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THE EFFECTS OF FISH FARMS ON WATER SOURCES

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ABSTRACT

Fishing and aquaculture have an effect on aqueous medium where these activities are performed, which is the case in many other activities. Negative environmental pressures appear with the industrialization in each production branch. Although the spread of the fishery industry and the fast growth in aquaculture activities have brought important socio-economic benefits, they have also caused important ecological changes, and the negative effects of aquatic ecosystems on water quality and ecologic structure cause that various concerns are mentioned about the environment. The changes in water quality, eutrophication, algae explosions, the increase in the amount of phosphor, the decrease in dissolved oxygen amount, the changes in benthic fauna, the colonization in filament bacteria, the precipitation of solid matters, the increase in TSS, turbidity, the change in the color of the water, smell, disruption in the area use or changes in biological variety are some of the environmental pressures caused by fishing industry and aquaculture activities. When these effects are considered, it is easily understood that the fishery and aquaculture activities in aquatic media may damage the conformity of the water sources for drinking and usage, they may even cause that these sources disappear completely. In order to sustain water sources and aquaculture activities, the factors that might affect the water quality and aquatic ecosystem must be kept under control both before and during these activities; and it is also clear that protection and monitoring programs in aquatic systems are necessary and wise planning and management strategies must be prepared for these purposes.

Keywords: Fish Farms, Water Sources, Water Quality, Environmental Effects.

INTRODUCTION

Specialists mention that the production throughout the world must be doubled in order to feed the increasing world population in an adequate and balanced way by 2050s because of the global threats. It has been known since ancient times that water products have an important place in nutrition of humans (1).

In periods when aquaculture and fishery activities were not common as today, in those times when the food requirement of the world population was less, the water products that were needed were covered mostly with hunting (2). However, the increasing population, excessive and unconscious hunting and negative environmental effects caused unfortunately that fish population decreased in a fast way and some species became endangered. In this context, although some precautions were taken, it is an extremely important issue mentioned by specialists that the fish stocks will never increase at the desired level, and the gap that appear with the decrease in fish stocks will only be covered with culture fishery activities. In another point of view, the increasing need for food with the increasing population, technological developments, economic growth, the importance given to healthy nutrition and similar factors increased the production amount with aquatic organisms, which are the cheap and quality protein sources, by culture fishery methods (2). In this context, when the fact that the gap that appears with the decrease in fish stocks may only be covered with culture fishery activities is considered, it becomes obvious that fishery and aquaculture activities are indispensable activities for the world (1).

Nearly 40% of the world fishery and aquaculture production consist of fishery growing activities. According to the scientific activities conducted so far, the investment on aquatic products will increase in forthcoming years; and by 2030, the amount of water products obtained with fishery activities will equal to the water products amount that will be obtained by hunting; and in the long run, it is estimated that the fishery growth activities will surpass the hunting sector. This increases the importance and ecological value of the seas and internal water bodies in the world in socio-economic terms. However, it is extremely important and necessary to protect and use water sources in a planned manner with the precautions that will be taken in terms of sustainable environment (1).

The dam lakes and reservoirs in which culture fishery activities are made, there may appear changes in the nutrient levels due to intensive breeding activities. Nitrogen and Phosphor fractions, which are main potential pollutants specific to fishery systems, enter the aquatic environment in dissolved of particle form. In intensive fish breeding activities, the feed and stool wastes create negative effects on the sediment, and the particles and dissolved nutrient elements create additional negative effects on water column. While main changes in water quality are characterized with nitrogen and Phosphor concentrations, the changes in the sediment quality include the variations in total nitrogen amount, total phosphor, carbon and organic matter and redox potentials (3).

In recent years, the spread of growth water products with net cages in dam lakes have brought some environmental concerns and problems. One of the major ones among these concerns is the environmental pressure that may be caused by water products activities in receiving bodies (3,4,5). In aquatic areas, pollution, area use disruptions or changes in biological variety and similar negative environmental effects constitute some of the environmental pressure factors (6).

When the drying and shrinking lakes and aquatic areas are considered in our country, it is possible to observed that it is necessary to develop management strategies with protection and monitoring programs for the purpose of sustainable use of water sources and sustain water product growth. There are many studies conducted on this field, and it is observed clearly that there is a need for legal regulations (3).

Fishery and water products growth activities in our country

Surrounded by seas on three sides, Turkey has 8.333 km coastal line, and 177.714 km streams and rivers. Turkey has an aquatic area consisting of nearly 26 million hectares. 24,69 million

hectares of the total water area consist of seas; 1,39 million hectares consist of natural lakes and dam lakes. When this potential of our country is considered, it is understood that it is extremely suitable in terms of water products growth potential, and it is important to use fishery activity areas in an efficient manner (1, 2).

With the development of fishery activities in Turkey, dams and ponds have been used for the purpose of ensuring protection from floods, providing drinking and irrigation water, and energy production as well as fishery activities as of the 1990s. In our country, in the dam lakes and ponds, net cages are used in fish production in a widespread manner, and in seas, dam lakes, concrete and fiberglass ponds intensive breeding is performed; and in soil-pools and lakes, semi-intensive breeding is performed, and in some areas, it is performed with closed-circuit systems (7). The amount of production obtained in internal water bodies has an important place in the total production in water products breeding activities, which is also the case in the whole world.

The effects of fishing and aquaculture activities on water quality

The increase in the population of the world, and depending on this, the increase in the gap in covering the food and animal nutrients has also increased. In order to eliminate this gap, the importance of culture fish breeding is also increasing (11). While the rate of fishing activities performed with hunting is decreasing in total production in our country, which is also the case in the whole world, the rate of fish breeding activities performed with culture growth is increased in a fast pace (2).

The favored location of estuaries and coastal zones for maritime exchanges and their large diversity of exploitable resources have encouraged the extensive development of urban, agricultural and industrial areas which threaten their ecosystems (12- 15).

Although the spread of fishing and water product breeding activities have brought important socio-economic benefits, it has also caused important ecological changes. The negative effects of aquatic ecosystems on water quality and ecological structure also produce various concerns. The type and influence area of ecological and environmental change depend on the water products breeding method, the amount of the production, and on the physical, chemical and biological character of the aquatic medium. The main input is the fish feed in the majority of intensive fish breeding systems. Partly fish biomass, partly organic solid matters or dissolved matters, wasted feed, and stool enter the system from the kidneys andgills. Other pollutants are the residues of medication with the various formulation used to cure diseases (6, 7).

In studies conducted so far, it has been accepted that aquaculture causes less negative effects on the ecosystem (9). However, in some coastal areas, for example in companies in Europe where intensive fish breeding is performed, and in some shrimp companies in Southeastern Asia and Latin America, environmental destructions have been reported (6, 9, 10).

Table 1. The effects stemming from the wastes of the breeding plant reported in a study conducted on 200 fish breeding plants (11)

The Effects	**The Number of the Cases**
Eutrophication	22
Increase in the phosphor amount	15
Increase in the sanitation indicator bacteria	11
Decrease in the dissolved oxygen amount	9
Increase in the algae explosions	8
Filament bacteria colonization and precipitating solid matters	5
Increase in the chlorophyll-a concentration	4
Increase in the macrophytes	3
Turbidity	2
Smell	2
Bad taste in fish	2
Non-drinkable water	2
Limitation of drinkable water sources	1
Fish measurements	1
Changes in the benthic fauna	1
Polluted fish traps	1
Disruption in the hunting	1

Table 2. The effects stemming from the wastes of the plant reported in a study in 141 Fish breeding plants in the UK (11)

Effect Type	**The Number of the Cases**
Changing the color of the water and suspended solids increase	17
Algae explosions	3
Smell	1
Total	21

In Table 1 and Table 2, the effects observed depending on the nutrient elements stemming from fish breeding activities will change depending on the breeding capacity, the quality of the water body in which the breeding activity is performed (depth, temperature, hydraulic retention time, etc.) aside from the factors related to with the breeding plant, and on the quality of the fish feed (11).

The negative effect of fish breeding in cages on water sources stem mainly from the wastes of the fish breeding activities (7). Feed and fecal pellet wastes, the soluble wastes that accumulate in the sediment layer spread in the water column. Nearly 70% of the nitrogen compounds consumed by fish are eliminated from the body as ammonium and urea, and cause hyper nutrition with the other soluble compounds like vitamins. Changes may be observed in phytoplankton and zooplankton composition as a result of the local eutrophication caused by hyper nutrification. In addition, breeding activities also limit the oxygen use. The storing of organic wastes cause that the oxygen used by the sediment increases; and as a result, the oxygen in the bottom finishes (8, 16).

The effects of fish breeding activities in cages may be summarized as follows;

- Negative effects of aquatic medium on some physico-chemical and water quality parameters,
- The effect of aquatic medium on sediment quality,
- Ecological, biological and nutrient network interaction,
- The disruption of the aquatic ecosystem,
- Negative effects that will be caused by uncontrolled use of chemicals (2, 7, 17).

Limiting nutrient elements

The enrichment of lakes, rivers, coastal area waters and similar surface water sources in terms of nutrient elements in time is called as eutrophication or hyper-nutrification. It is possible to observe the examples of dam lakes, ponds and lakes that are extremely enriched with nutrients both in the world and in Turkey.

The concept of “limiting” in ecology is defined as the elements that limit biological development when they do not exist in the medium. The basic two elements that limit development are inorganic nitrogen (N9 and phosphor (P). these basic elements that play roles in the development of organisms are also called as “macronutrients”. When these elements are terminated in the aquatic ecosystem, algae development stops. When they are included in the system, the algae population (or the primary production) increases until it is limited again by nutrient elements or by different environmental factors.

While the limiting nutrient element is generally phosphor in stable water bodies, it is the Nitrogen in sea ecosystems. In aquatic ecosystem, nitrogen may be reduced to nitrate, nitrite, ammonium and molecular nitrogen. In oxidant medium, ammonium nitrogen may and oxidized to nitrite and nitrate. Nitrogen nutrient element is released from fish breeding cages; and ammoniac is released as dissolved and particle organic compounds. As long as there is not intense bacterial nitrification in and around the area where cages are located, they exist in water at low concentration levels (19, 20). Phosphor exists less in aquatic media when compared with other macro nutrient elements. Especially is unpolluted water bodies, phosphor concentration in less. In fresh waters, total phosphor values show a wide range of distribution as 0,005 mg/L in very infertile lakes, and as 0,1 mg/L in very fertile lakes. The surface waters of unpolluted lakes contain total phosphor between 0,01 - 0,05 mg/L; and the high phosphor concentration shows that there is pollution. Since phosphor exists less in biosphere when compared with nitrogen, it exists less in natural lakes that have not changed (18, 19).

The release of nitrogen and phosphor to aquatic medium occurs due to losses of the fish feed, fecal residues, and metabolic wastes. When the use of phosphor by fish is considered, the excessive existence of phosphor in the fish feed becomes obvious. The excessive phosphor is released without being used. In a previous study, it was determined that the amount of the phosphor released with stool is at a rate of 2% of the stool. In order to obtain 1000 kg fish, 1500 kg fish feed is used in salmon cages, and the carbon and phosphor release was calculated (21). Although the amount of nitrogen taken with feed changes according to fish species, nearly 20-30% of it remains in the fish body and the remaining 70-80% is left to the water. The nitrogen that is in the form of ammonium and urea accelerates the development of phytoplankton, and causes eutrophication. There appear changes in the amount of life and organisms as a result of this (8).

The entry of nutrient elements to water occurs through the point of spread sources. Although eutrophication is controlled by point sources in some areas, generally spread sources are more effective. The nutrient elements reach lakes and dam lakes through agricultural and animal husbandry activities, erosion, and with the washing of the soil with rainfall, etc. Since eutrophication occurs very slowly in natural lakes, it was observed that some lakes reach eutrophic level in nearly 100 years. However, with the increase of nitrogen and phosphor stemming from cage fish breeding activities, and from erosion, agricultural pollutants, domestic wastes, the nitrogen and phosphor increases in lakes, and therefore, the eutrophication is accelerated.

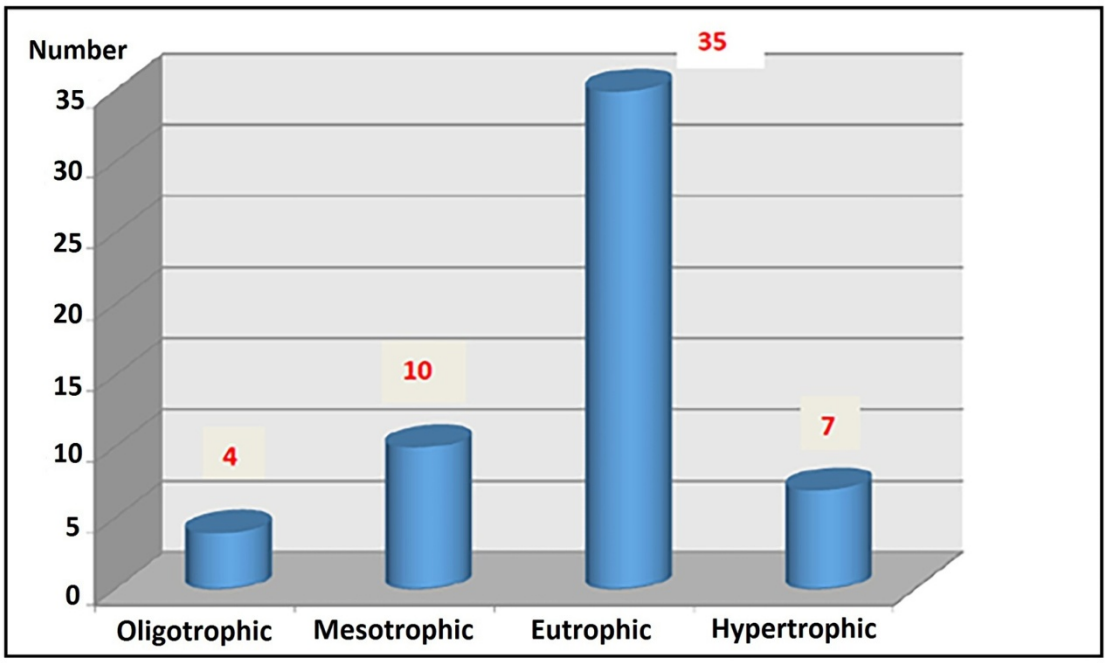

Figure 1. The distribution of trophic levels of the Dam Lakes where fish breeding is performed (2)

As it is seen in Figure 1, 35 of the dam lakes that are opened for fish breeding activities and where breeding is performed are eutrophic, and 7 of them are hypertrophic.

Organic wastes stemming from fish breeding

Algae explosions, the formation of the anoxic medium in water and sediment media are among the most important environmental problems caused by fish breeding activities. These waste sources consist of organic solid and dissolved wastes and inorganic nutrient elements. With the entry of these wastes in receiving body, in case the natural assimilation capacity of the aquatic ecosystem is exceeded, eutrophication occurs both in the water column and in the sediment; decreases are observed in oxygen concentration; and changes occur in the biovariety, which are all environmental problems (2, 22).

There are many studies conducted on the effects of fish breeding activities. According to the assumptions in the literature, nitrogen is released between 39 and 55 kg and phosphor is released between 5 and 10 kg per each ton of fish breeding in internal waters. The production of wastes and the environmental effects of them depend on the following factors;

- The amount of emission released from fish farm per unit,
- The breeding method applied in the plant,
- The content and amount of the feed used,
- The species bred in the plant,

- The concentration of the nutrient elements in the receiving body,
- The hydraulic retention time of the water body, and
- The temperature of the water (18, 23, 2, 11).

The waste types produced in the fish farms that are acting in fresh water or sea ecosystems are basically the same. The waste amount and content may only vary according to the species and breeding type. It is already known that the biggest share in waste formation stemming from fish breeding in cages belongs to the losses in the fish feed. Especially in fish breeding plants where a controlled feeding strategy is not applied, some of the feeds that are not consumed are dissolved in water and precipitate in the sediment layer below the cage and some of them are dissolved in water ringing the organic load of the water.

Fish may die unexpectedly due to diseases, poisoning, or technical problems in fish breeding plants. The removal of dead fish from the aquatic medium is an important factor both for the prevention of the spread of disease and for decreasing the nitrogen and phosphor loads (2).

The digested nutrient elements are absorbed through intestine walls of the fish. The excessive amount that is not needed for metabolic activities is released to the water as a side product. Especially nitrogen is released to the water in fish that are fed with fish feed whose protein/energy balance is not ideal (2, 7).

The effects on still waters

In areas where intensive cage fish breeding is applied, environmental effects were observed because the fish breeding activities affect the quality of the water, and biomass and variety of it with planktons, benthos, and nekton, and this will affect the other usage purposes of water bodies. The environmental effects vary according to breeding method and applications (breeding capacity and breeding method, etc.), the hydrography of the area, stock intensity, fam managements, the type of the fish feed, and the physical, chemical and biological characteristics of the area where breeding activity is performed (20, 24, 25). In order to assess the environmental effects of the wastes that come from fish breeding, the nutrient element concentration in the area before the establishment of the fish breeding farm, the hydraulic retention time of the water, and the nutrient element amount per unit released by the fish farm must be known. In addition, the layering and dispersion are also important in this context (2).

The observed effects of fish breeding in cages in still waters are also observed in fish breeding activities in seas. However, there are several differences between these two fish breeding activities. The current of the water is low and the organic matter accumulation is less in lakes when co pared with seas. The precipitation speed of the feed and metabolic wastes in still waters is lower than in the seas. In assessing the environmental effects of cage breeding in seas, benthic sediment composition and fauna changes should be assessed, which is emphasized in previous studies. In still waters, in assessing the effects of cage breeding, the status of the effects of the nutrient elements and the effects on the sediment, and depending on this, the eutrophication should be considered (2).

The effects on water quality parameters

The existence of soluble nutrient elements in water column may increase the toxic algae explosion risk, and may cause changes in phytoplankton intensity and in the composition of the species (26). These effects of fish breeding may appear in the short or long term (2).

The intense feeding in intensive fish breeding causes that nutrient elements enter the aquatic medium in dissolved form (nitrate, nitrite, ammonium, phosphate) and in the form of vitamins; unconsumed feed and wastes (solid and soluble).The excessive nutrient elements in the water column may cause;

- Excessive nutrient element enrichment,
- Benthos change,
- Mass death of fish,
- Algae explosions.

The studies conducted on the effects of the wastes that come from intensive fish breeding in cages on water column show that intensive breeding increases the nutrient element in the aquatic medium and the Suspended Solid Matter (SSM), and decreases the light transparency, dissolved oxygen amount, electric conductivity and pH parameter values (2, 17).

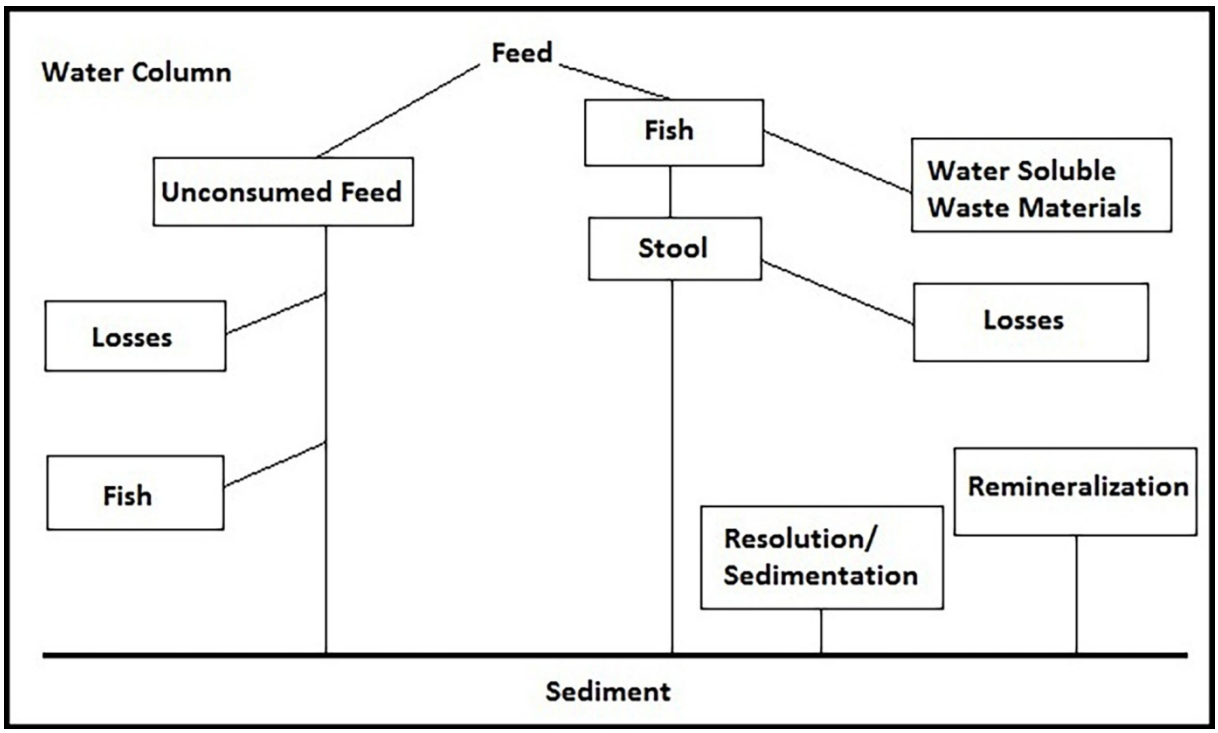

Figure 2. The formation and accumulation of wastes in water column in intensive fish breeding (27)

The effects on dissolved Oxygen concentration

Fish breeding activities limit the use of oxygen. The increase in the organic waste concentration causes that the oxygen concentration used by the sediment also increases, and as a result, causes that the oxygen finished in the bottom area (5, 28). As a result of the increase in the concentration of the organic matters in the water, the amount of oxygen in water decreases. When this rate decreases below 4 ppm, the life of living organisms is endangered (2, 7).

The organic matters in aquatic medium are decomposed in biochemical terms with the activities of bacteria. Aerobic bacteria decompose organic bacteria and convert them into CO_2, water and stable compounds. As a result of anaerobic decomposition, $NH_3$and H_2S and similar semi-stable compound also emerge. In such water types, the living organisms that are dependent on oxygen (aerobic) -mainly fish- cannot live. In addition, such water types are not suitable for drinking and use (2).

The effects of chemicals and drugs

The antifouling (killing fouling organisms), disinfectants (used for hygiene), algicides (algaekillers), herbicides (plant killers), pesticides (all of the plant and insect killers), parasiticidals (parasite killers), antibacterial agents (bacteria killers) and similar chemicals are used for the purpose of controlling diseases, increasing water quality criteria, and controlling aquatic plants (29). It was reported in a study conducted in Norway in salmon breeding plats that 18220 kg antibiotic (oxytetra cycline) was used. This amount corresponds to 210 grams per each ton of fish. When antibiotics are given with the feed, 20-30% are retained in the fish body, and 70-80% are released to the aquatic medium. 13 days after the treatment with oxytetra cycline, which was used frequently in the past in bacterial fish diseases, important antibiotic

accumulation was detected in the fish that were caught near the cages and that were caught in a distance of 400 miles and in the mussels caught 80 m away from the cages (5, 30).
In fish breeding in culture medium, when diseases are detected in fish, it is inevitable to use drugs for treatment (31). There are several studies showing that the antibiotics used in the treatment of bacterial diseases and the chemicals used for other purposes are accumulated in various living organisms in the aquatic medium (fish, mussels, shrimps, lobsters) (5, 20).

Benthic effects

It was reported in many previous studies that the wastes coming from fish breeding plants cause changes in the sediment chemistry and in the benthic ecosystem. It was also determined that the wastes stemming from fish breeding activities caused several effects on the benthic ecosystem in physical, chemical and biological terms. These effects basically depend on the location and breeding method. The effects were associated with the assimilation capacity of the area, physical variables, the depth, topography, currents and oxygen regime, stock intensity, feed type, feeding rates and area management (2, 7).

The effects of sediment quality

The solid wastes coming from fish breeding activities accumulate in the sediment. It was observed generally that the nitrogen, phosphor and carbon accumulate in the sediment. Some of the solid wastes that enter the aquatic ecosystem and that contain mainly carbon and nitrogen cause that the water quality in a negative way by being retained in the water column as Suspended Solid Matter. An important part is accumulated in the sediment and causes the enrichment of the benthic system, and leads to important changes in the benthic macro fauna and sediment chemistry (32).
When the participles stemming from fish breeding activities enter the aquatic medium, a series of chemical and biochemical events occur. The excessive carbon that precipitates in the substrata of the ground eliminates the current oxygen slowly causing that the sediment becomes anoxic. The micro flora changes towards anaerobic species, and the bacterial that produce methane and sulfide, which are unwanted in the medium, emerge. In previous studies, it was observed that the organic matter accumulation in the sediment stops after the fish cages are removed and the chemical structure of the sediment and the water above the sediment returned to the values that were measured before the breeding activity (2).

RESULTS AND RECOMMENDATIONS

As the population of the world increases, so does the gap for food and animal nutrients. The increase in the need for food increased at a rate of 3.2% leaving the population increase rate, which was 1.6% behind. Since fish breeding is considered as an alternative in filling the gap for food, this sector is growing in a fast pace. Parallel to the growth in fish breeding plants, the effects of fish breeding plants on water sources have become to a level that arouses concerns. Many studies have been conducted to minimize the environmental effects of fish breeding activities and to sustain the breeding sector in many countries. In recent studies, it was determined that the works intended to reduce the effects of fish breeding activities in Turkey on water quality and aquatic ecosystem were not at an adequate level. In this context, the studies conducted for the purpose of reducing the effects stemming from fish breeding activities were examined and recommendations were developed to reduce these effects.

In order to reduce the environmental effects of fish breeding plants;

- Fish breeding plants must be established in areas where there are fast currents instead of slow currents;
- Preliminary observations must be conducted in areas that are planned to use for fish breeding activities;
- The water quality must be monitored and assessed in areas where there are fish breeding activities;

- The fish feed types that may stay at the desired time in water and may be consumed completely by fish must be selected for the purpose of improving the feed quality;
- Plant-originated feed that has lower phosphor content and that support the fish development must be used in order to limit the phosphor content that exists in the fish feed;
- Especially in cage fish breeding activities, the capacity of the medium must not be exceeded;
- Environment-focused strategic plans must be prepared for fish breeding activities;
- Environment-friendly technologies must be investigated and the use of proper systems must be encouraged in fish breeding activities;
- The water quality and aquatic ecosystem must be assessed in areas where fish breeding activities are or will be performed;
- Programs must be prepared to monitor the water quality in areas where fish breeding activities are or will be performed;
- Good practices must be developed and applied in fish breeding plants;
- With the principle of ecosystem-focused fish breeding activities, the requirements of the environment management must be determined and applied;
- Strategic plans must be prepared for national fish breeding activities in which principles are adopted to reduce and prevent the negative effects of fish breeding activities on water sources, water quality, and aquatic ecosystem.

As a conclusion, important contributions will be made to the sustainability of environment-friendly fish breeding activities and to environment-friendly breeding activities by preparing multi-year national strategic plans intended to regulate the fish and water products breeding activities in Turkey and by considering the activities with environment-focused criteria.

REFERENCES

1. Su Ürünleri Raporu. İzmir Su Ürünleri Yetiştiricileri ve Üreticileri Birliği. 2014.
2. Tokgöz Yayan D. Durgun sularda balık yetiştiriciliğinin besin elementleri açısından etkilerinin azaltılması. 2015.
3. Yavuzcan H, Pülatsü S, Demir N, ve ark. Türkiye'de Sürdürülebilir Su Ürünleri Yetiştiriciliği.
4. Pülatsü S. The application of phosphorus budget model estimating the carrying capacity of Kesikköprü Dam Lake. Turkish Journal of Veterinary and Animal Sciences. 2003; 27(5), 1127-1130.
5. Bahadır Koca S, Terzioğlu S, Didinen BI, Yiğit NÖ. Sürdürülebilir Su Ürünleri Yetiştiriciliğinde Çevre Dostu Üretim. Ankara Üniversitesi Çevrebilimleri Dergisi. 2011; 3(1): 107-113
6. Orçun E, Sunlu U. Sığacık (Seferihisar-İzmir) Bölgesi ağ kafeslerde yapılan balık yetiştiriciliğinin sucul ortama olan etkilerinin araştırılması. E.Ü. Su Ürünleri Dergisi. E.U. Journal of Fisheries & Aquatic Sciences 2007; 24, (1-2): 01-09.
7. Varol M. Alabalık işletmelerinin çevreye olan etkileri ve alınacak önlemler. Sürdürülebilir Alabalık Yetiştiriciliği Çalıştayı. 2016.
8. Bayram S, Altunçiçek H. Balık yetiştiriciliğinden kaynaklanan kirliliğin çevreye etkisi ve çözüm yolları üzerine bir araştırma. Erzincan Üniversitesi Aqua Club Su Ürünleri Araştırma ve Geliştirme Bilim Kulübü Kemaliye 5.Geleneksel Su Ürünleri Bilimsel ve Kültürel Platformu. 2008.
9. Barg UC. Guideline for the promotion of management of costal aquaculture development of coastal aquaculture development. FAO Fisheries Technical Paper. No.328.,122p. by N. De. Pavas et al., Bredene, Belgium, E.A.S, 1992; 1071-1080.
10. Sreenivasan A. Pollution from industrial shrimp culture: A serious environmental threat. Fish Chimes. 1995; 15(5),19-20.

11. Pillay T. Aquaculture and environment. Blackwell Publishing. 2004.
12. Elliott M, Whitfield AK. Challenging paradigms in estuarine ecology and management. Estuar. Coast Shelf S. 2011; 94: 306–314.
13. Halpern BS, Selkoe KA, Micheli F, et al. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv. Biol. 2007; 21: 1301–1315.
14. Lotze HK. Historical reconstruction of human-induced changes in US estuaries. Oceanogr. Mar. Biol. 2010; 48: 267–338.
15. Teichert N, Borja A, Chust G, et al. Restoring fish ecological quality in estuaries: Implication of interactive and cumulative effects among anthropogenic stressors Science of the Total Environment. 2016; 542: 383–393.
16. Yıldırım Ö, Korkut AY. Su ürünleri yemlerinin çevreye etkisi. E.Ü. Su Ürünleri Dergisi. 2004; 21:167-172.
17. Pülatsü S, Topçu A, Atay D. Su kirlenmesi ve kontrolü. Ankara Üniversitesi Ziraat Fakültesi Yayınları, Yayın No:1617. 2014.
18. Canadian Council of Ministers of the Environment (CCME) Phosphorus: Canadian Guidance Framework For The Management Of Freshwater Systems. 2004.
19. Devlet Su İşleri Genel Müdürlüğü (DSİ). Ermenek Baraj Limnolojisi. 2013.
20. Yıldırım Ö, Korkut Y. Su ürünleri yemlerinin çevreye etkisi. Ege Üniversitesi Su Ürünleri Dergisi, 2004; 21(1-2): 167-172.
21. Yiğit M, Ergün S, Önal U. ve ark. Aquakültür ve turizm. Türkiye'den ve Dünya'dan Aqua Life of Turkey , Suda Yaşam Dergisi. 2006; 2(8): 60-63.
22. The World Conservation Union (IUCN). Guide for the Sustainable Development of Mediterranean Aquaculture No:1. 2007.
23. Fisheries and Oceans Canada, Canadian Technical Report of Fisheries and Aquatic Sciences 2450. 2006.
24. Beveridge M. Cage Aquaculture, Blackwell Publishing 2004; 230.
25. Davies P. Cage Culture of Salmonids in Lakes: Best Practice and Risk Management for Tasmania. 2000.
26. Yeo S, Binkowski P, Morris J. Aquaculture effluents and waste by-products characteristics. Potential Recovery and Beneficial Reuse. 2004.
27. UNEP/MAP. Mariculture in the Mediterranean. MAP Technical Reports Series No. 140. 2004.
28. Yıldırım Ö, Korkut Y. Su ürünleri yemlerinin çevreye etkisi. E.Ü. Su Ürünleri Dergisi. 2004; 21 (1-2): 167 – 172.
29. Haya K. Environmental impact of chemical wastes produced by the Salmonoid aquaculture industry. 2005.
30. Çelikkale MS, Düzgüneş E, Okumuş İ. Fisheries sector in Turkey: potential, current state, constraints and recommendations (in Turkish). 1999; (2): 414.
31. Çağırgan H, Degirmenci U, Nemli E, ve ark. Yurdumuzda balık hastalıklarının tedavisinde ilaçların yasal kullanımı. I. Ulusal Alabalık Sempozyumu. 2008.
32. Alvarado J. Aquafeeds and the Environment. CIHEAM. 1997; 275-289.