Chapter 8

IS CLIMATE CHANGE A PROBLEM FOR SUSTAINABLE AQUACULTURE?

Pınar Yıldırım[1*], Ertan Ercan[2], Ergi Bahrioğlu[3], Ezgi Aslandoğan[4]

[1]Department of Fisheries Technology, Faculty of Çanakkale Applied Sciences, Canakkale Onsekiz Mart University, Canakkale, Turkey

[2]Faculty of Fisheries, Muğla Sıtkı Koçman University, Muğla, Turkey

[3]Faculty of Eğirdir Fisheries, Isparta University Of Applied Sciences, Isparta, Turkey

[4]Graduate Education Institute, Department of Natural Resorces Managment, Canakkale Onsekiz Mart University, Canakkale, Turkey

***Corresponding author:** pinaryildirim@comu.edu.tr

Summary

Global warming, which is defined as the increase in the average temperature of the atmosphere, seas and the earth with the effect of greenhouse gases, can be felt all over the world. Climate changes affect the nutrition, reproduction, growth and biodiversity of living things in aquatic ecosystems. Climate change, which is effective in the functional changes of marine ecosystems, is the main factor that changes the geographical distribution of species by triggering species invasions. Warming of waters is one of the causes of increased acidification and indirect extinction of aquatic species diversity.

Most areas of our planet have a very high potential for aquaculture production due to water quality and coastal features. But humankind has hunted aquatic creatures until they destroyed them throughout history. Aquaculture is the controlled production and cultivation of aquatic organisms. Aquatic creatures can be offered for human consumption through reproduction. The overuse of fisheries and the fatigue of aquatic ecosystems could lead to a crisis of global aquaculture food production. Changing climatic conditions can pose serious dangers in aquaculture areas. For this reason, it is important to take a series of measures to reduce the emission of greenhouse gases in the atmosphere and to provide sustainable fishery products. In this study, the role of climate change has been evaluated in order to ensure sustainable aquaculture with a sense of responsibility.

Key words: Aquaculture, Sustainability, Biodiversity, Global Warming,

1. Introduction

With the industrial revolution, carbon resources are used more and global warming and climate change are seen with the increasing effects of greenhouse gas (Köse, 2018). Climate change is considered one of the most important crises that countries have faced because it is related to the existence of human beings. Because climate change directly affects all living things, especially through natural disasters, health, water resources, and nutrition, and the ecosystem formed as a result of the mutual relations of these living things with the inanimate environment that surrounds them (Başoğlu and Telatar, 2013). Although climate change is perceived as a meteorological problem, it has the potential to affect many environmental factors in natural ecosystems, especially in nutrient cycles or hydrological cycles. Many sectors can be directly or indirectly affected by global warming. Apart from the sectors where these effects are observed intensely, some sectors contribute to global warming. The greenhouse gas contributions of fisheries and aquaculture are small compared to other sectors (Cochrane et al., 2009). For this reason, it is important to understand well which areas will be affected by climate change and to what extent, by increasing the severity of the measures to be taken and creating a driving factor for action.

Today, while technological developments have brought very important mobility to the fishing sector, on the other hand, it has also been one of the main sources of human-induced destruction in the marine ecosystem. Scientific evidence supports the conclusion that climate change causes changes in marine ecosystem productivity, fisheries, carbon dioxide uptake in aquatic ecosystems, oxygen concentrations, and terrestrial vegetation (Solomon et al., 2007). In addition, the climate crisis is one of the most important factors that endanger natural biodiversity in aquatic ecosystems (Rahel et al., 2008). Stress factors such as pollution, climate change, and reduction of habitats threaten the vitality of the earth we live on. Aquatic ecosystems are unique habitats for hundreds of plants and animals, accounting for one-third of all species at risk (Kingsford et al., 2016). Moreover, these ecosystems allow rich and diverse plant and animal species to live. Due to increasing temperatures in aquatic ecosystems, species migrate to new settlements and compete with native species in their new areas. Due to migrations, changes occur in population density such as growth, distribution, and abundance of species over time. In addition, 80% of the world trade is carried out by sea transportation, and 7,000 living species are displaced daily (Öztürk et al., 2017). Aquatic ecosystems store carbon instead of releasing it into the atmosphere as carbon dioxide, a greenhouse gas that affects the global climate. Peatland and forested wetlands are of great importance as the world's carbon absorbers.

At the center of the concept of sustainability is the efficient use of water resources, which are important natural resources. Examples of ecologically sustainable systems are healthy oceans, lakes, rivers, wetlands. Reducing the use of these resources is the key to providing healthy food to the growing population in an environmentally sound manner. Damage to the aquatic ecosystem affects the creatures living in this ecosystem as well as other elements that benefit from this system. As the consciousness level of societies increases, knowing, protecting, and maintaining biological diversity has become the common values of humanity.

Climate change has become an important part of fisheries management. Climatic conditions can pose serious economic hazards in aquaculture areas. In this study, the effect of climate change on reliable and sustainable aquaculture activities in taking precautions against sources that may pose a threat was examined.

2- The relationship between the aquaculture sector and climate change:

The aquaculture sector covers the controlled production and cultivation of aquatic organisms. Therefore, water is the main source of aquaculture. Almost every aquatic creature is an important natural resource used for human consumption. Seafood is an important source of protein in human nutrition (Şahin, 2003). While in the past almost all of the aquaculture needs were obtained through hunting, today nearly half of the fishery products are obtained by aquaculture in the ocean, sea, and inland waters. The most important reason for this situation is the decrease in the number of products that can be obtained from the seas and oceans by hunting and the large fish herds due to overfishing (Yavuzcan et al., 2010). In addition, some species are in danger of extinction due to overfishing. Despite the deterioration of the ecological balance in aquatic environments, the demand for aquatic products is increasing. Consumers want aquatic products of the quality they desire to be presented to them on time. For this reason, it is important to present these creatures obtained through breeding with a well-organized marketing system (Doğan, 2003). Aquaculture is global and is the fastest-growing food production technology. The supply of fish products to the market should be considered as an investment area that increases both the economy and employment.

The effects of climate change such as temperature, precipitation, ocean acidification, and sea-level rise are known. These impacts may affect fishing or aquaculture systems in marine and freshwater systems and cause changes in fish availability. Climate change factors, alone or in combination, can affect fish production systems and operate under the influence of several non-climatic factors such as overfishing, pollution, and increased fish demand.

Water quality and coastal features are important factors in aquaculture. Increases in water temperatures affect the phytoplanktonic organisms that have an important place in primary production and the fish species that feed on these organisms nutritionally. Warming of waters affects phytoplankton eruptions and timing changes in zooplankton composition. As a result, the change in the yield and primary production of the hunted species may cause changes in stock abundance and development with the effect of possible incompatibility between prey (plankton) and predator (fished species). As a result of the warming of the waters, it can change the physicochemical properties, physiology, and reproduction ratios of prey species, spawning timings, migrations, stock abundance, increased invasive species, diseases, and physiology of algae. These changes can result in potentially lower production levels between marine and freshwater systems, or have consequences that could reduce or increase the production of certain species in marine and freshwater systems. Since the increase in temperature, which is one of the important water quality parameters, causes a decrease in the oxygen values in the water, the fish will have to continue their uninterrupted swimming by taking more water from their gills to obtain sufficient oxygen. Therefore, as the temperature increases, the oxygen requirement for supporting body development is sensitive for fish in aquaculture.

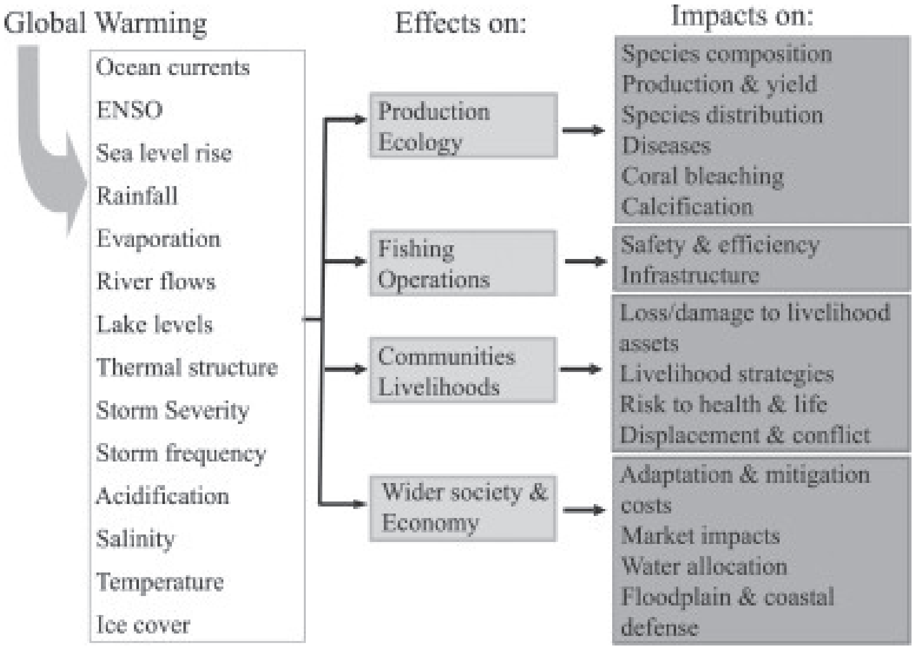
Climate changes cause a decrease in pH values in aquatic environments. This decrease increases the chemical reaction in the direction of acidification in the pH scale. This phenomenon, called acidification, is seen as a factor that directly or indirectly affects the life of coral reefs, known as carbon dioxide scavengers. Chemical reactions occurring in aquatic ecosystems cause the organisms that use calcium carbonate in their skeleton and shell structures to react, and the growth stages of bivalve organisms such as mussels and skeletal structures of fish to change or stop, especially in coral reefs (Khoshnevis Yazdi and Shakouri, 2010). These changes can cause stress, diseases, adaptation problems, migration, and death of living things in all aquatic organisms from phytoplankton to mammals in aquatic ecosystems.

Marine aquaculture sites often make use of naturally existing coastal habitats suitable for target species. Therefore, species accustomed to seawater and the daily rhythm of tides and waves are typically bred in estuaries and shallow coastal waters. Exposes it to risks associated with changes in water temperature, wave regime, storm frequency, or sea level. Sea level rise rates are likely to accelerate due to climate change (Jenkins et al., 2009). Sea level rise may result in the spatial variability of habitats suitable for aquaculture. This can be seen as one of the biggest challenges facing aquaculture in coastal environments. The lack of sediment available to reshape coastal morphologies in landward locations hinders shoreline recovery and increases the vulnerability of coastal habitat to wave erosion (Orford and Pethick, 2006).

Tropical storms have a variety of effects on shrimp aquaculture through sea-level rise, floods, and low waterline advancement, and coastal erosion (Nguyen et al., 2017). The economic effects of marine and coastal aquaculture are an important issue among studies targeting adaptation strategies at the national level (Rosegrant et al., 2016; Dey et al., 2016).

There are many reported studies on climate change and the scenarios that climate change will bring to fisheries (Barange et al, 2018; Ahmed et al, 2019; Cochrane et al., 2009). It was felt that it was necessary to frame this complex structure to understand the connections of the issues on the effects of climate change on fisheries and aquaculture. As shown in Figure 1, the conceptual framework of Badjeck et al., (2010) was seen to represent the intersection of many classifications, so this framework was used in the classification. The natural resource is in danger, but the most worn out and rapidly decreasing resource is undoubtedly 'water', which is the source of life for humans and nature. The fact that water resources are so worn down is seen with the water problems in many settlements today. The reason for this is the pollution of water resources and the inability to use them effectively.

Figure 1. Potential climate change impact for fisheries and aquaculture



3-Sustainability in Aquaculture:

Seafood is one of the most important and healthy components of the human food chain and keeps its place in the system via its high value. This value comes from their taste, commercial profitability, and high balanced nutritional value especially by their highly unsaturated fatty acids (HUFAs) content which represents polyunsaturated fatty acids (PUFAs). Consumers usually choose seafood for their taste; sometimes it became an economic status indicator but always kinds of seafood are consumed. Per capita, apparent consumption of seafood increased from 13.4 kg in 1995 to 20.5 kg in 2018. An increase in consumption drives seafood production for increased production each year. Seafood products can be gathered from two types of production. These production types are Aquaculture and Fisheries. Total production of aquaculture and fisheries reached 178.5 million tonnes in 2018 (FAO, 2020a). In 2018, capture fisheries production in the globe was reported as 96.4 million tonnes (32.4 million tonnes from algae) with an all-time high record by FAO. In parallel, aquaculture production was reported as 114.5 million tonnes which was also an all-time high record (FAO, 2020a). Both of the seafood production methods do not include only animals (fish, crustacean, mollusks, etc.) but also includes micro and macro algae species. Most of the aquaculture product consisted of finfish and 47 million tonnes were harvested from inland. Marine finfish aquaculture has consisted of 7.3 million tonnes. The rest of the aquaculture products were mollusks, crustaceans, marine invertebrates, aquatic turtles, and frogs, respectively from higher to lower record. Global aquaculture production grew 5.3 percent per year in the last decade whereas fisheries production grew 5.4 percent per year in the last three years (FAO, 2020a). The ratio between aquaculture and capture fisheries was 1:5.8 in the early 2000s and the gap between these production methods is almost closed while the latest ratio became 1:1.2 in 2018 data. The data records of FAO shows that how fast aquaculture is growing and becoming an important food source for human more than ever.

Global authorities carry out worldwide research activities based on stock estimations of capturable fish, the environmental impact of aquaculture, and to provide sufficient global seafood production for future demand. FAO's Strategic Framework 2022-31 is already endorsed in June 2021 and one of the highlighted topics under the "Drivers regarding environmental systems" is the "Blue Economy" which was defined by World Bank in 2017. The target of FAO's Strategic Framework is achieving the transformation to more efficient, inclusive, resilient, and sustainable agri-food systems by four principles (4B); Better production, better nutrition, better environment, and a better life. In the manner of sustainability, 18 Sustainable Development Goals (SDG) were defined In the FAO's 2022-31 Framework. The SDG 14 represents Life below water which spans all of the 4B principles (FAO, 2020b). FAO's plan with SDG 14 was mentioned as "supporting the sustainable intensification of aquaculture production, investing in transformative and innovative fisheries management, transforming and upgrading fish value chains, and making fish an indispensable component of food security and nutrition strategies" (FAO, 2020b). In Addition, European Commission released a Future Brief for sustainable aquaculture in 2015.

The definition of Aquaculture is almost identical for all authorities around the world which can be defined as the production or farming of fish, shellfish, and aquatic plants (Science for Environment Policy, 2015). In many European Union Framework Calls, the EU calls for sustainable approaches for aquaculture to fill the gap between demand and supply while the global capture fisheries fall short.

The sustainability of aquaculture can be examined under three topics; Environmental sustainability, Economic sustainability, Social and community sustainability. In detail, from the industrial point of view, water management, disease management, stock management, the efficacy of feed utilization, environmental monitoring systems, green energy, and food safety are becoming the most important topics to consider in terms of sustainable aquaculture production.

Water usage in aquaculture depends on the production methods used in the facilities. Extensive and Intensive systems require different water volumes to produce seafood. Also, fish stocking densities, level of feeding, target biomass, spend time until the harvest, potential of disease outbreaks, utilization of disinfectants and chemicals have a heavy impact on water usage. The industry is using flow-through or "Recirculating Aquaculture Systems (RAS)" systems (Calone et al., 2019). Flow-through systems can be found in the inland rainbow trout aquaculture facilities (d'orbcastel et al., 2009). These facilities are usually built on rivers or streams that are highly efficient by their water flow rate. Flow-through or open-systems operates by changing the waterway, using it with high flow rates, and discarding the used water directly to the environment. These systems have a polluting effect on the environment to some extent and they have been confronted with water reduction and waste treatment questions that have given SDGs (d'orbcastel et al., 2009). On the other hand, RAS facilities are known for their water usage efficacy by their 100 times lower water requirements for 1 m^3 kg feed (MacMillan, 1992; Blancheton et al., 2007; d'orbcastel et al., 2009). RAS facilities usually consist of the water pump station, filter systems, reservoir tanks, feeding tanks, and sometimes quarantine tanks. These treatments depend on the degree of water reuse in the facilities. Filter systems generally include suspended solid removal, biological filters, and sometimes gas control unit. In RAS, biological filters eliminate the ammonia to nitrates by a series of reactions carried out by nitrification bacteria. This process is the one that makes the RAS more efficient than the flow-through systems. Therefore, facilities run on RAS are more sustainable in terms of water management by controlling the waste released to the environment after a production cycle ((Heinen et al., 1996; d'orbcastel et al., 2009).

One of the relatively new and mixed versions of RAS and flow-through systems is In-pond Raceway System (IPRS) that is used for inland fish farming activities. These systems are built in a natural pond, lakes, etc., and use the flow-through system in the ponds without any external water sources out of the pond. The principle of IPRS is to increase the stocking density of the cultured fish in a concrete raceway pond, circulate the surrounding water from the outer pond to the raceway, concentrate and remove the solid waste from the downstream end of the raceway unit. These systems were promoted by U.S. Soybean Export Council (USSEC) to reduce the environmental impact of inland freshwater aquaculture activities.

Sustainability doesn't only mean inland aquaculture also for marine has to be. Offshore system aquaculture has been the most effective way for aquaculture production. According to stocking densities and high oxygen levels, aquaculture companies prefer breeding at marine water bodies. There is a way for sustainability for seas and oceans for aquaculture effluents. Ecologically friendly production systems could be done. Integrated multitrophic aquaculture systems (IMTA) are the way on ecological friendly production models. Organic pollutants which come from aquaculture facilities can be converted to the economy by-products like mussel and micro/macroalgae. Bivalve farming needs algae, algae need organic nitrogen and other minerals. Aquaculture effluents were also to fully meet these needs. This is the main concept for integration. So ecologically models can clean water bodies and returns the organic effluents to a blue growth economy which is important for sustainability next generations.

4- Conclusion

To leave healthy food for future generations, we must protect the ecosystem. This goes through the protection of terrestrial or aquatic creatures. Pollution means where every hand of a person touches. If we want to continue our lives in this order, we need to pay attention to environmental factors. We need to protect our future with the concept of respect for the environment and our world. To minimize the environmental impacts that have occurred since the industrial revolution, we need to ensure the continuity of new production models, especially with environmentally friendly systems. The human population is increasing every day, for this, we must regulate our lives with the principle of protecting healthy and sustainable resources. Aquaculture in the form of production with the lowest values in animal production as a carbon release. It is a duty for us to protect nature for the next generations.

References

AHMED, N., THOMPSON, S., & GLASER, M. (2019). Global aquaculture productivity, environmental sustainability, and climate change adaptability. *Environmental Management*, 63(2), 159-172.

ATAR, H.H., KIZILGÖK, A.B., (2018) Effects Of Global Warming On Fisheries, Third Sector Social Economic Review,2018,53(3):1102-1125

BADJECK M-C., ALLISON, E., HALLS, A. & DULVY, N. 2010. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy, 34: 375-383.

BARANGE, M., BAHRİ, T., BEVERİDGE, M. C., COCHRANE, K. L., FUNGE-SMITH, S., & POULAİN, F. (2018). *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. fao.

BAŞOĞLU, A., & TELATAR, O. M. (2013). THE IMPACT OF CLIMATE CHANGE: AN ECONOMETRIC ANALYSIS ON AGRICULTURE, *Karadeniz Technical University, Institute of Social Sciences, Journal of Social Sciences*, (6), pp.7-25.

BLANCHETON, J.P., PIEDRAHITA, R., EDING, E.H., ROQUE D'ORBCASTEL, E., LEMARIE´, G., BERGHEIM, A., FIVELSTAD, S., 2007. Intensification of landbased aquaculture production in single pass and reuse systems. In: Aquaculture Engineering and Environment, (Chapter 2).

COCHRANE, K., DE YOUNG, C., SOTO, D., & BAHRI, T. (2009). Climate change implications for fisheries and aquaculture. *FAO Fisheries and aquaculture technical paper*, *530*, 212.

DEY, M. M., GOSH, K., VALMONTE-SANTOS, R., ROSEGRANT, M. W., & CHEN, O. L. (2016). Economic impact of climate change and climate change adaptation strategies for fisheries sector in Solomon Islands: Implication for food security. Marine Policy, 67, 171-178.

DOĞAN, K., (2003), Ülkemizin Akuakültür Potansiyeli ve Pazar Durumu, Deniz ve Balıkçılık. Aylık Sektörel İhtisas Dergisi, Sayı 3 (Eylül 2003) 10-12 Kısım II.

FAO (1995). Code of Conduct for Responsible Fisheries. Food and Agriculture Organization of the United Nations, Rome, 41 p

FAO. 2020a. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

FAO. 2020b. The Strategic Framework 2022-2031. Endorsed at 42nd session of the FAO Conference on 18 June 2021. Access Link.

HEINEN, J.M., HANKINS, J.A., 1996. Water quality and waste production in a recirculating trout-culture system with feeding of a higher-energy or a lower-energy diet. Aquaculture Research 27, 699–710.

JENKINS GJ, MURPHY JM, SEXTON DS, LOWE JA, JONES P, KILSBY CG. 2009. UK Climate Projections: Briefing Report. Met Office Hadley Centre, Exeter, UK.

KHOSHNEVIS YAZDI, S., & SHAKOURI, B. (2010). The effects of climate change on aquaculture. International journal of environmental science and development, 1(5), 378.

KINGSFORD, R. T., BASSET, A., VE JACKSON, L. (2016). Wetlands: Conservation's poor cousins. Aquatic Conservation: Marine and Freshwater Ecosystems, 26, 892–916

KÖSE, İ., (2018) Negotiations On Climate Change: The Process For Turkey To Sign Paris Agreement, Ege Strategic Research Journal, *9*(1), 55-81.

MACMILLAN, R., 1992. Economic implications of water quality management for a commercial trout farm. In: Blake, J., Donald, J., Magette, W. (Eds.), National Livestock, Poultry, and Aquaculture Waste Management. American Society of Agricultural Engineers, St. Joseph, MI, pp. 185–190.

NGUYEN, T. A., VU, D. A., VAN VU, P., NGUYEN, T. N., PHAM, T. M., NGUYEN, H. T. T., & Hens, L. (2017). Human ecological effects of tropical storms in the coastal area of Ky Anh (Ha Tinh, Vietnam). *Environment, development and sustainability*, *19*(2), 745-767.

ORFORD, J. D., & PETHICK, J. (2006). Challenging assumptions of future coastal habitat development around the UK. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group*, *31*(13), 1625-1642.

ÖZTÜRK, B., TURAN, C., ÖZSOY, E., ÖZTÜRK, H., GÜVEN, K.C. & ALGAN, N. (2017). 2017 yılı Türkiye Denizleri raporu, TÜDAV, İstanbul, Türkiye, 44s.

RAHEL, F. J., BIERWAGEN, B., & TANIGUCHI, Y. (2008). Managing aquatic species of conservation concern in the face of climate change and invasive species. *Conservation Biology*, *22*(3), 551-561.

ROSEGRANT, M. W., DEY, M. M., VALMONTE-SANTOS, R., & CHEN, O. L. (2016). Economic impacts of climate change and climate change adaptation strategies in Vanuatu and Timor-Leste. Marine Policy, 67, 179-188.

ŞAHİN, T., (2003). Su ürünleri yetiştiriciliğinde biyoteknoloji, SÜMAE Yunus Araştırma Bülteni, 3:1, 2-5.

SCIENCE FOR ENVIRONMENT POLİCY (2015) Sustainable Aquaculture. Future Brief 11.

Brief produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol.

SOLOMON, S., QIN, D., MANNİNG, M., CHEN, Z., MARQUIS, M., AVERYT, K.B., TİGNOR, M., MILLER H.L., (2007). Intergovernmental Panel on Climate Change, IPCC Summary for Policymakers, Clim. Chang. Phys. Sci. Basis, Contrib. Work. Gr. I to Fourth Assess. Rep. Intergov. Panel Clim. Chang. Cambridge Univ. Press. Cambridge, United Kingdom New York, USA

YAVUZCAN, H., PULATSÜ, S., DEMİR, N., KIRKAĞAÇ, M., BEKCAN, S., TOPÇU, A., DOĞANKAYA, L., BAŞÇINAR, N., (2010). Türkiye'de sürdürülebilir su ürünleri yetiştiriciliği, Bildiriler Kitabı-2, TMMOB Ziraat Mühendisliği VII. Teknik Kongresi, 767-789.