural effects
Microplastics	Waste reduction, fibre filtration and fishing-gear recovery	Less ingestion, tissue exposure and chemical transfer
Oil pollution	Spill prevention, response planning and habitat restoration	Lower smothering, PAH exposure and marine-animal mortality
Habitat degradation	Wetland, riparian and ecological-flow restoration	Improved spawning, feeding and nursery habitats
Weak enforcement	Monitoring, penalties and polluter-pays application	Stronger accountability and deterrence

Source: Measures compiled from evidence on nutrient pollution, dissolved oxygen, heavy-metal toxicity, pesticide effects, microplastic ingestion, oil-spill impacts and biodiversity protection frameworks, including Carpenter et al. (1998), USEPA (2026), Javed et al. (2017), Beketov et al. (2013), Kidd et al. (2007), Browne et al. (2008), Rochman et al. (2013), NOAA (2017), CBD (2022) and UNEP (2024).

Figure 3 presents an integrated model for pollution prevention and aquatic animal protection.

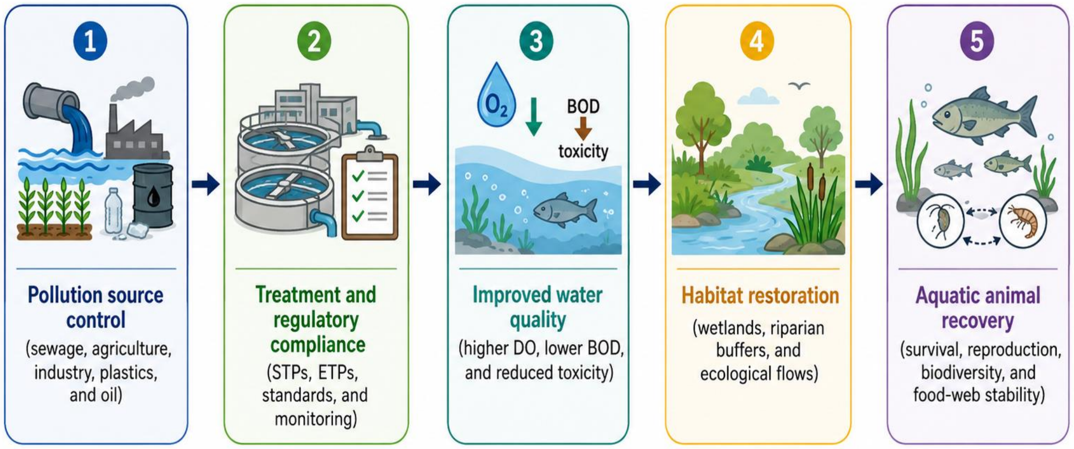

Figure 3: Integrated Model for Preventing Pollution and Protecting Aquatic Animals

Source: Figure developed from USEPA (2026), Carpenter et al. (1998), CBD (2022), Javed et al. (2017), Rochman et al. (2013) and NOAA (2017).

Conclusion

Water pollution harms aquatic animals through several linked pathways. Sewage and other organic wastes raise biochemical oxygen demand and lower dissolved oxygen. Excess nutrients encourage eutrophication, algal blooms, hypoxia and fish mortality. Heavy metals and industrial chemicals can injure gills, liver, kidneys, DNA and metabolic processes. Pesticides and endocrine-disrupting chemicals can affect reproduction, development and population recruitment. Persistent pollutants such as methylmercury accumulate in organisms and become more concentrated along food chains. Microplastics may be swallowed and may transport hazardous chemicals, while petroleum hydrocarbons can smother animals, cause developmental toxicity and contaminate habitats.

The central point is that water pollution is not simply a matter of chemical contamination; it is also a problem for biodiversity and ecosystem functioning. Its effects can be seen in individual organisms, recruitment of new individuals, community composition, food-web stability and habitat quality. The Gulf hypoxic zone, Minamata, Deepwater Horizon and polluted Indian rivers show impacts ranging from local mortality to long-term ecosystem decline.

Protection of aquatic animals therefore needs combined action: sewage and industrial effluent treatment, lower nutrient runoff, strict control of metals and pesticides, prevention of plastic and oil pollution, biological monitoring and restoration of wetlands, riparian areas and ecological flows. Legal frameworks should be applied in ways that protect ecological integrity as well as human water use. Clean, oxygen-rich and biologically balanced water is necessary for aquatic animal survival, reproduction and long-term biodiversity conservation.

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