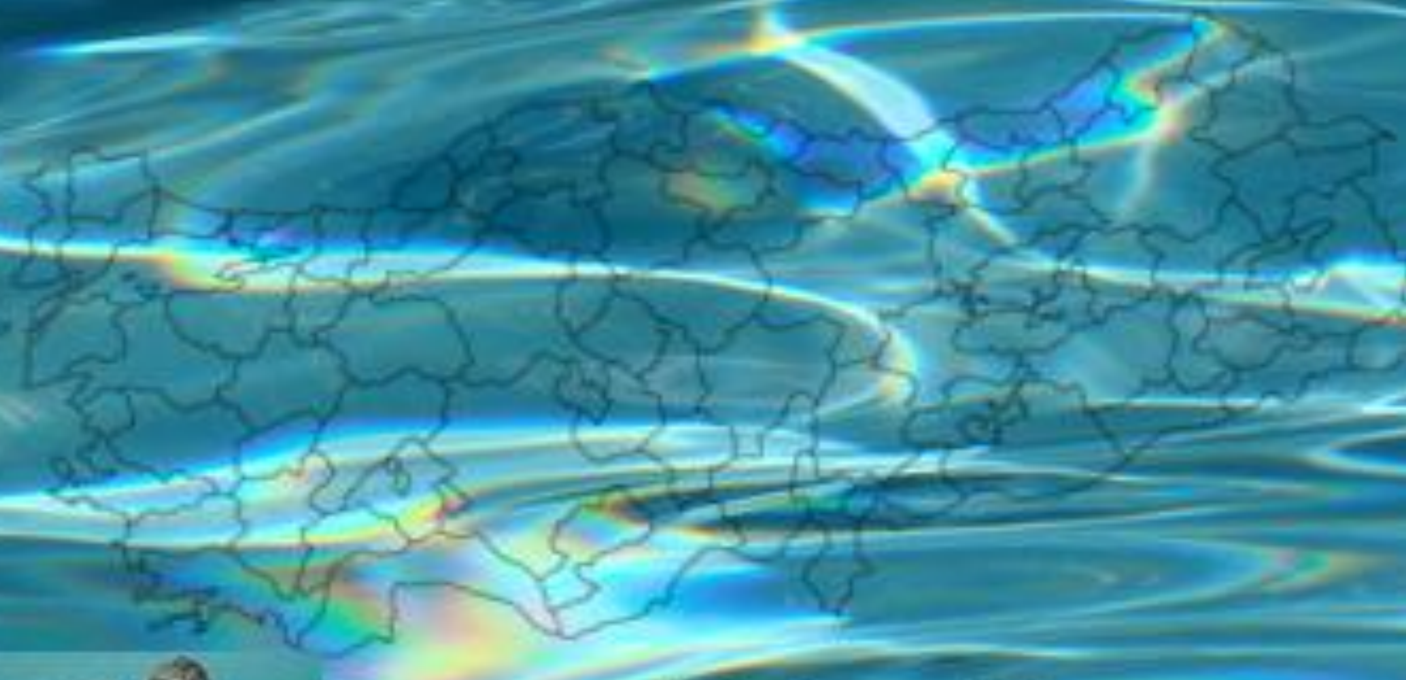
The Zebra Mussel in Turkey



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Contents

FOREWORD

Water mismanagement, overuse, unplanned and uncoordinated water management and climate change effects can be counted as emerging threats on renewable water resources and sustainable water use. These effects can also lead to a water supply security threats for the end user of water.In another words, water supply security is a very important part of the water security chains and directly depends on operational security of the water supply systems.

Turkey has experienced with zebra mussels problems in Atatürk Dam and HEPP since 1997. Zebra Mussels accumulation has also created some problems in Birecik Dam in 2000. DSI (DG State Hydraulic Works) has started the site investigation on monitoring studies in Kesikköprü Dam and Atatürk Dam during years of 2001 and 2002.

According to DSİ report (1), in Turkey, 629 small and large dams ,384 irrigation schemes ,98 water supply systems has been opened by State Hydraulic Works (DSİ) since 2005. Private sector has also built 510 river and canal type hydroelectric power plants since 2008. More than 100 small HEPP projects are under construction in different basins. About 550 small dams mainly for irrigation purposes are planned to built in near future. In fact some of them is under construction. Many of these water storage and diversion structures have completed in places where Zebra mussels were previously identified.

This study aimed to raise awareness of decision makers, designers and operators about zebra mussels problems in different hydraulic structures in Turkey . We also aimed to share our experinces and discuss preventive measures used for zebra mussel infestation at some dams in Turkey.

Dursun Yıldız
HPA Director   Feb. 2017 Ankara /Turkey

CHAPTER I

1.1.INTRODUCTION

Main goal of the integrated water resources management at the basin level is supplying clean water to end users without forcing border of natural life cycle. During this management process, water authorities can be faced different type of water security threats that can be created by antrophogenically or naturally. Last 25 years there has been observed an emerging water supply security threats that has been created by invasive species called as Zebra mussels and Qagga mussels in different part of the World.

Zebra mussels originally lived in the lakes of Southeast Russia. The first sighting of zebra mussels outside of Russia was in the early 1800s in Europe. They were able to disperse through man-made canals that linked European waterways.

Because zebra mussels prefer hard surfaces at moderate water depth, water intake structures, such as those used by power plants and city treatment plants, are susceptible to clogging by zebra mussels. In fact, since 1989, some facilities located on Lake Erie have reported big reductions in pumping capacity and occasional shutdowns caused by encrusted zebra mussels.

Richard Steffen Professor of Plant, Soil, and General Agriculture with the Southern Illinois University thinks zebra mussels could eventually become part of a closed-loop system, where water cycles back into hog pens (2).

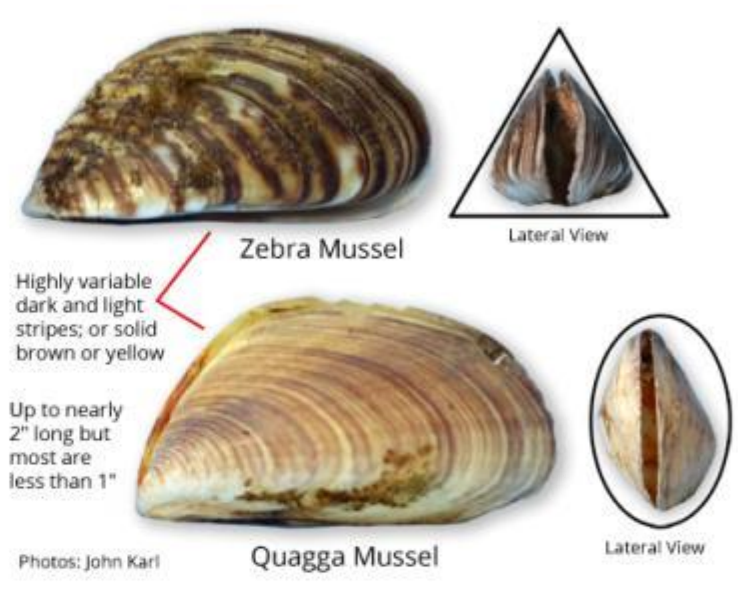


Figure1. Zebra Mussels and Quagga Mussels

Zebra mussels create enlarging biomass in suitable places of the water supply systems clogging pipes, hydraulic structures and threatening water supply security. Zebra mussel achieves high densities immediately after colonizing a new habitat. Zebra mussel densities on an intake screen around Great Lakes area climbed from 200 individuals/m^2 to 700,000 individuals/m^2 in one year (3). Geometric increases in population on the order from 1 to 105 in 2 years have been reported in the Mississippi Valley (4).

The ballast water of ships could transport exotic species such as the zebra mussel. O'Neill and Dextrase (1993) describe the spread of mussels in North America in detail.

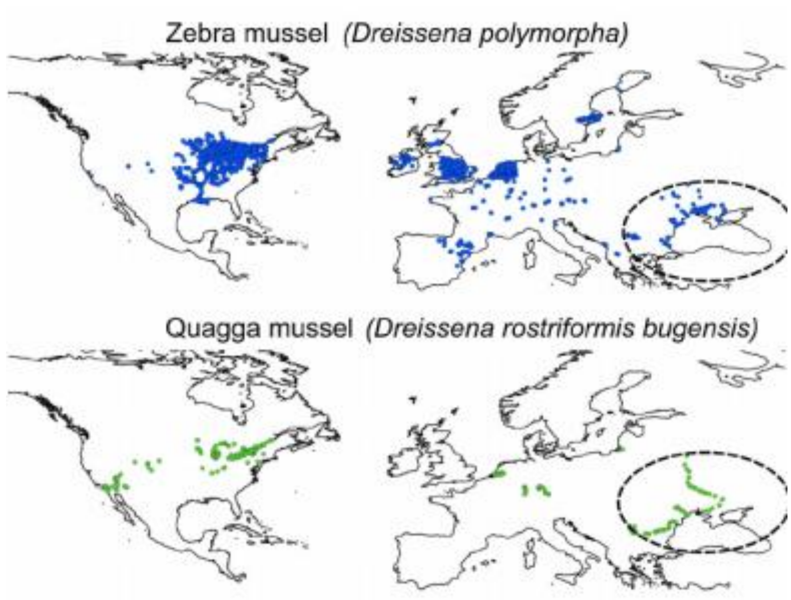


Figure2. Location of Zebra and Quagga mussels presence points in Europa and America (5).

Last 25 years there has been observed an emerging water supply security threats that has been created by invasive species called as Zebra mussels and Qagga mussels. Zebra mussel, Dreissena Polymorpha, is a biofouling organism that lives generally in freshwater ecosystems and get its name from the striped pattern on their shells.

During its most mobile stage, planktonic veliger, zebra mussel larvae can attach to an object with more than 100 proteinaceous byssal treads that are secreted from a gland at the base of its muscular foot. Large numbers of byssal attachments to hard surfaces in raw water systems is the main reason why this species causes water supply problems in agricultural, industrial and domestic water system operation.

Existing hydropower facilities and water supply structures have been affected by zebra mussel infestation in Turkey .Zebra mussel infestation has occurred at various freshwater structures and systems including raw water intakes, industrial and domestic water supply pipelines and hydropower facilities. It is therefore that there have been some studies to protect water supply systems from Zebra Mussels and Qagga mussels accumulation.

1.2.SPREADING AREAS IN THE WORLD

According to the paleontological evidence, the first records of the presence of D. polymorpha are dated 10 -11 million years ago. It is noted that the species is recorded in the estuaries of the Tethys Sea, which separated Africa from Europe and Asia at that time. The natural spreading areas of the species are the Black Sea and Caspian Sea in the Northern Hemisphere and the Aral Lake basins and related estuaries, coastal waters, fresh water lakes, reservoir lakes and rivers. Turkey is also located within natural spreading areas (Figure 3).

Figure 3. Natural Spreading Areas of D.polymorpha (6).

It is noted that D. polymorpha lived in the seas until the end of 1700, then passed into fresh waters and spread to Europe since the 18th century. D. polymorpha was discovered in England in 1824 and later spread to Denmark, Sweden, Finland, Ireland, Italy and other European countries (Figure 4).

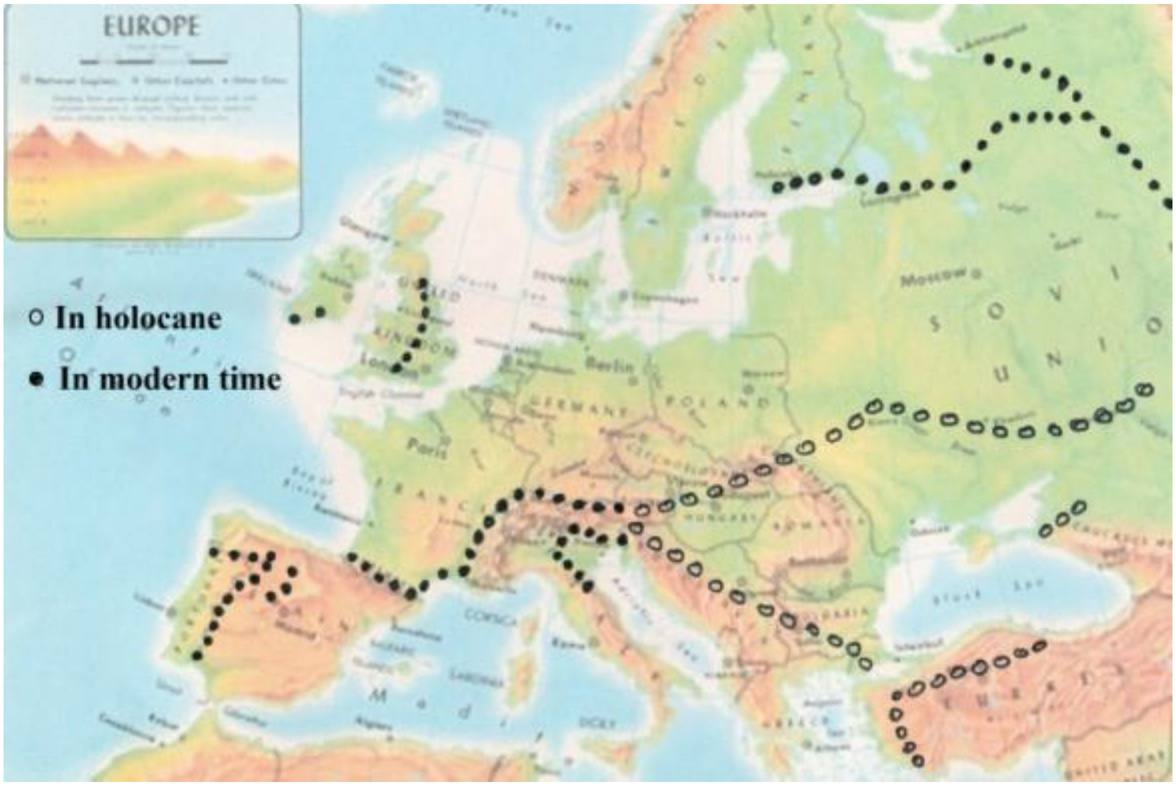


Figure 4.Natural Spreading Areas of D.polymorpha in Europa (6).

Mussels was found in Lake Clair in the Great Lakes region in North America in 1988 and reached the Misisippi Delta in the south by all the lakes in the basin and the Misisippi River (Figure 5).

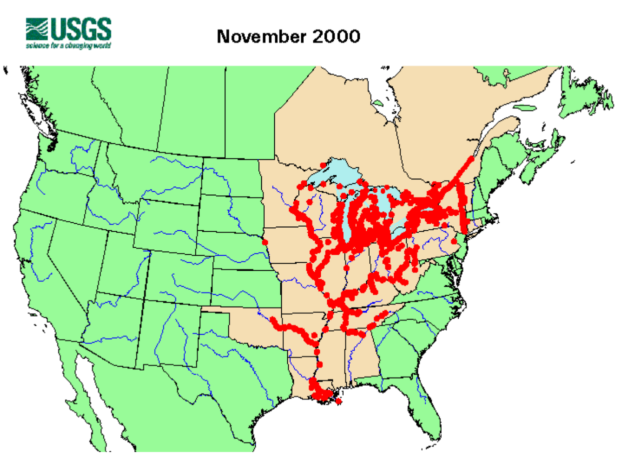


Figure 5.Spreading Areas of D.polymorpha in North America (8).

It is considered that the most important factor in the expansion of the spreading areas of Dreissena species is marine transportation and ballast water discharge of the boats to non-dirty areas (6). Other natural or human-induced factors that contribute to the spread are water plants transported by boats, water currents, migratory water birds and crayfish (7). However, the zebra mussel which was discovered in England in 1824 was transmitted to North America 164 years later in 1988 despite intensive commercial boat transportation between Europe and America.

CHAPTER II

2.1.ZEBRA MUSSEL HISTORY

Zebra mussels originally lived in the lakes of Southeast Russia. The first sighting of zebra mussels outside of Russia was in the early 1800s in Europe. They were able to disperse through man-made canals that linked European waterways. Zebra mussels have been in western and central European waterways for nearly 200 years. While we can learn a lot from looking at how zebra mussels behave in Europe, zebra mussels face a different ecosystem in North America. Comparisons and predictions based on European experience may not be accurate.

Zebra mussels are native to western Russia, near the Caspian Sea. Canals built during the late 1700s allowed the mussel to spread throughout Eastern Europe. During the 1800s, canals were built across the rest of Europe. The canals made shipping easier but also allowed rapid expansion of the zebra mussel’s range. By the 1830s, the mussels had covered much of Europe and Britain.

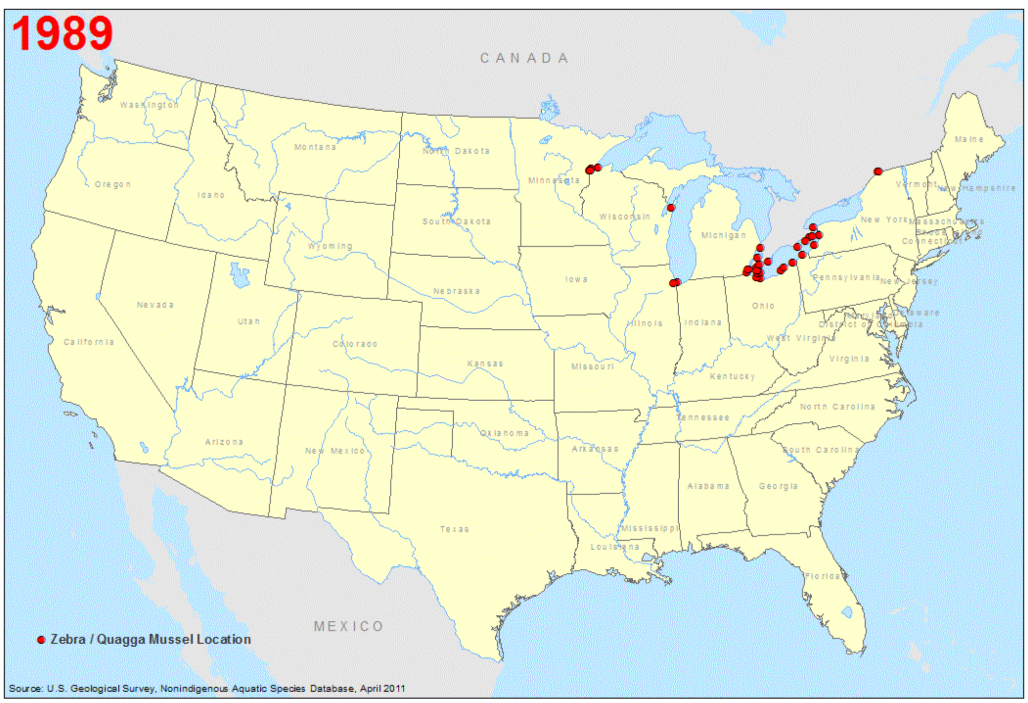


Figure 6. Map shows the spread of Zebra Mussel and Quagga Mussel in the United States in 1989.(8)

Zebra mussels (*Dreissena polymorpha*) were first discovered in the Great Lakes in 1988.(Fig.6). Within one year, zebra mussels colonized nearly every firm object in Lake Erie. Zebra mussels quickly spread to all the Great Lakes.

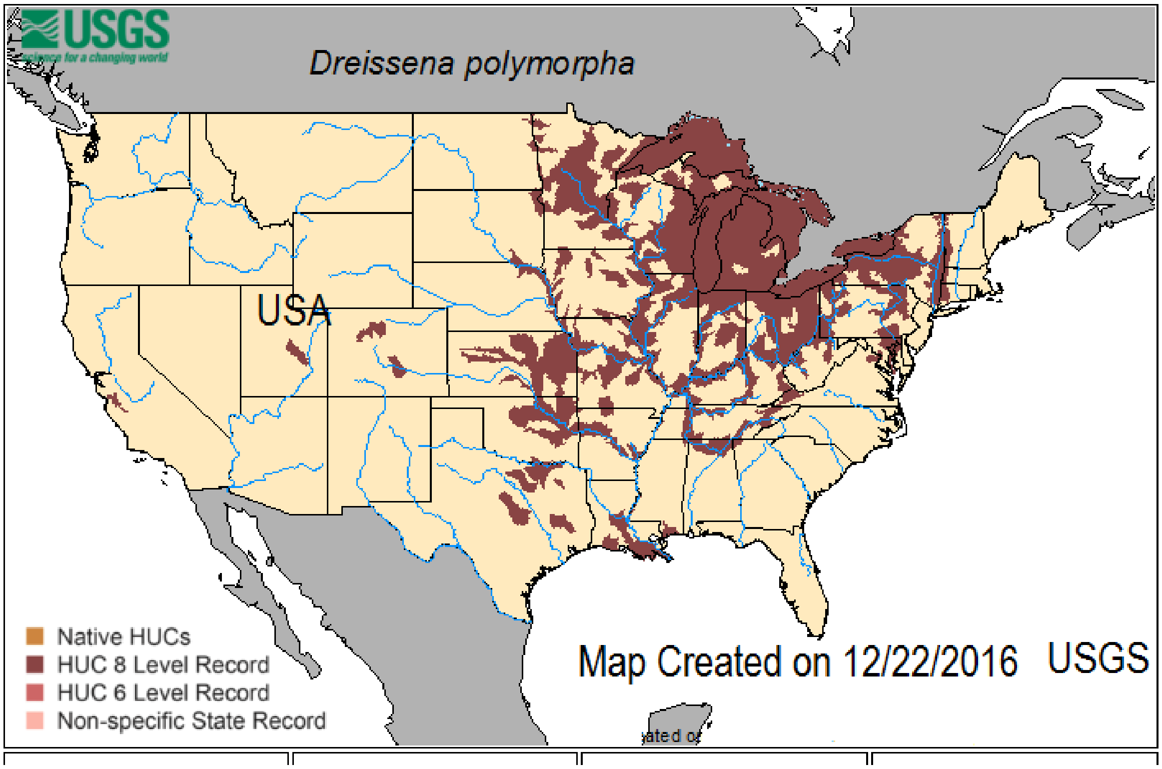
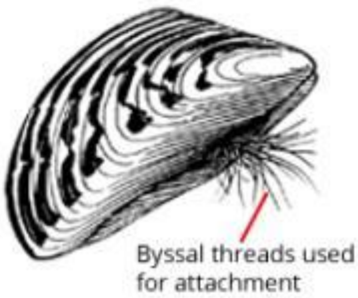


Figure 6. Map shows the spread of Zebra Mussel and Quagga Mussel in the United States on 2016 (8)

Expansion to inland waters continues at an alarming rate. For example, in 1992 zebra mussels made their way out of Lake Michigan into the Mississippi River basin via the Chicago Sanitary Shipping Canal – an artificial channel that links the Great Lakes drainage basin with the watershed drained by the Mississippi River. At the end of the 1992 season, zebra mussels were being found in isolated pockets from Minneapolis to St. Louis.

Successful introduction of zebra mussels into the Great Lakes probably occurred in 1985 or 1986, when one or more transoceanic ships discharged ballast water into Lake St. Clair. The freshwater ballast, picked up in a European port, contained zebra mussel larvae and possibly juveniles. Being a temperate, freshwater species, they found the plankton-rich lakes St. Clair and Erie to their liking.
Map shows the spread of Zebra Mussel and Quagga Mussel in the United States on 2016 is given in Fig 6.

2.2.ZEBRA MUSSEL BIOLOGY



The mussel's reproductive cycle is one key to its rapid spread and high abundance. Egg production starts when water temperature warms to about 12 degrees ^{0}C. A fully mature female mussel may produce several hundred thousand eggs per season. Within a year, a zebra mussel can grow up to an inch and become sexually mature. European studies report mussels may live four to six years, but in Lake Erie three years seems to be the maximum, and the average is much less[1].

Zebra mussels generate a tuft of fibers known as a byssus, or byssal threads, from a gland in the foot. Any hard surface that is not toxic can be colonized by zebra mussels – rock, metal, wood, vinyl, glass, rubber, fiberglass, paper, plants, and other mussels.

Zebra mussels can become established regardless of depth, light intensity, or even winter temperature. Colonies grow rapidly wherever oxygen and particulate food is available and water currents are not too swift – generally less than six feet per second. Colonies are rare in wave-washed zones, except for sheltered nooks and crevices. In most European lakes, the greatest densities are at depths ranging from 6 to 45 feet[2].

Zebra mussels also colonize soft, muddy bottoms. Hard objects, such as pieces of native mussel shells, act as a base for settling veligers. As a few mussels begin to grow, they serve as substrate

[1] Zebra Mussels Threaten Inland Waters: An Overview
http://www.seagrant.umn.edu/ais/zebramussels_threaten

[2] Zebra Mussels Threaten Inland Waters: An Overview
http://www.seagrant.umn.edu/ais/zebramussels_threaten

for additional colonization. In this way, extensive mats of zebra mussels can form on soft lake and river bottoms[3].

Zebra mussels can attach and settle on the natural stones, rocks, other adult mussels, macrophytes and on the structures made of cement, iron, PVC and sheet iron. Furthermore, although possible they are rarer that they will successfully establish a colony on soft, fine sediments like silts and clays. Zebra mussels can often live in such silty sediments by initially attaching to small fragments of plants, wood, shells, and stones and subsequently attaching to each other to form druses(14)

The distribution of Zebra mussel larvae in water column is not homogeneous and larvae concentrate in trophic zone. Besides other factors, it should be considered that the depth of water intake will be also able to influence zebra mussel problems. In addition to natural substrate and hard surfaces for attachment, artificial substrates such as water intake and transport structures of dams constructed on the rivers have been provided to form new substrates and to increase mussel densities(14).

The major environmental factors that effect the life cycle of mussels are: Physical and chemical qualities of water (temperature, pH, dissolved oxygen, calcium level, salinity), attachment and settlement substrate, water velocity, abundance of food and natural enemies.

2.3.ZEBRA MUSSELS EFFECTS

Zebra mussels are filter feeders. They strain water for the food they need. The long-term consequences of colonization of Zebra Mussels on environment are still being studied. As zebra mussels spread, biologists are concerned that species. The life span of a zebra mussel is about 4-5 years. An adult female zebra mussel may produce between 30,000 and one million eggs per year. However, only abut 2-5% of those eggs reach adulthood. Within 2-3 weeks of their birth, zebra mussels “settle” and attach by strong byssus threads to hard, still surfaces such as rock, wood, glass, rubber, and other sessile (immobile) animals.
Zebra mussels are filter feeding organisms; their filter out nearly all the phytoplankton and small zooplankton in an area. Because of their large populations, they can eat the majority of important producers in an aquatic ecosystem (9).

[3] Zebra Mussels Threaten Inland Waters: An Overview
http://www.seagrant.umn.edu/ais/zebramussels_threaten

Their colonies can become so dense and thick that they clog pipes and waterways. Once zebra mussels enter an ecosystem, it is very difficult to control them. Their populations grow at a rapid speed. Because their threads are so strong, it is difficult to remove them from objects once they are attached. The cost of trying to control zebra mussels is extreme – the cost in the Great Lakes alone exceeds $500 million per year (9)

2.3..1.Negative Effects of the Zebra Mussels on Hydro-Power Energy Generation

After mussel infestation, there will be an additional loss at the trash rack and added friction in the tunnels. Since it was not possible to predict the change in the other items, no adjustments were made for these remaining head losses. A study was conducted to perform risk assessment and to develop preventive measures for zebra mussel infestation at a planned hydroelectric power plant (Alpaslan II HEPP) in southeast Turkey (10). Possible energy reduction study results indicate that zebra mussel colonization can reduce the power generation as much as 4.2%. Similar reductions in power generation along with capacity reduction up to 7.0% have been reported by Jones et al. (11) for Wheeler Hydro Plant due to excessive trash accumulation at the trash racks (10). In addition, critical damage to the penstock and turbine is possible if surge tank tunnels or water cooling systems are clogged (Figure 7).

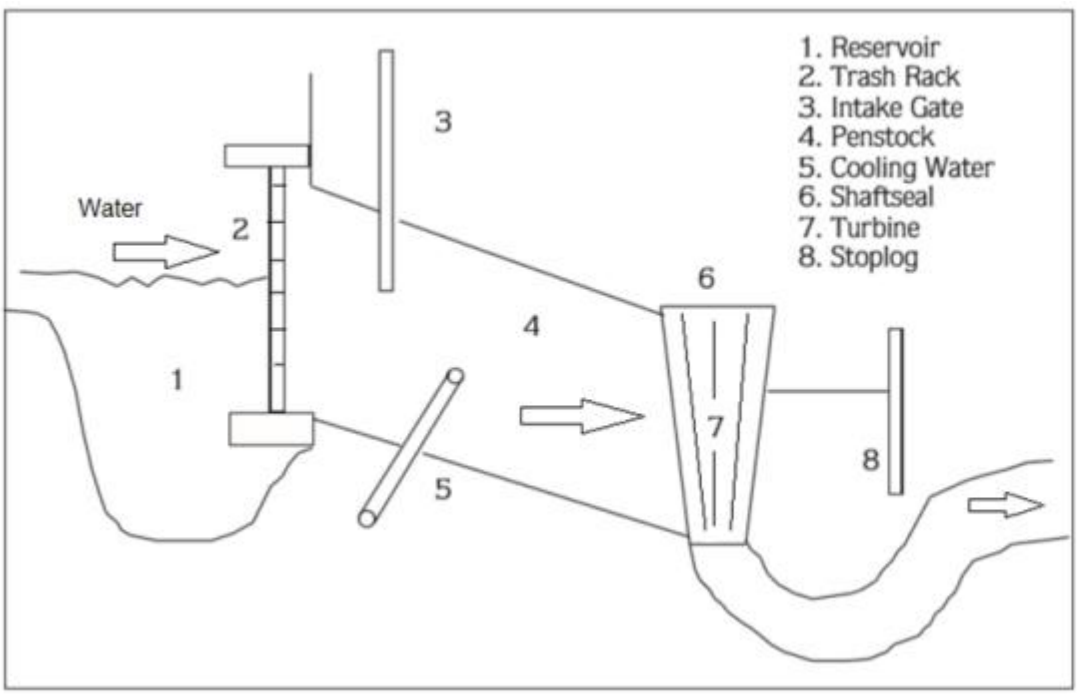


Figure 7. The parts of a HEPP may be affected by Zebra Mussel infestation

CHAPTER III

3.1.ZEBRA MUSSELS HISTORY AND OBSERVATIONS IN TURKEY

The first records concerning the presence of Dreissena in Turkish freshwaters have dated to 1897. Zebra mussel was first recorded in Bursa and its surrounding freshwater in 1936. Fouling problems by zebra mussel in Hydro Power Plants of Turkey were first determined in Kovada I HEPP in 1964 (12).

Table 1: Availability of Zebra Mussels in Some Dams in Turkey

Dam Name	Basin Name	River-Lake Name	Opening Date for Operation	Mussels Availability and Date
Kovada I	Göller Region	Eğirdir-Kovada	1960	A - 1964
Kovada II	--	--	1971	A
Keban	Fırat Basin	Fırat	1975	A
Karakaya	--	--	1987	A
Atatürk	--	--	1992	A - 1997
Birecik	--	--	2000	A - 2000
Karkamış	--	--	2001	A - 2001
Kesikköprü	Kızılırmak Basin	Kızılırmak	1966	A
Seyhan	Seyhan Basin	Seyhan	1956	A
Çatalan	--	--	1996	A
Aslantaş	Ceyhan Basin	Ceyhan	1984	A

A: Available *NA: Not Available* **Source : DSİ 2005**

In the same period, the application to the U.S. Bureau of Reclamation from Turkey has been answered that Zebra mussels are not located in the USA States. A study carried out in the Soviet Union for the solution of problems was sent to Turkey (13) by the USBR

3.2.Spreading Areas in Turkey

The distribution of zebra mussel in Turkish freshwaters were determined in the following regions until the year of 2005 (14): Terkos, Sapanca, Acarlar, Poyrazlar, Akgöl, Taşkısığı, Bafa, Eğirdir, Kovada, Beyşehir, Burdur and Yarışlı Lakes; Hirfanlı, Kesikköprü, Kapulukaya, Derbent, Keban, Karakaya, Atatürk, Birecik, Karkamış, Seyhan and Aslantaş Dam and HEPPs; Gazibey, İkizcetepeler,Atıkhisar and Bolu Gölköy Dam Lakes (Fig 6). The records in relation to the distribution of zebra mussel in Turkey and all over the world show that zebra mussel is native to Turkish freshwaters. However, it can potentially transfer to uninfected areas.

Atatürk and Birecik Dam and HEPPs may have been infected by means of boats brought to the Ataturk Dam Lake for water sports (15). Studies conducted by Şeşen and other experts reveal that the distribution areas in Turkey also tend to expand.

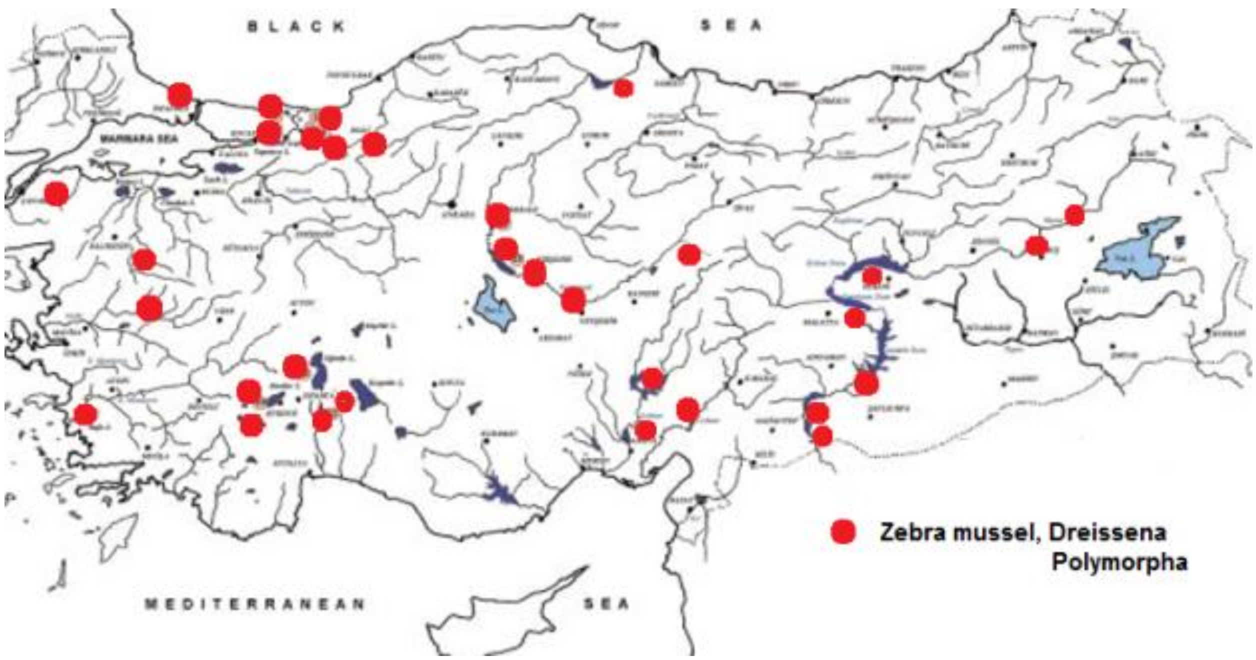


Figure 6. Map shows presence points of Zebra Mussel (Dreissena polymorpha) in freshwaters and dam lakes in Turkey (After 10,14,16)

According to Geldiay and Bilgin (17), D.polymorpha (Zebra Mussel) is located in Egirdir, Kovada, Beysehir and Sapanca Lakes.in Turkey. From the northern shores of Lake Burdur, only the eroded shells could be collected. According to Baykal (18) (1960), there are fossils of D.bouldrourensis d'Arch in Burdur Lake.

Yildirim and Şeşen (19) found that four bivalve species (D. polymorpha, D.bouldrourensis, Pisidium and Anadonta cygnaea) were detected in the 58 freshwater habitats around Burdur and Isparta and that D.polymorpha was found in Burdur, Yarışlı, Eğirdir and Kovada Lakes.

Since 1997, the type of mussel that caused the problem at Atatürk Dam and HEPP was defined as D. polymorpha. The same species are also found in the Euphrates River and all the reservoir lakes in the Euphrates Basin (Keban, Karakaya, Atatürk, Birecik and Karkamış). It is stated[6] that the species is also common in Lake Terkos[4] , Bolu Gölköy Dam Lake and Poyrazlar, Taşkısığı, Akgöl and Acarlar Lakes in Sakarya basin[5].Zebra Mussel has also been observed in İkizcetepeler Dam reservoir that supplies Balıkesir City Drinking Water .

It has also been observed that the Zebra midye was located in Kesikköprü Dam, Hirfanlı Dam, Derbent Dam lakes on Kızılırmak river and Gazibey Dam Lake on the Osügülüç branches of the Kızılırmak river. It is stated that the mussel is also located in the Kapulukaya Dam Lake which is on the upper site of Kesikköprü Dam[6]. It is thought that the living conditions of Zebra mussels in the Bafa Lake in the 1980's where salinity was 04% have been lifted as a result of the increase of salinity to 1.4% in recent years. According to studies carried out in Mediterranean Region in 2002, it was determined that D. polymorpha was located in in Seyhan, Çatalan dam lakes in the Seyhan Basin and in the Aslantaş dam lake in.Ceyhan Basin.

As stated by Bobat, Hengirmen and Zapletal (20), Zebra mussel (D. polymorpha) has to reach problematic densities trough the flow of water to the still water system, and the formation of appropriate holding places as a result of structures made in natural lakes and dams in rivers. Turkey has been in a rapid progress to built small HEPP, small dams for irrigation and water supply systems since 2005 that was the most comprhensive investigation has completed on zebra mussel presence regions in Turkey rivers and reservoirs. But there hasn't been studied and investigated on possible Zebra Mussel's spread movements since last decade.

According to DSİ report (1), in Turkey, 629 small and large dams ,384 irrigation schemes ,98 water supply systems has been opened by State Hydraulic Works (DSİ) since 2005. Private sector has also built 510 river and canal type hydroelectric power plants since 2008. More than 100 small HEPP projects are under construction in different basins. About 550 small dams mainly for irrigation purposes are planned to built in near future. In fact some of them construction has already been started . Many of these water storage and diversion structures have completed in places where Zebra mussels were previously identified. This situation shows that zebra mussels in the near future can make it difficult to provide safe water from these systems and that problems arising from zebra mussels in Turkey will increase [7].

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[4] Çamur Elipek, B., 2001. Qualitative and Quantitative Distributions of Benthic Makroorganizms in Terkos Lake. Trakya University İnstitution of Natural and Applied Sciences, Edirne (PhD Thesis).

[5] Altınayar, G. ve H. Çevlik, 2001. "Eskişehir Sulama Birliğindeki Mekaniksel Yabancıot Savaşımı Uygulamalarının İzlenmesi ve Sakarya Irmağında Zebra Midye İncelemeleri (16-18-08.2001)"(Gezi Raporu) . DSİ Genel Müdürlüğü Ankara-(in Turkish)

[6] . Sea creatures in Bafa , National Geographic, Türkey,November, 2001.

[7] Üstündağ, S., 2002. DSİ VI.ve XV. Bölge Müdürlüğü Baraj Göllerinde Zebra Midye İncelemeleri (17-28.06. 2002) (Gezi Raporu)

3.3.Investigations on Zebra Mussel in Turkey

Zebra mussel, Dreissena polymorpha , has been caused biofouling problems in Atatürk Dam and HEPP since 1997, in Birecik Dam and HEPP since 2000. To obtain the data related to control methods of the pest, monitoring activities were carried out in Atatürk Dam and HEPP, and Kesikköprü Dam between 2001 and 2002. The investigations in Kesikköprü Dam Lake have shown that zebra mussels have three reproduction periods (April-May, June-July and July-September).

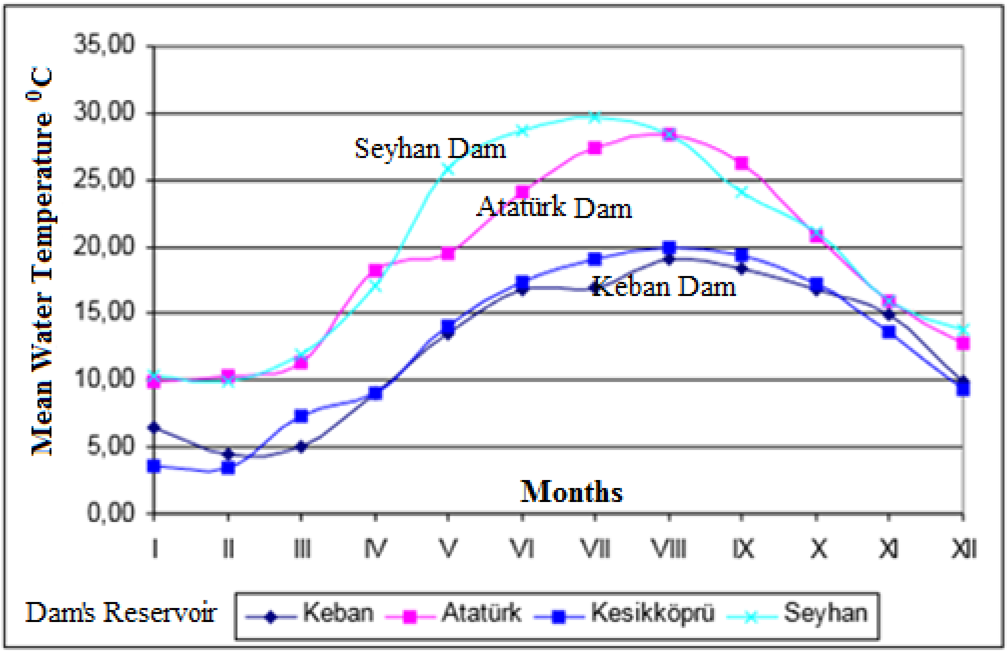

Figure 8. Water Temporatures of the lakes of Keban, Atatürk, Kesikköprü and Seyhan Dam's Reservoirs. Source: (14).

Long-term average temperatures of Keban, Atatürk, Kesikköprü and Seyhan Dam lakes are given in Figure 8. The first larvae in the water began to appear when the surface water temperatures were around 10 ºC. While the surface water temperatures increase during the period of the larval period, there are lower temperatures preferred by the larvae in the deeper part of the lake. However, in order to survive the lives of the larvae, other conditions at these depths must be at an appropriate level.

Surface water temperatures are lower in the Kesikköprü Dam Lake than in the Atatürk Dam Lake. As a result, the larvae are seen later in the Kesikköprü Dam Lake than the Atatürk Dam Lake.There are larvae in April-September in Kesikköprü Dam Lake and in all year in the Atatürk Dam Lake.

In Atatürk Dam and HEPP there have been mussel larvae throughout the year, although there have been great differences among larval densities. The highest larval density has been determined to be 13 000 individuals /m^2 at the part of Şanlıurfa Tunnels of Dam Lake.

Densities of mussel larvae were higher at the depths between 9 -15 meters relatively. Juvenile densities on the stones installed in Dam Lake have ranged from 46.537 to 131.111 individuals/m^2 depending on reproduction periods, suitable substrate for attachment and water depths.The appropriate temperatures for larval development have been determined as 14-16 ° C and inappropriate temperatures, as higher than 24 ° C. The appropriate temperatures for plantigrade are between 18- 22 ° C, and inappropriate temperatures higher than 24 ° C.

Since calcium is the main component of zebra mussel shells, quantity of calcium in the water is of vital importance for zebra mussels. Calcium levels in Kesikköprü Dam Lake is mean 102.65 mg/l that is sufficient for life cycle of mussels. Salinity level in aquatic environment is one of the major factors which effect mussel availability and survival. Salinity in Kesikköprü Dam Lake has not been greatly changed depending on seasons and depths of the Lake. Salinity level of Kesikköprü Dam Lake is mean 0.699 ppt which is appropriate for life cycle of Zebra mussels.

Although temperature levels in Keban and Kesiköprü Dam Lakes are suitable for good growth of zebra mussels, pH levels are suitable only for moderate growth of zebra mussels. One of the factors that limit the development of zebra mussels have been assessed as pH of Lakes (14).

In Atatürk Dam Lake both water temperatures and pH levels are suitable for best growth of zebra mussels. One of the reasons of the problems by zebra mussels in Atatürk Dam an HEPP is that water temperature and pH levels are suitable for spawning and development of zebra mussels in contrast to that in Kesikköprü Dam Lake. High temperatures of water in Seyhan Dam Lake could be effective in control of Zebra mussel densities (14).

Following main points have been observed during the Zebra Mussel investigation in the Kesikkoprü and Atatürk Dam (14).

- Mussel attachment was not determined on cooling water serpantines made of copper in and HEPP of Atatürk Dam.
- The bottom structure with sand and silt of Kesikköprü Dam Lake is not suitable for attachment of mussels. Mussels settling the bottom of the Lake have been survived on the small stones and by attaching to each other and their densities have been changed greatly.
- In Atatürk Dam and HEPP, shaft seal is one of the places where mussels cause important problems. Water velocity in shaft seal is 1.25 m/sec. And this velocity can not hinder mussel attachment.

- The observations implemented in Atatürk, Gazibey and Kesikköprü Dam Lakes indicate that the changes in annual water levels of Lakes were a significant factor in the control of mussel densities.

3.4.Problems created by Zebra Mussels in Turkey

The environmental impacts of zebra mussels in Turkey are largely pollutant (biofouling) effects. Below are the problems of Zebra mussels in Dams and HEPPs, Drinking Water and Wastewater Facilities and Irrigation Facilities in Turkey.

Zebra mussel problems, which are economically important in Turkey, have been observed for the first time in dams and HEPPs. In 1964 and the following years, Zebra mussels, have been found to cover the tunnels and the pipes of the Kovada I and II HEPPs and reduce the sections by narrowing in 1964 and later years (12). After this first detection of mussel damage, Zebra mussel problems have not been seen for many years in Turkey. Then, Zebra mussel problems occurred in Atatürk, Birecik and Karkamış Dams and HEPPs. located in the downstream part of the Fırat Basin.

ATATÜRK Dam HEPP Cooling system

Irrigation Systems Hidrant

Figure 9. Zebra Mussel problems in cooling water inlets and hidrants (21)

Zebra Mussels were first noticed during the annual revision in August 1997 at Atatürk Dam and HEPP. Places where the Zebra Midies are in trouble and precautions taken are given below:

Atatürk Dam HEPP Unit 8 intake gates couldn't be opened. The mussels were cleaned for about 1 month (07.08/ 03.09.1997). The slides of the water inlet cover can be cleaned using 400 bar of pressurized water. Unit cooling water inlet filters (Fig. 9) are cleaned from the mussels in each revision period. Cleaning takes 5-6 days. At Ataturk Dam HEPP, the speed regulator cooling coils are cleaned every year during revision periods. It takes 2 days. Cleaning the shaft release takes 7-10 days (Figure 10). As a result, during the annual revision studies, the revision time is extended for each unit about 10 days due to the mussels.

Figure 10. Problems created by Dreissena polymorpha in different parts of Atatürk Dam and HEPP (15).

The problems of Birecik Dam and HEPP were determined about 2 months after the operation of the plant on August 26, 2000 (Figure 11). Considering that mussel problems can temporarily disable the plant, authorities have sought urgent solutions (15).

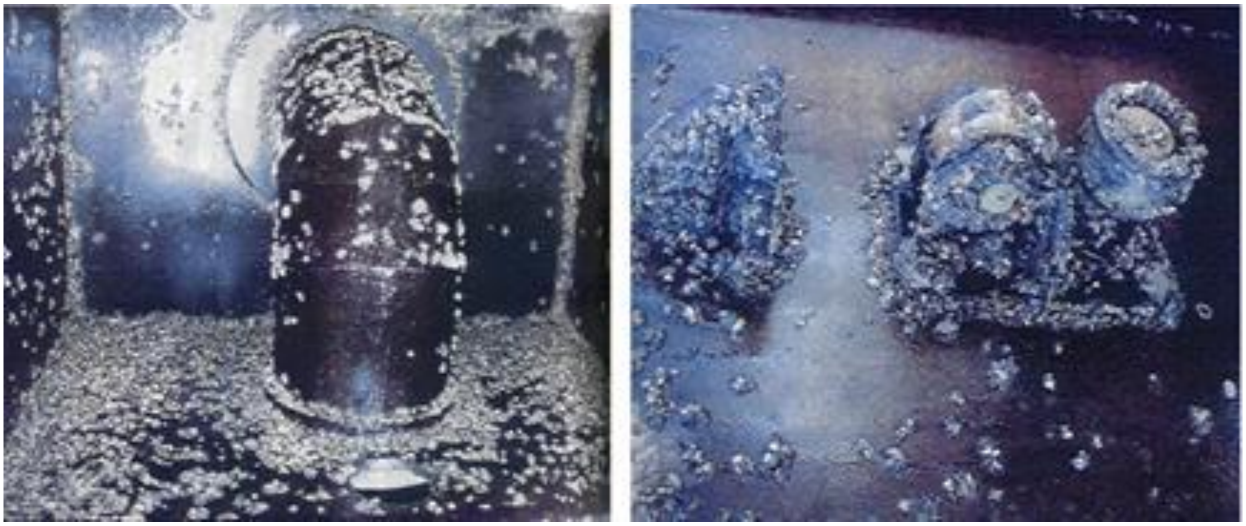

Figure 11. Problems of Dreissena polymorpha in Birecik HEPP (15).

Figure 12. Zebra Mussel Accumulation on the Water Intake Trash Racks (21).

Zebra mussel accumulation can also be seen on the water intake trash Racks in HEPP (Fig 12).
In September 2001, in the examinations made with divers in Birecik dam lakes, garbage grids were observed at 3-10 cm thick mussel contamination at the intersections where there was little or no water flow and about 9-10 m depth at the base and upper part. The size of the largest mussel collected was measured as 3 cm (20).

Intensive mussels were found in 2001 in the water intake structure covers of Karkamış Dam and HEPP, which was started operation in 1999 and mechanically cleaned by divers.

In Karakaya Dam and HEPP, very small amount of mussels were found on the water intake mouth covers, but no problem occurred. Zebra mussel complaints have not been addressed in response to the presence of Zebra mussels in rivers and reservoirs of Gazibey, Hirfanlı, Kesikköprü, Kapulukaya and Derbent Dam and HEPPs located in Kızılırmak Basin. Mussel problems were investigated in Gökçekaya and Yenice Dam and HEPPs in Sakarya Basin in 2001 due to the presence of mussel in Sapanca Lake and the connection of the lake with the river. In the limited section of the Sakarya River, no mussels were detected in adult or larval periods, and central authorities reported that there were no mussel problems.

Investigations in 2002 show that, Zebra mussels are present at, Seyhan, Çatalan and Aslantaş Dam and HEPPs but there were no serious problems, and mechanical cleaning were done when necessary at the revision periods [8]

It is noted that mussels were seen at Ömerli and Darlık Dam Lakes that provide drinking water to Istanbul, entry structure of the Ömerli Treatment Plant should be cleaned from the mussels, there is danger in the Melen-Alaca-Ömerli and Yeşilçay-Darlık-Ömerli systems, mussels can also be seen in the Istranca-Terkos system due to the wide variety of sources [9] ..

[8] Üstündağ, S., 2002. DSİ VI.and XV. Regional Directorates, Zebra Mussel Reviews in the Reservoir Lakes (17.2806.2002) (Travel Report)
[9] Istanbul Master Plan Consortium, Final Report, Volume 2.

Figure 13 .Urfa Bozova Irrigation Pump Station's Filters in 2010 (21)

Figure 14. Zebra Mussel Accumulation on the Urfa Tunnel Raw Drinking Water Intake (21)

Zebra Mussels are observed to develope intensively in Urfa Bozova Irrigation Pump Station's Filters (Figure 13) , the Eyüp Bağları Pump Station which receives water from Keban Dam

Lake,in the The Köprüköy Irrigation System which receives water from Kesikköprü Dam Lake and on the covers of the water intake of Şanlıurfa Tunnels (Fig.14) which take water from Ataturk Dam Lake. They are cleaned mechanically during maintenance-repairs.

The Nizip Drinking Water Facilities that received water from the Birecik Dam Lake were noted to have caused significant damage due to the zebra mussels. The "Shock Chlorination System" is projected for solving problems that originate in the zebra mussels in Şanlıurfa City raw drinking water supply pipe (Fig.15) and Sanliurfa Water Treatment Plant which will take water from the Atatürk Dam Lake by Sanliurfa Tunnels .

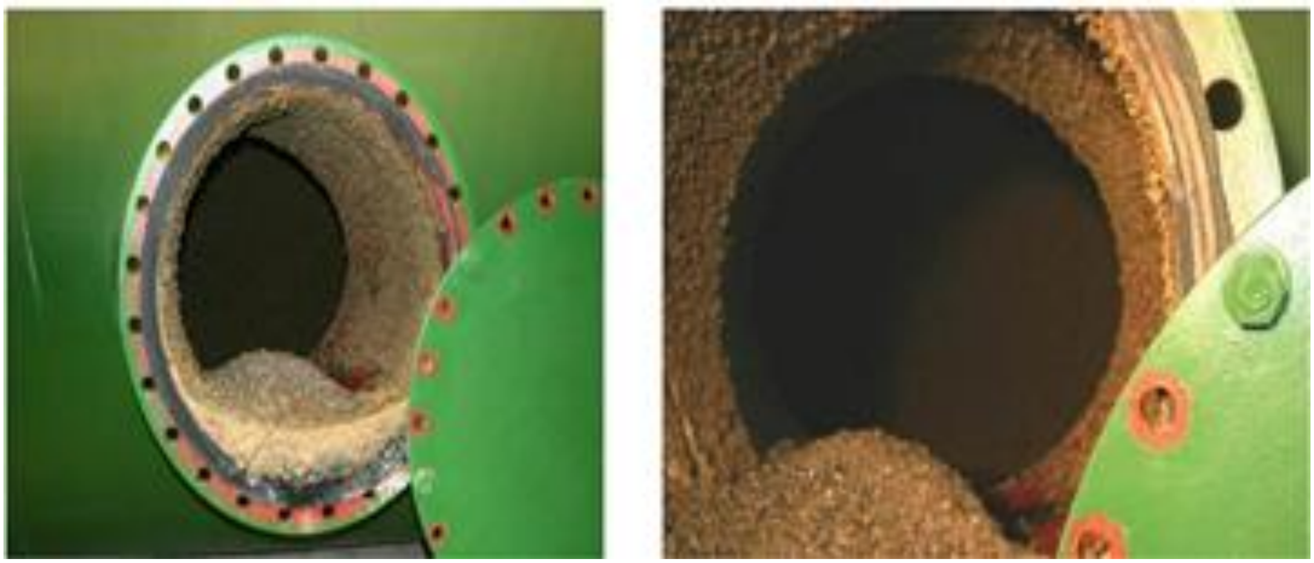

Figure 15. Zebra Mussel accumulation in Şanlıurfa City raw drinking water supply pipe.(21).

Site investigations showed that there is a danger of the occurrence of zebra mussel problems in Turkey and measures must be taken in planned and operated facilities that generate hydroelectric energy, supply drinking or irrigation water from the water sources with Zebra Mussels presences

Figure 16. Zebra Mussel accumulation in the pipes.

3.5 Kesikköprü Dam Case

Studies done by State Hydraulic Works expert on biology of the Zebra Mussel showed that the shell lengths and weights of adult mussels have been changed depending on the age of mussels and qualities of their habitat such as depth, food, water quality (temperature, pH, dissolved oxygen etc.).

Figure 16 a. Plankton collection devicies at the Kesikköprü Dam Reservoir (DSİ 2005).

In Kesikköprü Dam Lake, shell lengths of adult mussels had been measured as mean 22.5 mm (min. 12.0-max. 31.0) and their weights as mean 1784.1 mg (min. 130-max.3770). The shell lengths of young adults had been measured as mean 10.8 mm (min. 6.0-max. 16.0) and their weights as mean 186.12 mg (min. 70-max. 730). The biggest mussels in Turkey were collected from İkizcetepeler Dam Lake. The shell lengths of these mussels were determined as mean 27.0 mm (min. 15.0-max. 43.0) and their weights as mean 1887.0 mg in (min. 460-max. 4660).

The shell length of D-shaped larvae was measured as mean 92.0 µ (min. 70-max. 110); that of plantigrade stage as mean 1.12 mm (min. 0.84 – max. 1.48 mm); that of young mussels as mean 5.39 mm (min. 3.82-max. 7.03). Adult mussel densities in previous years were determined as 13994 individuals/mPP2PP on the fish cages and 9154 individuals/mPP2PP at the bottom of Kesikköprü Dam Lake (DSİ 2005).

The data concerning adult mussel densities indicate that zebra mussels in Kesikköprü Dam Lake have lived in sublittoral and profundal zones; that the adult densities have greatly changed depending on different sampling points; and that mussel densities on fish cages and the rate of their survival were higher than those at the Lake bottom (DSİ 2005).

Fig 16 b. Measurements with water quality measurement system at the Kesikköprü Dam's Reservoir (DSİ 2005)

The investigations in Kesikköprü Dam Lake have shown that zebra mussels have three reproduction periods (April-May, June-July and July-September). In parallel to these periods, three larval peaks were determined in the Lake water. The densities of larvae in peak periods are 80213 individuals/mPP3PP in average for first reproduction period (25.04.2001); 157554 individuals /mPP3PP in average for second reproduction period (26.06.2001); and 22223 individuals/mPP3PP in average for third reproduction period (31.07.2001). The highest larval density was 203315 individuals/mPP3 PP(26.06.2001) in the Lake. The duration of the first reproduction period was found to be 6 weeks; that of the second reproduction period, 2-3 weeks and that of the third reproduction period, 11 weeks. Mussel larvae have been between April and September in Dam Lake water (DSİ 2005).

3,6 Some Obtained Results

The appropriate temperatures for larval development have been determined as 14-16 ° C and inappropriate temperatures, as higher than 24 ° C. The appropriate temperatures for plantigrade are between 18- 22 ° C, and inappropriate temperatures higher than 24 ° C. Those for juvenile development have been changed between 22-24 ° C. The depths that larvae transform into plantigrade and juvenile stages have been changed depending on water temperature and pH. In the second reproduction period that temperatures at the surface water increased, the depths transformed into plantigrade and juvenile stages have been risen (DSİ 2005).

Considering the shell lengths of juveniles in Kesikköprü Dam Lake, it can admit that juveniles start to transform to adult stage at about ends of July. The period from egg to new adult are approximately 16 weeks in 2001. The major environmental factors that effect the life cycle of mussels are: Physical and chemical qualities of water (temperature, pH, dissolved oxygen, calcium level, salinity), attachment and settlement substrate, water velocity, abundance of food and natural enemies(DSİ 2005).

Table 2. Height and weight of Zebra Mussels collected from differnet dams reservoirs.(DSİ 2005)

Place	Lenght of Zebra Mussel	Weight of Zebra Mussel
Kesikköprü Dams Lake (Surface)	***2,25 cm*** (min.1,20 – max.,10)	***1,784 gr*** (min. 0,130 -max. 3,770)
Kesikköprü Dams Lake (Deep)	***1,70 cm*** (min.1,20 – max.2,40)	***0,752 gr*** (min. 0,190 -max. 1,920)
İkizcetepeler *Dams Lake*	**2,70 cm** (min.1,50 – max.4,30)	**1,887 gr** (min. 0,460 -max. 4,660)
Atatürk Dams Lake	***1,44 cm*** (min.0,70 – max. 2,30)	***0,573 gr*** (min. 0,014 -max. 1,470)
Birecik Dams Lake	***1,24 cm*** (min.0,50 – max.2,00)	***0,359 gr*** (min. 0,020 -max. 1,050)
Karkamış Dams Lake	***1,33 cm*** (min.0,80 – max.2,20)	***0,440 gr*** (min. 0,040 -max. 1,610)
Euphrates River	***0,85 cm*** (min.0,60 – max.1,10)	***0,059 gr*** (min. 0,020 -max. 1,200)
Aslantaş Dams Lake	***2,30 cm*** (min.1,50 – max.2,90)	***1,083 gr*** (min. 0,420 -max. 2,000)

In studies made in Eurasia 21 predator bird species had been recorded. All of these birds have been lived in Turkish freshwaters. Except for gull and Fulica atra, it has not known if these birds have been in Kesikköprü Dam Lake. Anyway, Kesikköprü Dam Lake is not an important bird area.

One species (Cladophora) of seven biological competitors recorded in Eurasia has also determined in Turkish freshwaters. Green algae (Spirogyra) have been competed with zebra mussels in Kesikköprü Dam Lake. Moreover, a sponge species of biological competitors, Spongila lacustris (L.) has also identified in Kesikköprü Dam Lake (DSİ 2005).

Three species of ten predators, crayfish (Astacus leptodactylus), crab and freshwater rat (Rattus norvegicus) determined in Eurasia and North America have been lived in Turkish freshwaters, too.

Natural enemies could be effected to control zebra mussel populations in Turkish freshwaters. However, the detailed investigations on this subject should be made in Turkey.

The sufficient data concerning life cycle and environmental relations of zebra mussels in Turkish freshwaters were obtained from the field works carried out in Kesikköprü and Atatürk Dam Lakes between 2001 and 2002 (DSİ 2005).

CHAPTER IV

4.1.Preventive Measures in Turkey

Studies have shown that zebra mussel problems identified in Turkey are less frequent than those in North America and they are seen especially in newly constructed facilities. The main reason for this situation is that this species is considered as an indigenous species for Turkey and an exotic species for North America (DSİ 2005).

Every method has no application in every environment when fighting with Zebra mussel. The methods of struggle against zebra mussels in water structures are summarized below:

1.Jet cleaning with high pressure water
2. Low-frequency electromagnetism application
3. Heat applicati application
4. High flow rate application
5. Use of repellent materials
6. Biological combat
7. Mechanical cleaning
8. Use of chemical substances
9. Paint systems.

One of the methods applied is spraying water with 3000 psi pressure and removing zebra mussels from the place where it is held. This method was applied at Atatürk HES water intake covers and positive result was obtained.

Metalizing (zinc-aluminum coating), Line-x (polyurethane based surface coating), CTP pipe, HDPE pipe which are being used in closed system irrigation networks are used for control purposes in Ataturk Dam Lake and Mardin Regulator in 2007, At the end of the observation, the most zebra mussel clinging was observed in Line-x coated plate and the least adhesion was observed in CTP type pipe (22).

Mechanical methods (scraping and study of divers) against Zebra mussel are still being used in Atatürk, Karkamış, Seyhan and Aslantaş HES and Yaslıca Tunnel.

In the hydrants of the Mardin-Ceylanpınar pressurized irrigation system, 2 mg / l high chlorine doses were initially applied to the test line to prevent zebra mussel collection. Then 0.5 mg / l chlorine was applied for 15 minutes and 30 minutes was given. In this way, chlorine application was carried out every 21 days for 3 days (Aksu et al., 2008). Images taken before and after the irrigation season with the robot camera in order to compare the collection of mussels are given in Figure 17 (21).

Within the scope of these studies, the zebra mussel problem (Figure 15) in the raw water supply line of Sanliurfa drinking water treatment plant was investigated and it was suggested to install the pre-chlorination unit at the exit of the tunnel where raw water was taken for treatement. Satisfactory results were obtained from both chlorination applications. However, it has also been stated that using chlorine continuously will not be economically and environmentally appropriate (21).

Figure 17. Robotic Camera and Zebra Mussels accumulation into the connection part of the pressured CTP type pipe (21).

Another alternative applied in the scope of these studies is coloring. In dyeing, the most common and successful are silicone based nontoxic paints. As a result of this painting, a slippery surface is formed which minimizes the adhesion of the zebra mussels. However, the effect of the paint which is more suitable for environmental health is about 5 years and its cost is high.

In studies conducted against Zebra Mussel, the Bernoulli filter (Figure 18) was tested in the Yaylak Closed Irrigation System and Zebra mussel pinning was not detected at the end of the irrigation season, even when the Bernoulli filter was fitted (21)

Figure18. Bernoulli Filter (21)

4.2.General Evaluation

Zebra mussel colonization can result in losses in hydraulic capacity of the systems, the clogging of strainers and filters, the obstruction of valves, and nuisance problems associated with the decay of proteinaceaus flesh and the removal of shells (24,25). Mussel infestation of natural and artificial constructions increases the operation and maintenance of water systems (26), thereby affecting individual residents, municipalities and industries.

Zebra mussel densities can be so high that the diameter of pipes at some plants have been reduced by two-thirds in water treatment facilities. Zebra mussels cause expensive problems, blocking pipes that deliver drinking and process water to cities and factories and cooling water to power plants.

Bobat (27) claimed that methods for the management and control of Zebra mussel can be essentially classified into 3 categories: chemical, physical and biological. While each of these management types have some advantages and disadvantages, given the nature of each strategy, one type may be more appropriate for a particular habitat or situation than the others. Some of these strategies are primarily reactive, while others are proactive/preventive.

Preventive control methods include toxic construction materials, antifouling paints or coatings, chemical treatments, and mechanical filtration and some non-chemical processes such as acoustical vibration and electric fields. Reactive control methods, those applied after infestations have been detected, consist of mechanical cleaning, high-pressure water jetting, carbon dioxide pellet blasting, freezing, and desiccation.(27).Thermal treatment and chlorination can be used initially as a reactive treatment to clean a system, and then preventively as regular maintenance to prevent further fouling. Moreover, the use of extremely lowfrequency electromagnetism may prove to be a viable means of nonchemical Zebra mussel control.(27).

At the end of the studies done in Turkey, it can be said that there is a danger of problems with Zebra Mussels in the hydraulic facilities that receive drinking water, irrigation water and hydroenergy production or cooling water from the water sources that zebra mussel is present. However, it is understood that Zebra mussel problems identified in Turkey are lighter than the problems in North America, especially in newly constructed facilities and they are seen especially in newly constructed facilities. The main reason for this situation is that this species is considered as an indigenous species for Turkey and an exotic species for North America (14).

Zebra Mussel Prevention researches carried out recently in Turkey are concentrated in the dams on the Euphrates River due to the increasing problems. In the Euphrates Basin, the regime of flowing water has changed into that of lakes (i.e. stagnant water), due to the cascade of dams and HEPPs. Furthermore, the discharge of domestic wastes into Atatürk Dam Reservoir has played a role in enhancing mussel reproduction and population development.
It has been observed that Atatürk Dam Lake both water temperatures and pH levels are also suitable for best growth of zebra mussel
Therefore, Zebra mussel has reproduced in appropriate aquatic conditions. However, the fouling problems associated with Zebra mussel in the Euphrates Basin are less severe than those in the freshwaters of North America and Europe at present. Zebra mussel is likely to cause more severe consequences in both the Euphrates Basin and freshwater systems in other geographical regions of Turkey in the near future.

Various protection measures have been tried between 2006 and 2008 in order to determine the most suitable and economical method for protecting water structures from zebra mussel effect. During this period, dyeing with preventive dyes, use of different materials, chemical application and filtration methods have been experimented. In the case of closed system irrigation, a filtration experiment was carried out in 2010 to determine the efficiency of the filtration.

At the end of the researches carried out in Turkey, it has been determined that the most important parameters affecting the living environment of zebra mussels are temperature, pH, calcium ion concentration, properties of attachment site and water flow rates.

In particular, the operating programs of the dams under the risk of zebra mussel must be determined in order to minimize the adverse effects of zebra mussels that accumulate in reservoirs and water intake openings.

The investigations have shown that Dreissena species in Turkey are D. polymorpha (Pallas) but the observation studies and updated records on the distribution of zebra mussels are limited. For this reason, it is necessary to update the distribution map of the zebra mussels and determine the problematic areas by carrying out studies in dam and HEPPs which are increasing rapidly in the last period.

Turkey has implemented approximately 700 small dams, hydraulic structures and 510 new small HEPP projects since last 10 years. It has also decieded to rehabilitate irrigation systems from classical open channel system to modern pressuresied systems So this new modern irrigation systems as well as several new water storage and diversion structures have created suitable stagnanted water environment for zebra mussel to be growth since last 10 years.But there hasn't been enuogh studies to identify the last situation in these new areas. Therefore ıdentification of places where zebra mussel species are present and spreading out causing problems in the operation of water structures has been more important for operational safety. In addition to this, it is also important to take precautions against mussel contamination of other habitat.

Risk assessment should be conducted for zebra mussel infestation for new hydro power plants as well as existing structures. In addition, preventive measures should be included against zebra mussel infestation in the design and operation of these major facilities based on the local conditions at a site.

Zebra mussel preventive measures experienced in Turkey showed that fouling problems caused by the Zebra mussel are not generally solved by one control methodology. For each location or situation the best solution can be a combination of physical, chemical and biological applications in that declining order of acceptance.

Criteria for selecting an appropriate control method must include environmental and economic concerns and ease of application. Moreover, careful attention must be given before, during and after the implementation of control strategies to ensure that there are minimal adverse environmental impacts.

Mechanical methods in control of zebra mussel have been already applied in Turkey. Attempts have been continued to use nontoxic antifouling paints and Extremely Low Frequency Electromagnetism (ELF-EM) as alternative preventing control methods in control of zebra mussels.Natural enemies could be effected to control zebra mussel populations in Turkish freshwaters. However, the detailed investigations on this subject should be made in Turkey.

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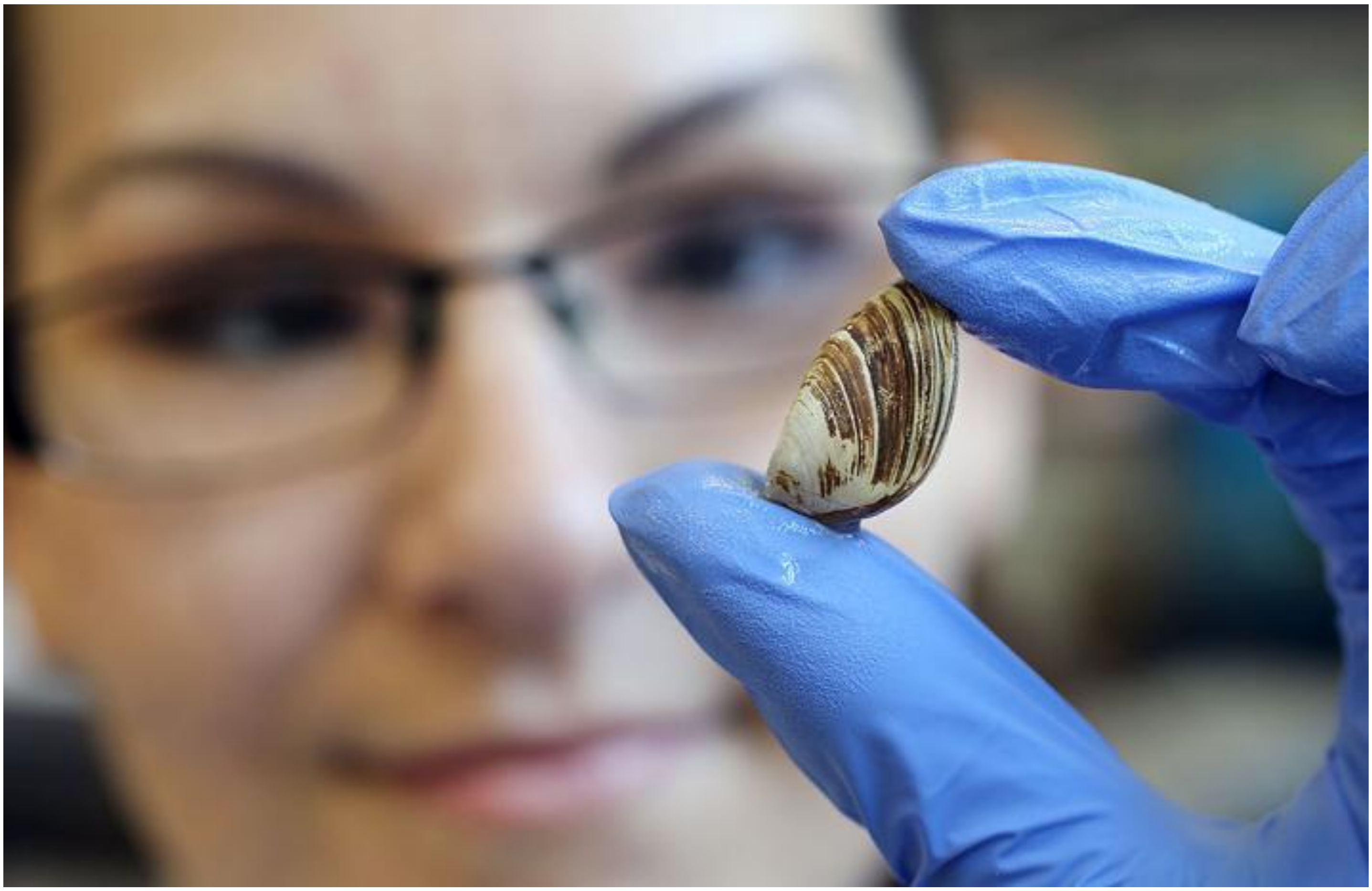


BLACK SEA
MARMARA SEA
MEDITERRANEAN SEA
Zebra mussel, Dreissena Polymorpha