ZEBRA MUSSEL

INFESTATION RISK ASSESSMENT

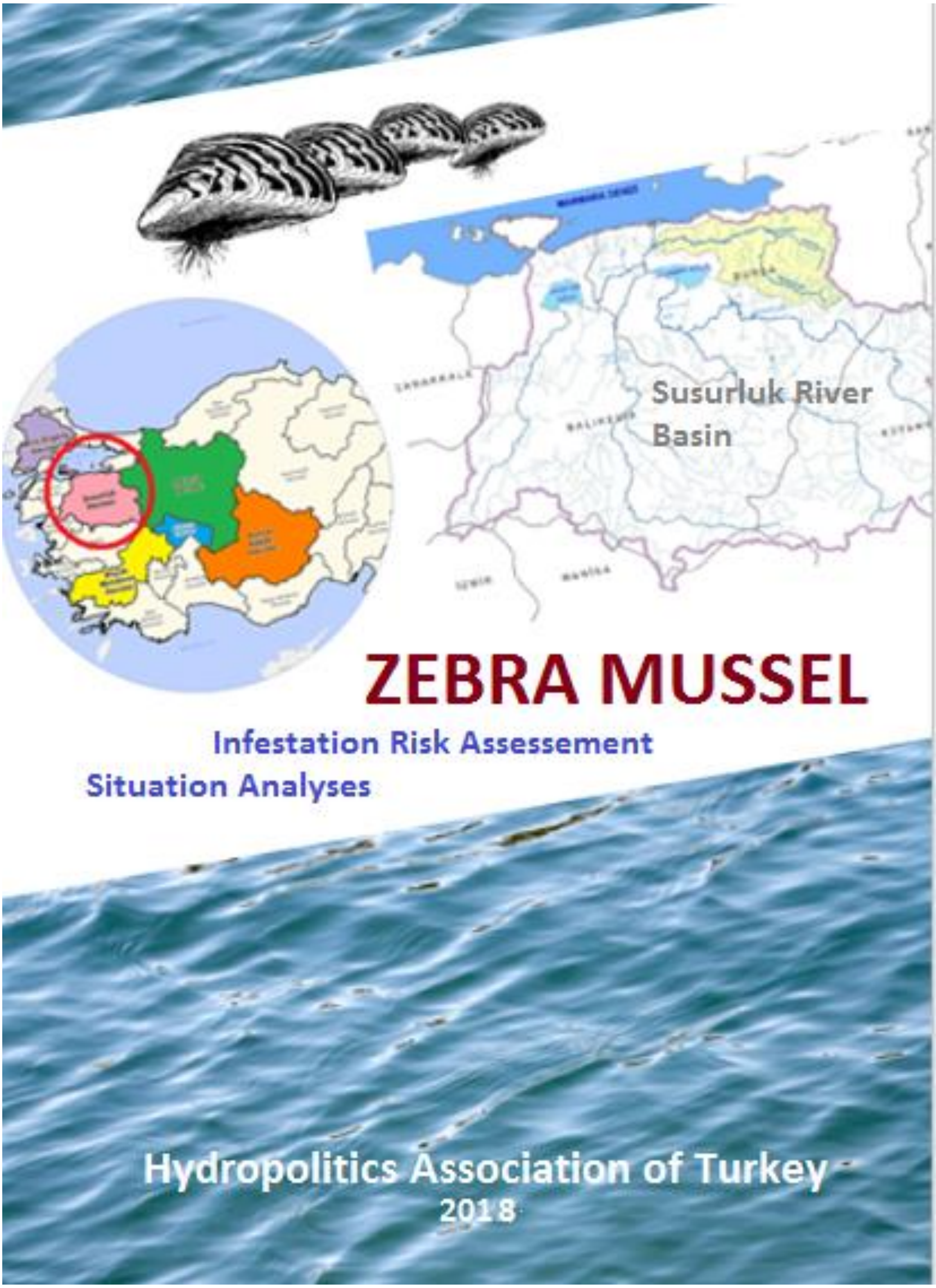
&

SITUATION ANALYSES

in the Susurluk River Basin in TURKEY

2018

The Hydropolitics Academy Center of the Hydropolitics Association & Yıldız Technical University ,Applied Statistics Research Center



Hydropolitics Academy Center & Yıldız Technical University , Applied **Statistics Research Center**

Assessment of Zebra Mussel (Dreissena Polymorpha) Infestation Risk in the Susurluk River Basin

Report Name : Zebra Mussel (Dreissena Polymorpha) Infestation Risk Assessment and Situation Analyses in the Susurluk River Basin in Turkey
Report No : 8
Authors : Dursun Yıldız ,Assoc. Prof Dr. Doğan Yıldız ,Research Assistance Mehmet Şamil Güneş
Edited by Dursun Yıldız

Contact information

Dursun Yıldız
Hydropolitics Association
Güfte Sok 8/9 06680 Kavaklidere/Ankara,Turkey
Tel.: +90-312 -4170041
Fax: +90-312-4166067
E-mail: dyildiz@hidropolitikakademi.org
dursunyildiz001@gmail.com

For citation : Yıldız D.,Yıldız D, Güneş.Ş.M. 2018 " Assessment of Zebra Mussel (Dreissena Polymorpha) Infestation Risk in the Susurluk River Basin in Turkey " .Report No: 8
Hydropolitics Academy Center and Yıldız Technical University Applied Statistics Research Center .Ankara-Turkey.

HYDROPOLITICS ASSOCIATION

----------------------------------- www.hidropolitikakademi.org

Contents

FOREWORD

Turkey has had seriously experienced with zebra mussels problems and had started the site investigations, monitoring studies in some dams and irrigation structures in the beginning of 2000's.

In Turkey, 629 small and large dams ,384 irrigation schemes ,98 water supply systems has been put in operation by State Hydraulic Works (DSİ) since the year of 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.

Therefore we as Hydropolitics Association aimed to raise awareness of decision makers, designers and operators about zebra mussels problems that are likeley to increase in Turkey.Susurluk Basin is a basin that zebra mussels were previously identified. We decieded to make a infestation risk assessment and situation analysis in the reservoirs , rivers and streams in the Susurluk River Basin.
In this study, the very valuable report titled Assessment of Zebra Mussel (Dreissena Polymorpha) Infestation Risk Using GIS for Water Basins in the North-West prepared by Teodora Trichkova & at all from Institute of Zoology, Bulgarian Academy of Sciences helped and gudied us to identify the problem

It is worthwile to mention that an interdisciplinary approach is necessary to address this potential problem.
It should include: management, resources (and other scientists), maintenance, interpretation/education, public affairs, concessions, enforcement efforts and local and private partners.

We hope that the results of the report can be taken as an early warning in the local and national level for preventive measures .

Dursun Yıldız
HPA Director
March . 2018 Ankara /Turkey

As. Prof. Dr..Doğan Yıldız

Deputy Director of the Applied Research Center of Statistics

Yıldız Technical University /Istanbul

1.INTRODUCTION

The invasion of non-indigenous species is now considered to be one of the most serious problems facing native ecosystems (Lodge, 1993; Simberloff, 1996; Wilcove et al., 1998) and the invaders are viewed as a significant component of global change (Vitousek et al., 1996). They have received increasing attention also for their considerable economic and social impacts (Pimentel et al., 2000, 2001).
A typical invasive species with great potential to cause ecological and economic damages is the freshwater bivalve mollusk zebra mussel (Dreissena polymorpha) (Ludyanskiy et al., 1993; Nalepa & Schloesser, 1993). This is a filter feeding, fast reproducing species (females producing up to one-half million eggs per year) with two stages of development - planktonic veliger larvae and attached adult form. With the help of strong byssal threads adult zebra mussels attach to hard submerged substrates or often to each other creating large colonies. When with high abundance, zebra mussels can dramatically change the ecology of infested water bodies by reducing plankton populations (MacIsaac et al. 1995, Caraco et al. 1997, Bastviken et al. 1998, Pace et al. 1998) or causing shift in their diet (Maguire & Grey 2006), and by adversely impacting benthic invertebrate communities and fish populations (Mackie 1991, Ricciardi et al. 1996, Nalepa et al. 1996, 2001, Schloesser et al. 1996, Karatayev et al. 1997, Burlakova et al. 2000, Strayer et al. 2004). At the same time they can interfere with vital water supply intakes and navigation structures and thus affect thermoelectic and nuclear power plants, drinking water treatment plants and various industries (Clarke 1952, Erben et al. 2000).

The Zebra Mussel Dreisenna polymorpha , has invaded a wide geographic area over the last century, causing economic, social and conservation concern.
Originally a native of the Baltic and Black Seas, it managed to disperse through aquatic systems in western Europe, reaching Great Britain in the 1820s (Aldridge et al. 2004) and North America in the 1980s (Schloesser 1995). It transports easily in a variety of ways and colonises suitable habitats extremely rapidly (Ram & McMahon 1996).

Zebra mussels are particularly harmful because they spread so rapidly and there are currently no effective treatment options. They attach to hard surfaces such as boats, docks, boat lifts, aquatic plants, and water intake pipes, and can clog pipes, cut feet, and damage boats.
Zebra mussels have a large economic impact to water treatment facilities, lakeshore owners, lake recreators, and the tourism industry.
Zebra mussels also affect the aquatic ecosystem by filtering out microscopic plankton from the water, and therefore removing the food source for other aquatic organisms. This has implications up the food chain, such as affecting fish populations.

2. ZEBRA MUSSEL OBSERVATION IN TURKEY

As of 2004 approximately 27 lakes and reservoirs are infested with Zebra Mussels (DSİ 2005) (Figure 1,2).

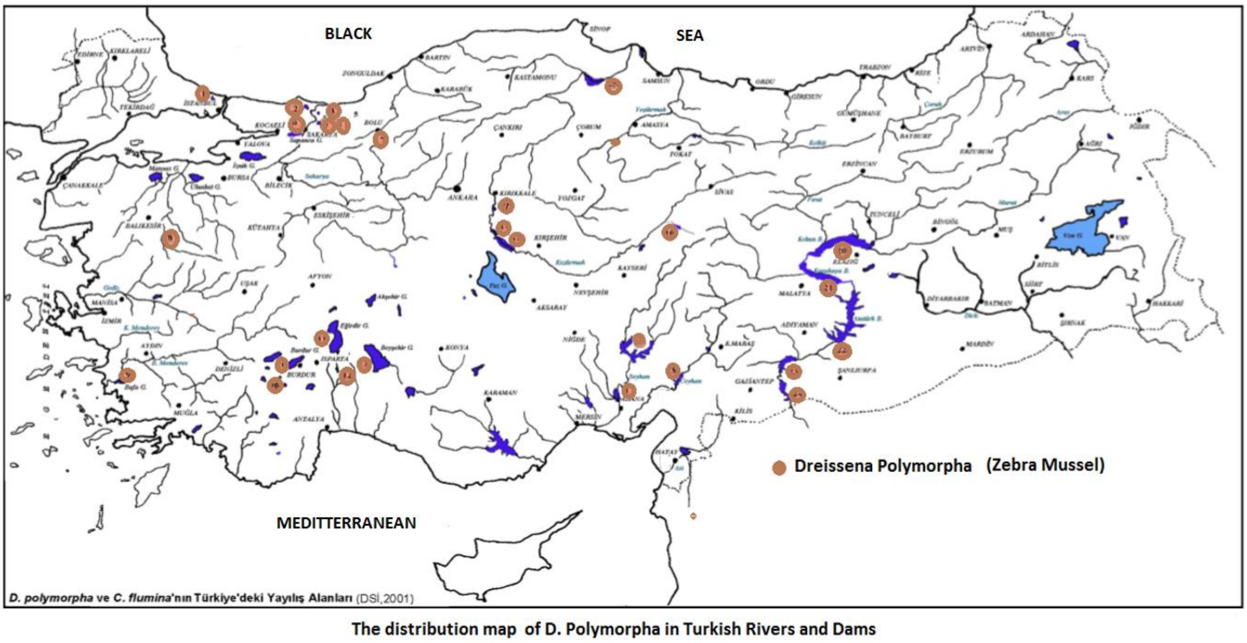


Figure 1. Zebra Mussel Distribution in Turkey (After Bobat 2002,İnci 2004)

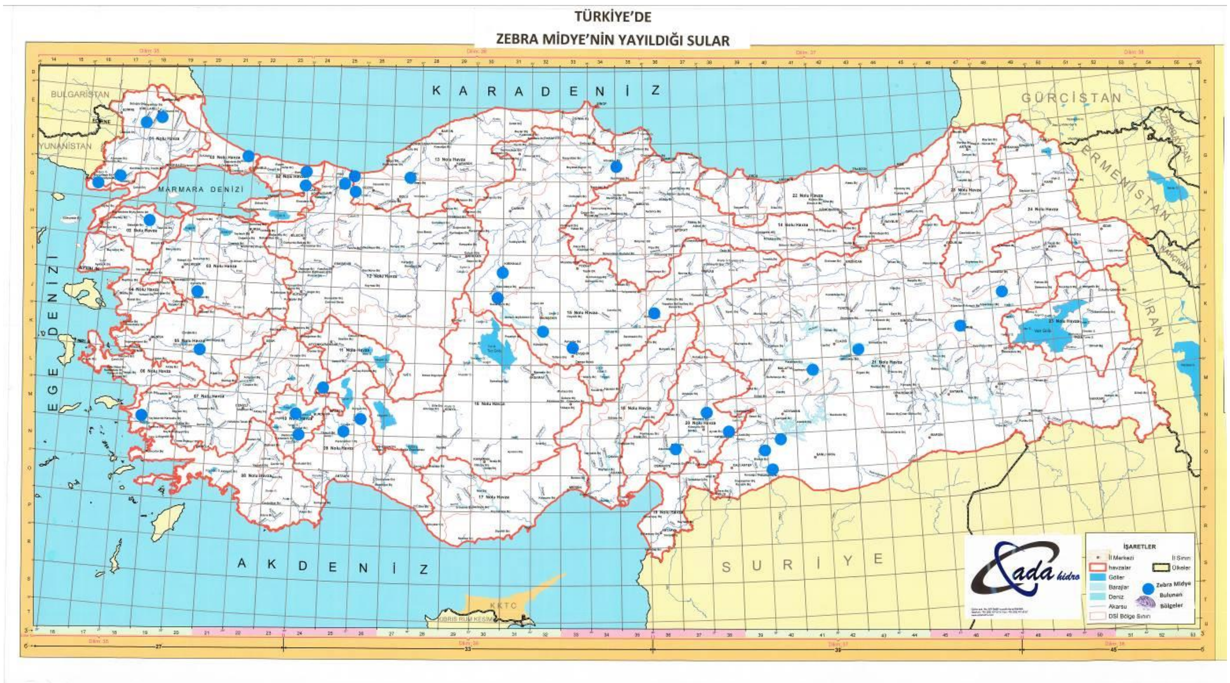


Figure 2. Zebra Mussel Distribution in Turkey (After Hydropolitics Association).,

In Turkey , zebra mussel (Dreissena polymorpha) has been observed since more than 120 years. 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 (DSİ 1969).

Turkey has seriously 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.

In the previous site investigation made by State Hydraulic Works (DSİ 2005) , İkizcetepeler Dam in the Susurluk Basin has been reported as infested with the most longest and weightest zebra mussel they have ever obtained in their investigation (Table 1).

The Hydropolitics Association focused on the issue and has prepared a comprehensive report titled ***"The Zebra Mussel in Turkey"*** in 2017(Aksu 2017). After preperation this report Hydropolitics Association management board has decieded to focus on prevention and response planning studies in on zebra mussel infestation in Turkey.

Figure 3. Susurluk River Basin in Turkey

After this decision, Susurluk River Basin , one of the most threatened basin in terms of zebra mussel infestation, has been choosen to study on. (Figure 3)

The goal of the study is to rise awareness by assesing the risk of zebra mussel infestation in this basin using available data. We assume that this study could be a key step further to develope action plans for vulnerable regions in Turkey.

Table 1. Height and weight of Zebra Mussels collected from different 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)

3. PREVENTION AND RESPONSE PLANNING FOR CONTAINMENT AND CONTROL OF ZEBRA MUSSELS

Prevention measures and preperation a response planning as soon as after observation in a reservoir are very important steps to make this struggle easier.

The first and most cost-effective option when dealing with invasive species is prevention. Assessment of potential risk of zebra mussel infestations would help water managers and responsible authorities to plan for and to prevent major adverse impacts from zebra mussels when they appear in a water body. Risk assessment methods have been widely used recently when dealing with issues concerning zebra mussel and other invasive species (Johnson et al., 2001, Brooks & Shlueter, 2004).

Scientific and response communities have identified best management practices (BMPs) for containment and control of Zebra mussels plan as;

- Prevention/education
- Early Detection and Monitoring
- Response

It should be noted that prevention and education studies can make this struggle in public .As it is well known no one entity can prevent the spread of Zebra mussels by itself. If zebra mussels become established at other lakes and reservoirs in the same river basin , containing them will become incrementally more difficult.

First Step: Situation Analysis

As a first step fort this strugle ,it is advised that given situation analysis form should be completed by responsible person to determine the level of risk for their resbonsibility areas with lakes and reservoirs.
A general guidelines for determining the level of risk for a particular water body is provided in Figure 4.

After determining the risk level, the appropriate list of recommended actions prepared by related organisations should be completed.

Interconnected waters are often managed by different agencies operating under separate authorities. Because of the potential for colonization by drifting larvae, an effective response will typically require coordination among these agencies.This analysis is quick and simple.

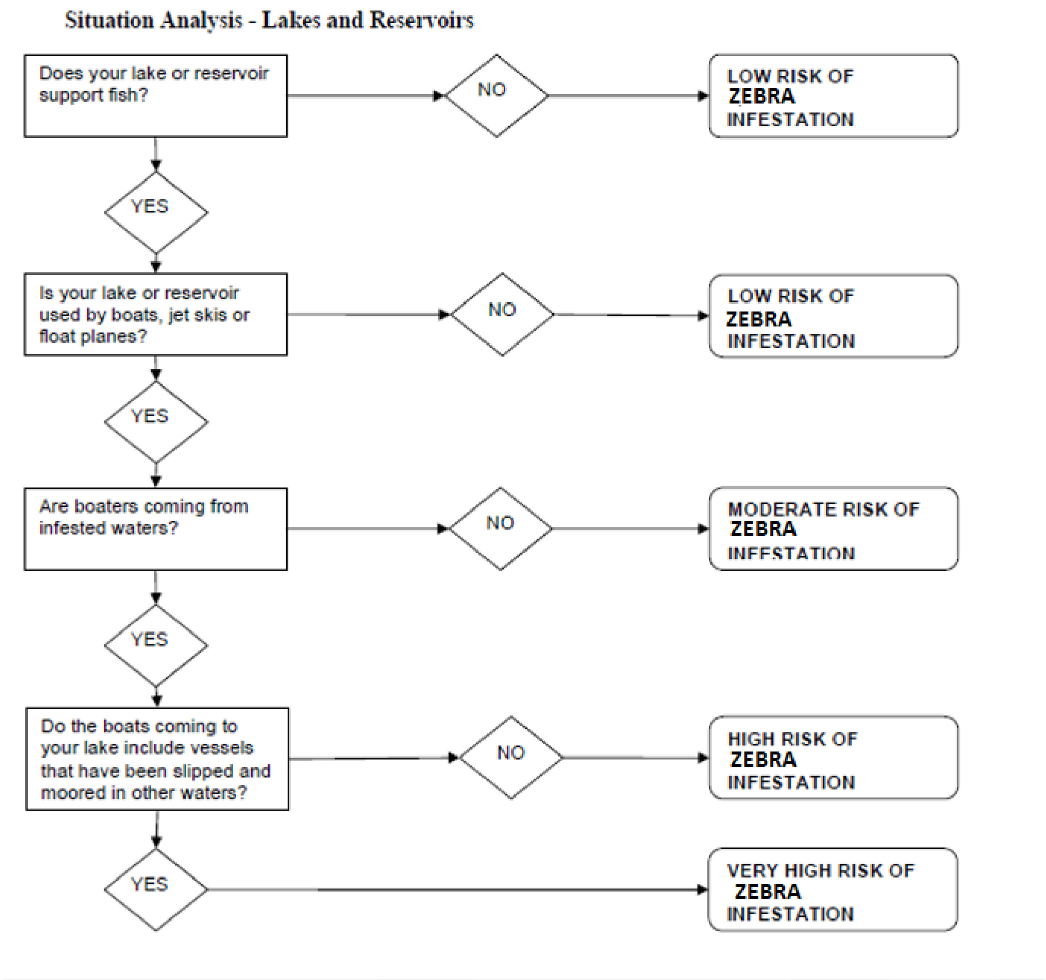


Figure 4. A general guidelines for determining the level of risk for a particular water body

Second Step: Dedection

After the situation analyses with infestatation risk assesment study,dedection can start. The goal of detection monitoring is to determine whether mussels are present in a waterbody as soon as possible after an introduction occurs.
As it is indicated before,early detection is important for containment and control. Detection monitoring can be done several ways, and can easily be accomplished with volunteers or minimal staff time. Detection of invasive mussels triggers response action

These efforts include developing classification schemes to predict invasiveness, identifying sources or pathways of introduction and susceptible resources and characterizing the potential biological consequences of establishment and spread.

A common method of most studies on zebra mussel is comparing limiting conditions for the species to environmental data (climatology, geology, water chemistry, etc.) (Strayer, 1991, Ramcharan et al., 1992, Schmidt & Hirsch, 1993, Strayer & Smith, 1993, Mellina & Rasmussen, 1994, Whittier et al., 1995, Hayward & Estevez, 1997, Lewis et al., 1997, Cohen & Weinstein, 1998a,b, Kozlowski et al., 2002, Jones & Ricciardi, 2005).

Third Step: Analyses and Assesment

The evaluation of physical and chemical characteristics of water bodies and their suitability to the zebra mussel requirements was made based on existing data from monitored river stations, spatial data and reservoir field survey.

Some reservoirs are sampled to determine which physicochemical variables explain the occurrence and abundance of zebra mussel. The principal component analysis used showed that the first two principal components related mainly to calcium concentration, pH, electroconductivity and Secchi disk transparency, explained the majority of total variance of data. pH, calcium concentration and dissolved oxygen were selected as habitat suitability parameters, and corresponding tolerance ranges based on the environmental requirements of zebra mussels during the larval and early growth stages, were defined.

These parameters were divided into three main categories that reflected the infestation potential of zebra mussel: Low, Moderate and High. After all spatial and attributive data were collected, they were processed and analyzed

3.1. **Assessment Methods**

3.1.1. Statistical Methods

For the purposes of the statistical analysis we used data from one sampling site at each reservoir. In the reservoirs, where more than one sampling site existed, the sites were selected randomly. Data from April and data from August-September were analyzed separately. Ordination technique based on principal component analysis (PCA) was used to summarise the major patterns of variation within the data obtained. Ordination was implemented by the computer program CANOCO 4.0 (Ter Braak & Šmilauer 1998). The program STATISTICA (StatSoft, Inc. 2001) was used to analyze correlations and to describe the distribution of important environmental variables in different water bodies.

3.1.2. Selection of physicochemical parameters and suitability criteria

Based on the results of the principal component analysis and review of available information, habitat parameters important for the larval and early stages of zebra mussel survival and growth were selected and suitability criteria defined. These parameters were divided into three main categories that reflected the infestation potential of zebra mussel: High, Moderate and Low Potential. The parameters that were in the range known to support reproducing zebra mussel populations were included in the category “High”; these in the range in which zebra mussel larvae areknown to survive but not well - in “Moderate”; and the parameters that were outside the range in which zebra mussel larvae are known to occur - in “Low”.

3.1.3. GIS Methods

All available information sources and different kind of input data were analyzed in order to select the spatial phenomena and to define their geometric and attributive characteristics.The building of the GIS database included 2 stages: 1) Creation of digital layers from analogue maps (digitizing); and 2) Organization of all layers into an object-oriented topologically correct geodatabase.

Each of the layers are properly geometrically registered with other layers. Paper maps are the primary source of input spatial information for developing the GIS database.A linear referencing algorithm is applied to capture information about the locations of hydrometric stations.

3.2. Study Area

The study area Susurluk Basin (Figure 5) is located in the Northwest of the Anatolian peninsula.

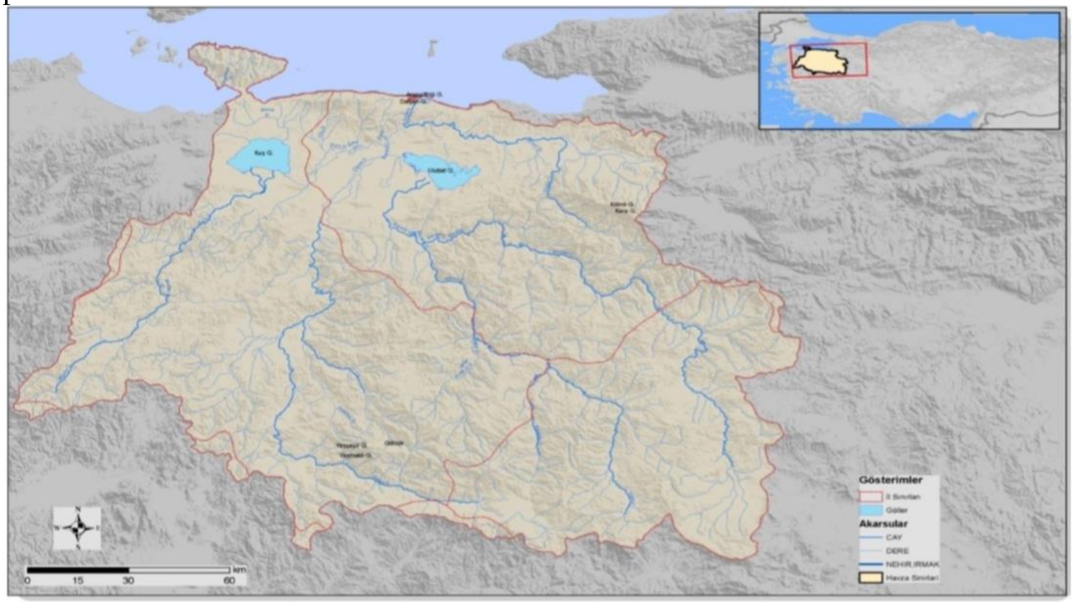


Figure 5. Main rivers in the Susurluk Basin

Figure 6. Provincies,Lakes and Rivers in the Susurluk Basin

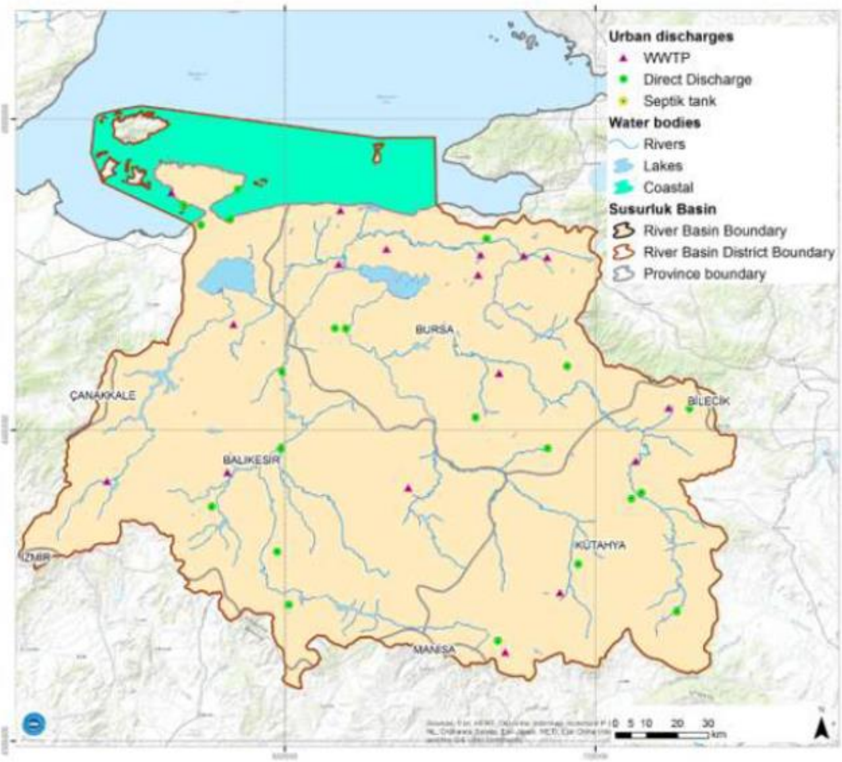


Figure 7.Urban discharges in Susurluk Basin (agglomerations > 2000 pe) (Executive Summary 2016)

Three major provinces (Balıkesir, Bursa and Kütahya) (Figure 6)share the larger part of the basin, while Bilecik, Çanakkale, İzmir and Manisa provinces cover less than 2% of the basin. Population in 2014 totals about 3.2 million(Executive Summary 2016).

Covering about 3.1% of Turkey's land, the total area of the river basin district is 26,790 km^2 (24,299 km^2, excluding coastal waters).

Forests and semi-natural areas cover the largest area in the basin (54.4%) and agricultural areas cover the second largest area in the basin (41.8%). The rest of land uses (3.8%) corresponds with artificial surface (urbanized areas), wetlands and water surfaces (Figure 7).
Among the agricultural areas, 36.9% corresponds to rainfed areas and 27.7% to irrigation areas, while the other 35.4% corresponds to pastures and others (mixed agriculture-natural vegetation)(Executive Summary 2016).

The industrial water use in the basin in 2012 is estimated at 45.39 hm^3, localized mostly in Bursa, Eskişehir and Bilecik. The number of hydroelectric power plants in the Susurluk Basin totals 12. The baseline scenario between 2012 and 2030 outline an upward trend on the overall water use (1.8% year-on-year rate of increase; 372 hm^3 more), due to the considerable growth of agricultural water use (1.7% year-on-year rate; 259 hm^3 more).
Three major provinces (Balıkesir, Bursa and Kütahya) share the larger part of the basin, while Bilecik, Çanakkale, İzmir and Manisa provinces cover less than 2% of the basin. Population in 2014 totals about 3.2 million (Executive Summary 2016).

About industrial discharges, the RBPAP considers that there are 25 direct discharges without treatment and 83 discharges with a previous treatment in a WWTP, so the 77% of the industrial discharges present a previous treatment.(Executive Summary 2016).

Diffuse pollution from agriculture/livestock affects water bodies (surface and groundwater bodies due to pollution of nitrates, bacteria (e.g. Escherichia coli) and pesticides. The increase of nutrients and pesticides generates a bad physicochemical and chemical status and thus the good status of the water body could not be achieved.

Susurluk Nehri

Photo1. Susurluk River

The significant water management issues are the major current and foreseable problems affecting the water environment. The SWMIs identified in the Susurluk Basin are:

- Industrial discharges and untreated urban discharges to surface waters. Geothermal water discharges
- Diffuse pollution from agriculture/livestock to surface and groundwater bodies
- Over-exploitation of water resources (surface and ground)
- Pollution discharges / leachates from municipal landfills to both surface and groundwaters
- Hydromorphological changes

The Susurluk Basin has 180 waterbodies: 24 groundwater, 107 river and 37 lake (above 50 hectares), 3 transitional (1 river and 2 lakes) and 9 coastal water bodies. (The Master Plan – Susurluk Basin. 2014), (Photo 1).
41 dams and ponds have been considered because as pressures of being located in water bodies. Out of all these dams and ponds, there are 22 operational dams or in advanced state of construction (Figure 8).

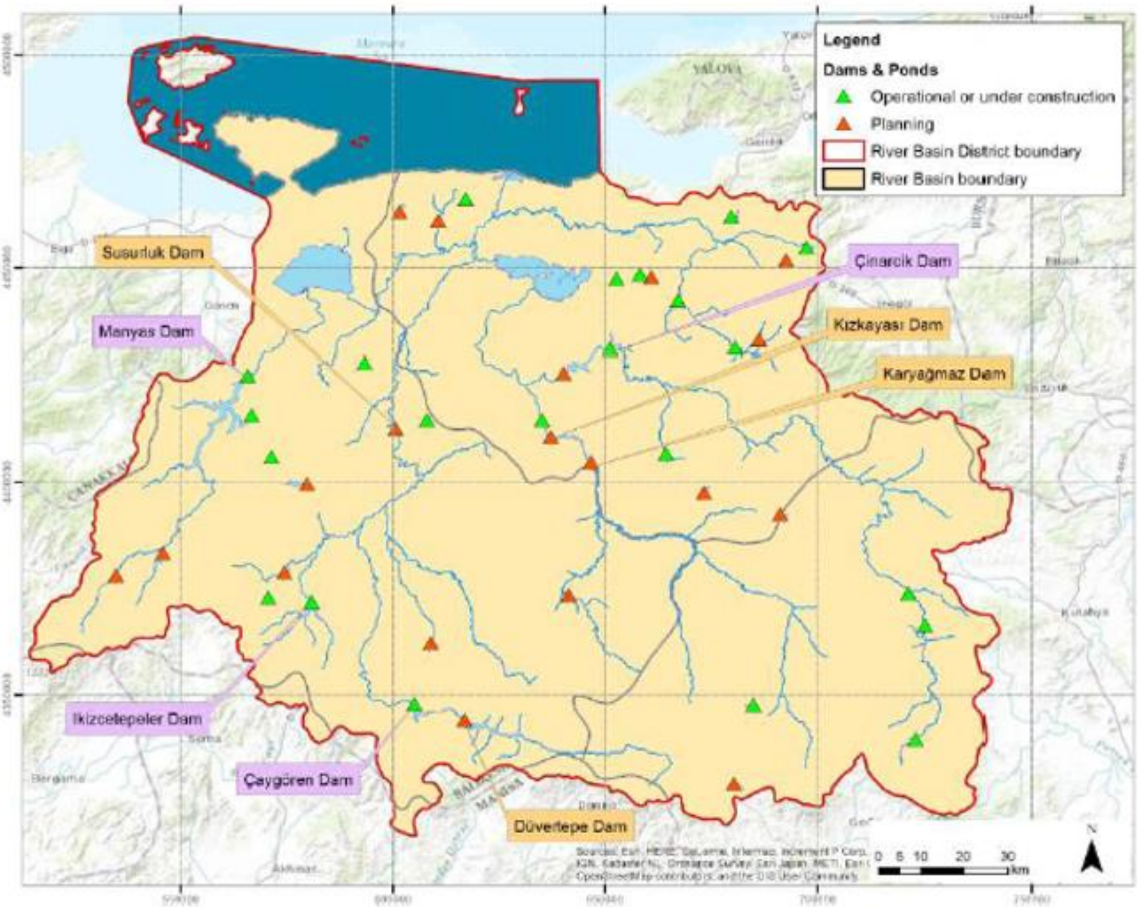


Figure 8. Dams and ponds in water bodies in Susurluk Basin (24).

3.3. Material and Methods

3.3.1. Data Gathering

Various sources were used for collecting data. Data about the physical and chemical characteristics of the water bodies in the region were collected from Regional Directorate of State Hydrauilc Works and Quality Control Labs of the Bursa Municipality,

3.3.2. Surveying Criterias

The analysis of depth, substrate type and Secchi disk transparency as parameters of importance to zebra mussel physiological and habitat requirements were based on literatüre survey and published data. The analysis of water temperature, pH, dissolved oxygen and calcium concentration were based on:
Literatüre survey data ,published data, spatial data from different hydrological stations and water quality monitoring stations.

Water quality parameters obtanined from one of the infested reservoir in the study region are reviewed and used to asses which physicochemical variables explain the occurrence and abundance of zebra mussel.

The reservoirs and rivers were selected according to the following criteria:

- River catchment – the most river catchments be represented
- Size - surface area above 20 ha
- Reservoirs most probably infested (Çayboğazı Barajı); reservoirs with possible connection with infested ones,

- Economic importance - reservoirs used for drinking water supply (Çaygören Dam), electricity production and fishery .
- The river and creek that has available related data for risk analyses .

Figure 9. Zebra Mussel accumilation in a pipeline

4. INFASTATION RISK ANALYSES WITH AVAILABLE PHYSICOCHEMICAL WATER QUALITY PARAMETERS

Many authors studied the potential distribution of zebra mussel (Figure 9) in different regions based on comparison of species physiological and ecological requirements with a variety of environmental factors, including climatic characteristics, geology, water chemistry, etc. Most frequently used and considered as most important for the survival, growth and reproduction of zebra mussel were the following physicochemical parameters:

- **Temperature** (Strayer, 1991, Whittier et al., 1995, Hayward & Estevez, 1997, Cohen & Weinstein, 1998a,b);pH (Neary & Leach, 1992, Ramcharan et al., 1992, Koutnik & Padilla, 1994, Whittier et al., 1995, Hayward & Estevez, 1997, Cohen & Weinstein, 1998a,b, Kozlowski et al., 2002);

- **Dissolved oxygen** (Whittier et al., 1995, Hayward & Estevez, 1997, Cohen & Weinstein, 1998a,b, Kozlowski et al., 2002);

- **Calcium concentration** (Neary & Leach, 1992, Ramcharan et al., 1992, Murray et al., 1993, Koutnik & Padilla, 1994, Mellina & Rasmussen, 1994, Whittier et al., 1995, Hayward & Estevez, 1997, Kozlowski et al., 2002, Jones & Ricciardi, 2005);

- **Substrate size** (Mellina & Rasmussen, 1994, Whittier et al., 1995, Hayward & Estevez, 1997, Jones & Ricciardi, 2005);

- **Depth** (Jones & Ricciardi, 2005);

- **Transparency** (Whittier et al., 1995, Hayward & Estevez, 1997

- **Salinity** (Strayer & Smith, 1993, Whittier et al., 1995, Hayward & Estevez, 1997, Kozlowski et al., 2002).

Firstly we need to select the suitability criteria which best correspond to the goal of our study and reflect the characteristics of the region,

Therefore we made a preliminary review of 5 available parameters:

- Size of the water body,
- Depth,
- Water temperature,
- pH,
- Dissolved oxygen.

Since the water bodies in the study region are contaminated ,salinity was also included in the review.

The water column assessment is used to determine if the water column environment is conducive to zebra mussel survivability and reproductive success in the reservoirs in the Basin. The suitability criteria are derived from a variety of sources. One of the most recent reference has been used for suitability criteria given in Table 2.

Table 2. Water column zebra mussel suitability criteria. (Mackie and Claudi 2010,Bartell at all.2007)

		Low Potential for Adult Survival	Low Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Calcium (mg/l)	Mackie and Claudi 2010	<8	8 - 15	15 - 30	>30
Dissolved oxygen (mg/l)	Mackie and Claudi 2010	<3	3 - 7	7 - 8	>8
Temperature (C)	Mackie and Claudi 2010	<10 or >32	26 - 32	10 - 20	20 - 26
pH	Mackie and Claudi 2010	<7.0 or >9.5	7.0 - 7.8 or 9.0 - 9.5	7.8 - 8.2 or 8.8 - 9.0	8.2 - 8.8
Potassium (mg/l)	(Bartell et al 2007)	>100	>50 (prevents settlement)	40 - 50	<40
Hardness (mg/l)	Mackie and Claudi 2010	<30	30 - 35	55 - 100	100 - 280
Alkalinity (as mg $CaCO_3$/l)	Mackie and Claudi 2010	<30	30 - 55	55 - 100	100 - 280
Conductivity (umhos)	Mackie and Claudi 2010	<30	30 - 60	60 - 110	>110
Secchi depth (m)	Mackie and Claudi 2010	<1 or >8	1 - 2 or 6 - 8	4 - 6	2 - 4
Chlorophyll a (ug/l)(food source)	Mackie and Claudi 2010	<2.5 or >25	2.0 - 2.5 or 20 - 25	8 - 20	2.5 - 8
Total phosphorus (ppb)	Mackie and Claudi 2010	<5 or >50	5 - 10 or 35 - 50	10 - 25	25 - 35

There is a general consensus that calcium concentrations, around 28-30 ppm or higher, produce optimal zebra mussel growth. Calcium concentrations would be high enough to support optimal zebra mussel growth on a lake-wide basis.
However, there is some uncertainty about the influence of three trophic indicators (Secchi depth, total phosphorous, and chlorophyll) on zebra mussel growth. Some investigators think high chlorophyll levels promote high zebra mussel growth, but

more recently, some think it could inhibit zebra mussel growth,especially if algae are dominated by blue green algae (Macki and Claudi, 2010).

4.1. Water Quality and Pollution Loads in the Susurluk Basin (TUBİTAK MAM 2015**)**

For water quality classification, water quality data between 2003-2009 obtained by State Hydraulic Works were used. Surface water quality classes were determined based on the quality classes criteria for terrestrial water resources described in Table 3 of Water Pollution Control Act.

Table 3. Water quality classes

Water Quality Parameters	Water Quality Classes (GROUP A PARAMETERS)			
A) PHYSICAL & INORGANICS- CHEMICAL PARAMETERS	I	II	III	IV
1) Temperature ^0C	25	25	30	> 30
2) pH	6.5-8.5	6.5-8.5	6.0-9.0	> 6.0-9.0
3) Dissolved Oxygen (mg $O_2/L)^a$	8	6	3	< 3
4) Oxygen (%)^a	90	70	40	< 40
5) Chloride (mg Cl^-/L)	25	200	400^b	> 400
6) Sulphate (mg $SO_4^=/L$)	200	200	400	> 400
7) Ammonium Nitrogen (mg NH_4^+-N/L)	0.2^c	1^c	2^c	> 2
8) Nitrite Nitrogen (mg NO_2^--N/L)	0.002	0.01	0.05	> 0.05
9) Nitrate Nitrogen (mg NO_3^--N/L)	5	10	20	> 20
10) Total Phosphorus (mg P/L)	0.02	0.16	0.65	> 0.65
11) Total Dissolved Solid (mg/L)	500	1500	5000	> 5000
12) Color (Pt-Co Unit)	5	50	300	> 300
13) Sodium (mg Na^+/L)	125	125	250	> 250

Water Quality Classes According to Turkish Water Pollution Control Regulation

As long as there was sufficient data, for each water quality monitoring stations , water quality classes (I,II,III,IV) were determined for COD, BOD_5, NH_4-N, NO_2-N and NO_3-N which are important water quality parameters in terms of Physical-inorganic,Chemical parameter groups (A,) described in the same table. All these data were inserted into maps prepared by the use of GIS (Figure 10).

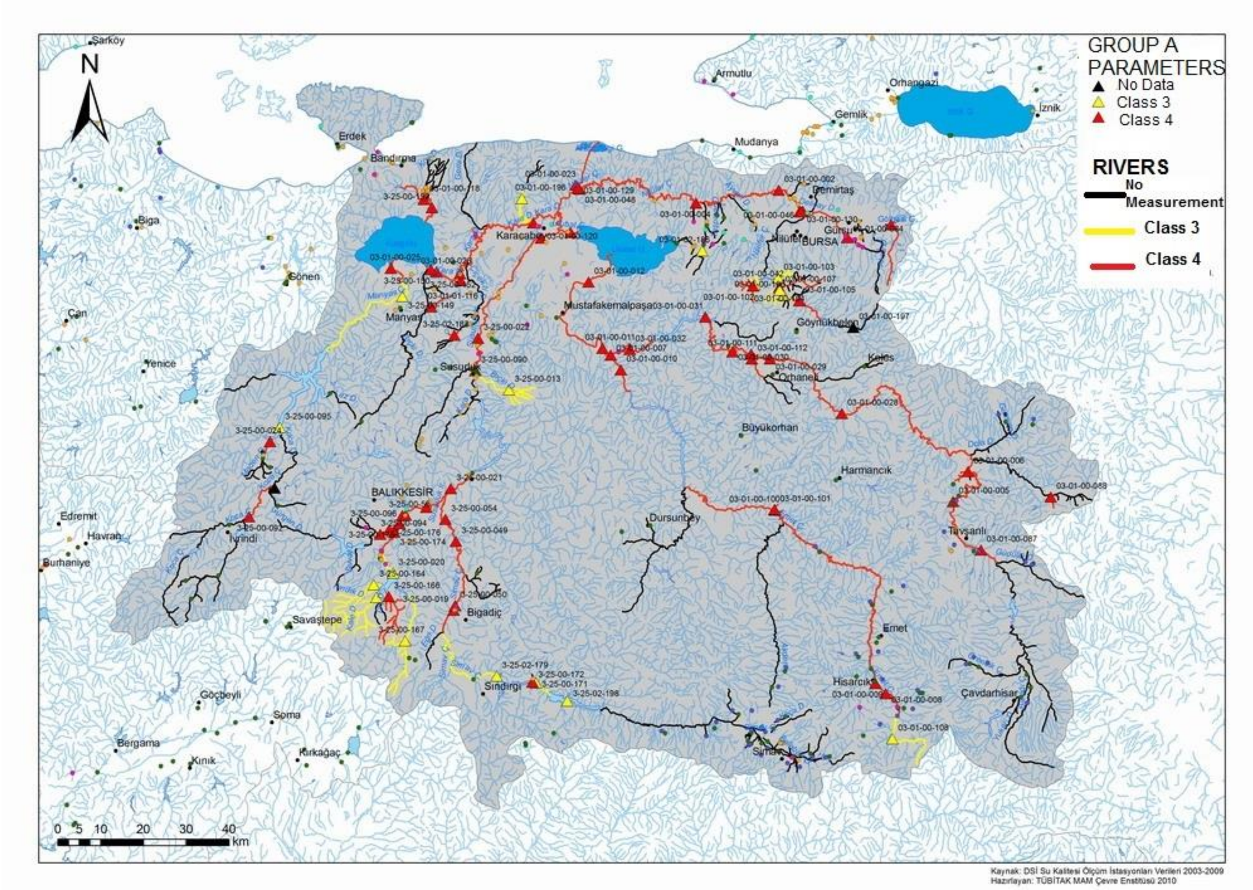


Figure 10. Water Quality of the rivers in Susurluk Basin in terms of Group A (Physical-inorganic,Chemical parameters)

4.2.Water Quality of Main Rivers in the Basin

A comprehensive action plan namely “Nilüfer Creek Sub-Basin Water Quality Action Plan” has been prepared to control the water quality problems observed in Nilüfer Creek and its tributaries. The action plan is being implemented since 2013 by the coordination of Ministry of Forestry and Water Affairs.
Main Rivers in the Susurluk Basin are Susurluk,Simav,Kocaçay,Emet ,Orhaneli and Nilüfer Creek. These rivers are discharged to Marmara Sea , Uluabat and Manyas Lakes.
There are several large and small dams in operation in these rivers (Table 4).(Figure 11)
According to the Study made By TUBİTAK, all of the abovementioned main rivers can be clasified as III and IV.group contaminated water in terms of physical and inorganical chemical parameters . These contaminated waters

In the Susurluk Basin, Nilüfer Creek is the most critical flowing water in terms of contamination . Before entering the Doğancı-S.Sayın Dam , Nilüfer Creek water has prone to eutrophication with the water quality parameters NH4-N is in I-II class, NO3-N is in I class, total P is in III class, NO2-N is in III and IV class. Physical and inorganic and chemical parameters of water indicate that the water is in III and IV class.

In terms of organic parameters the water can be classified as II-III class water. In terms of inorganic parameters the water is classified as I-III classes water.
In terms of bacteriological contamination water has been observed as II-III class.

Table 4. Charfactersitics of the Dams in the Susurluk Basin

DAMS	River /Creek	Town	Reservoir Surface km²	Reservoir Volume hm³	Height (m)	Turb udity	Water Temp. °C	pH	Ca	Dissolved Oxygen	Dam PURPOSE	Fishery Activity	Zebra Musssel Shells
BALIKESİR PROVİNCE													
MANYAS	Kocaçay	Balya	1,68	4,28	70						S+E+T		
İKİZCETEPELER	Kille Çayı	Merkez	9,6	157,9	45						İ S +S		Yes
ÇAMKÖY	Ayıtlıdere	Bigadiç	6,9	9,4	40						D		
ÇAYGÖREN	Simav	Sındırgı	8,5	154,91	50						S+T		Yes
ARDIÇTEPE	Madra(Kocaçay	İvrindi	2,27	37,6	35						S		
SARIBEYLER	Sarıbeyler Çayı	Savaştepe	1	16	35						S		
Söve	Yağlıdere	Susurluk	0,27	2,6							İ		
BURSA PROVINCE													
NİLÜFER	Nilüfer Çayı	Osmangazi	1,47	39,5	90						İ		
GÖLBAŞI	Aksu dere	Kestel	1,74	12,75	10						S		
DEMİRTAŞ	Ballıkaya dere	Osmangazi	1,0	14,46	50						S	Yes	
B.ORHAN	Cuma dere	Büyükorhan	1,0	5,0	32						S		
BOĞAZKÖY	Kocasu Çayı	İnegöl	6,5	41,6	38						S	Yes	
DEVECİKONAĞI	Emet çayı	M.Kemalpaşa	0,66	6,14	35						E		
HASANAĞA	Hasanağa dere	Nilüfer	3,2	3,71	33						S	Yes	
DOĞANCI 1	Nilüfer	Osmangazi	1,55	43,3	80						İ		
ÇINARCIK	Orhaneli	Orhaneli	10,14	372	125						İ		
KÜTAHYA PROVINCE													
ÇAVDARHİSAR	Bedir	Çavdarhisar	4	34	47						S		
KAYABOĞAZI	Kocasu	Tavşanlı	3	38	42						S+T+İ		
HASANLAR	Kabaklar	Hisarcık	4,45	8	45						S		

S: Irrigation,E:Electricity,T: Flood ,İ: Drinking Water , D:Waste Disposal

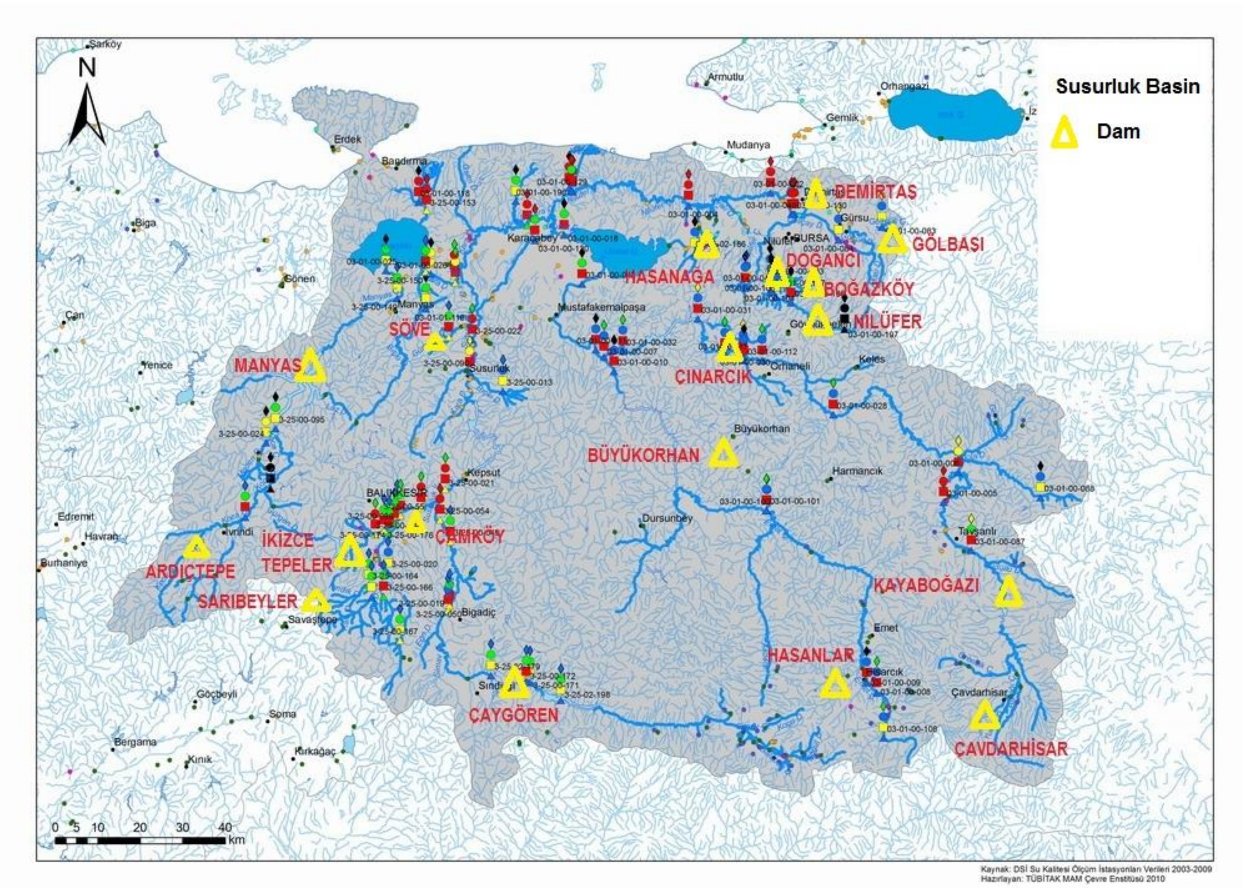


Figure 11. Main Dams Location in the Susurluk Basin

4.3. Zebra Mussel Growth Potential Based on Water Quality

Suitability criteria

The principal component analysis used by several researchers showed that calcium concentration, pH, electroconductivity and Secchi disk transparency were most important parameters in explaining the majority of total variance of data.
Based on these results, the review of the eight physicochemical parameters related to zebra mussel physiological and habitat requirements, and the available data, we selected calcium concentration, pH and dissolved oxygen as criteria in the GIS assessment.

The habitat suitability ranges defined for each of the selected criteria were adapted from Cohen & Weinstein (1998a) (Table 4). Cohen & Weinstein (1998a, b) analyzed the potential distribution and abundance of zebra mussel in California using tolerance ranges based on the environmental requirements of zebra mussels during the larval and early growth stages, which were more restrictive than those of adults.

For instance, adult mussels can tolerate pH levels as low as 6.5-7.0 and calcium levels as low as 12-15 mg/l, while larvae need more alkaline conditions, of at least pH 7.3-7.4 and calcium 15 mg/l (McMahon, 1996, Cohen & Weinstein, 1998a).

In this analysis April through September has been obtained as high risk of infestation period is similar the main period for growth and reproduction of zebra mussel given in the most literatures

In our pre analysis, we used mean values of three parameters of Temperatoure, Dissolved Oxigen and Ph were selected as suitability criteria because of the most available data from every measurement stations.

Calcium – 40 %
pH – 40 %
Dissolved oxygen – 20 %.

4.3.1 A pre investigation statistical study made by Yildiz Technical University - Applied Statistical Research Center

In this study , we used data obtained from 17 water quality monitoring stations in the Susurluk basin . These stations location are given in Figure…

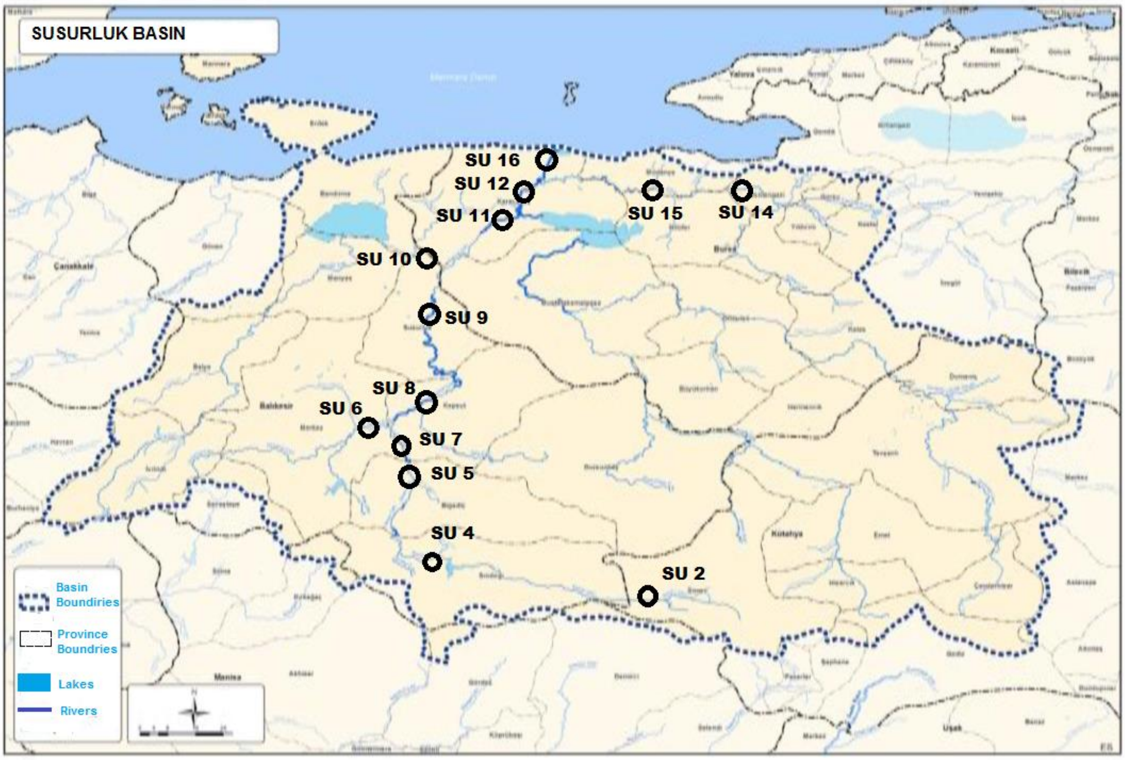


Figure 12. Water quality monitoring stations which data obtained and used for zebra mussel infestation risk analyses study

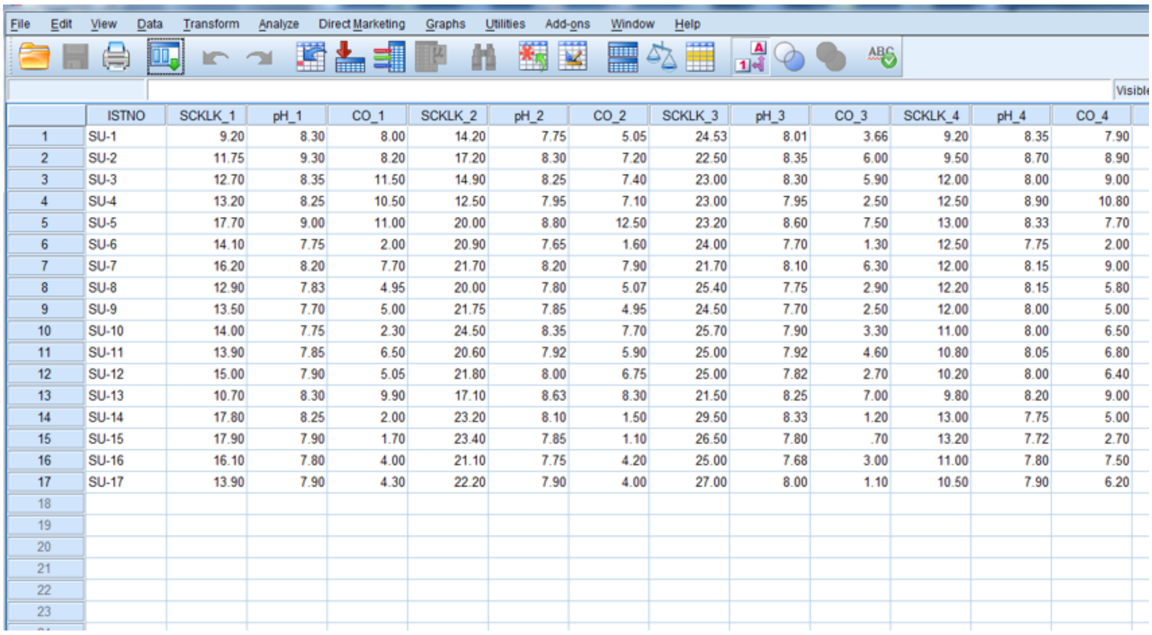
Data obtained water quality monitoring stations given in Figure 12. They are used in the MANOVA (Multivaried Analyses of Variance) and principle component analyses to obtain the areas under the risk of zebra mussel survive and infestation risk.
In this pre analyses study, Zebra Mussel suitability criteria used as it is given in Table 5.
The risk scours as low, moderate and high have been determined sesonally and given in Figure 13.

Table 5. Suitability ranges for the physicochemical parameters used in the analysis (according to Cohen & Weinstein, 1998a).

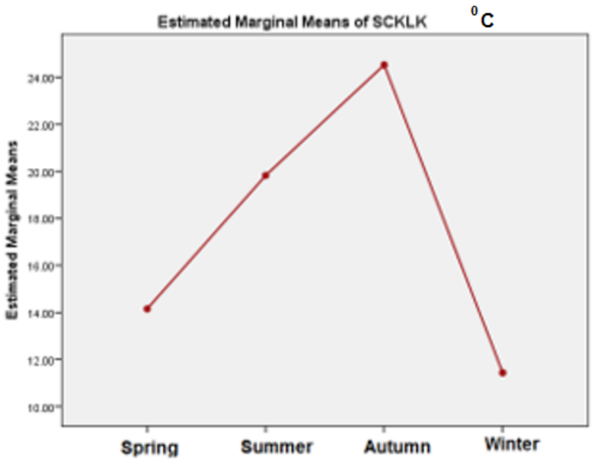
Parameters	High Potential	Moderate Potential	Low Potential
pH	7.5-8.7	7.3-7.5 or 8.7-9.0	< 7.3 or > 9.0
Water Temperature ^{0}C	15-31^{o}C and 10<max<31^{o}C	0-15^{o}C and 10<max<31^{o}C	max<10 or >31^{o}C
Dissolved oxygen (mg/l)	> 8	6-8	< 6

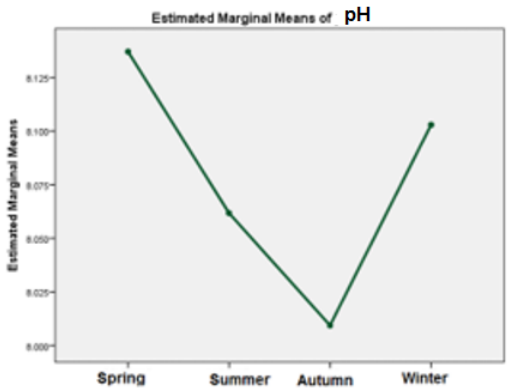
In fact, analyses should be done by distribution of the water temperature data from April-September (active reproductive months of zebra mussel.
Some authors reported that zebra mussels were usually found where dissolved oxygen was over 90% of saturation and become stressed at levels of 40-50% of saturation; others reported 80-85% oxygen saturation as optimal (Cohen, 2005).
The oxygen requirements of zebra mussel rose in warm water (25^{o}C and over), and decline in colder water allowing overwintering mussels to survive under ice (Cohen & Weinstein, 1998a).

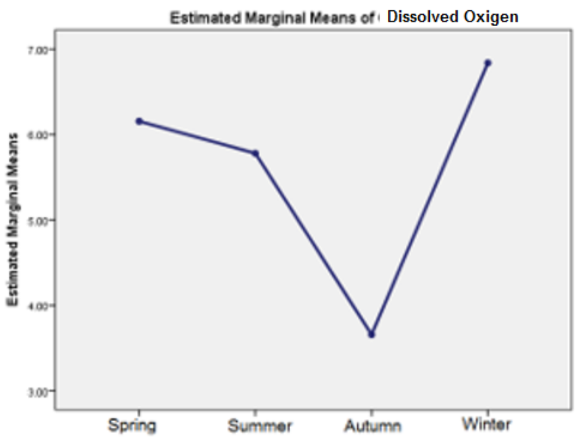
According to literature, in water basins, where zebra mussels occurred, oxygen content detected was between 2.35 and 10.17 mg/l

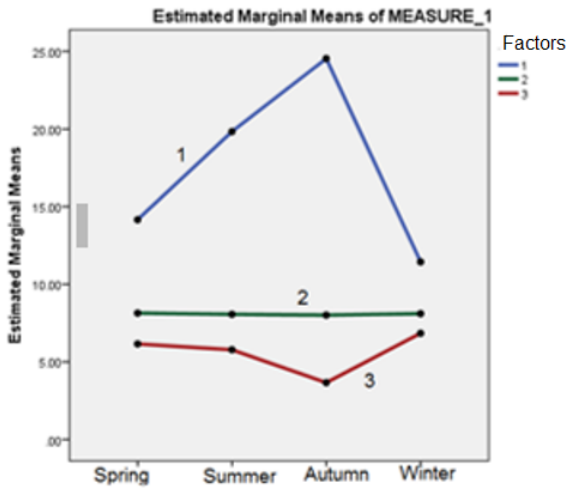


	ISTNO	SCKLK_1	pH_1	CO_1	SCKLK_2	pH_2	CO_2	SCKLK_3	pH_3	CO_3	SCKLK_4	pH_4	CO_4
1	SU-1	9.20	8.30	8.00	14.20	7.75	5.05	24.53	8.01	3.66	9.20	8.35	7.90
2	SU-2	11.75	9.30	8.20	17.20	8.30	7.20	22.50	8.35	6.00	9.50	8.70	8.90
3	SU-3	12.70	8.35	11.50	14.90	8.25	7.40	23.00	8.30	5.90	12.00	8.00	9.00
4	SU-4	13.20	8.25	10.50	12.50	7.95	7.10	23.00	7.95	2.50	12.50	8.90	10.80
5	SU-5	17.70	9.00	11.00	20.00	8.80	12.50	23.20	8.60	7.50	13.00	8.33	7.70
6	SU-6	14.10	7.75	2.00	20.90	7.65	1.60	24.00	7.70	1.30	12.50	7.75	2.00
7	SU-7	16.20	8.20	7.70	21.70	8.20	7.90	21.70	8.10	6.30	12.00	8.15	9.00
8	SU-8	12.90	7.83	4.95	20.00	7.80	5.07	25.40	7.75	2.90	12.20	8.15	5.80
9	SU-9	13.50	7.70	5.00	21.75	7.85	4.95	24.50	7.70	2.50	12.00	8.00	5.00
10	SU-10	14.00	7.75	2.30	24.50	8.35	7.70	25.70	7.90	3.30	11.00	8.00	6.50
11	SU-11	13.90	7.85	6.50	20.60	7.92	5.90	25.00	7.92	4.60	10.80	8.05	6.80
12	SU-12	15.00	7.90	5.05	21.80	8.00	6.75	25.00	7.82	2.70	10.20	8.00	6.40
13	SU-13	10.70	8.30	9.90	17.10	8.63	8.30	21.50	8.25	7.00	9.80	8.20	9.00
14	SU-14	17.80	8.25	2.00	23.20	8.10	1.50	29.50	8.33	1.20	13.00	7.75	5.00
15	SU-15	17.90	7.90	1.70	23.40	7.85	1.10	26.50	7.80	.70	13.20	7.72	2.70
16	SU-16	16.10	7.80	4.00	21.10	7.75	4.20	25.00	7.68	3.00	11.00	7.80	7.50
17	SU-17	13.90	7.90	4.30	22.20	7.90	4.00	27.00	8.00	1.10	10.50	7.90	6.20
18													
19													
20													
21													
22													
23													









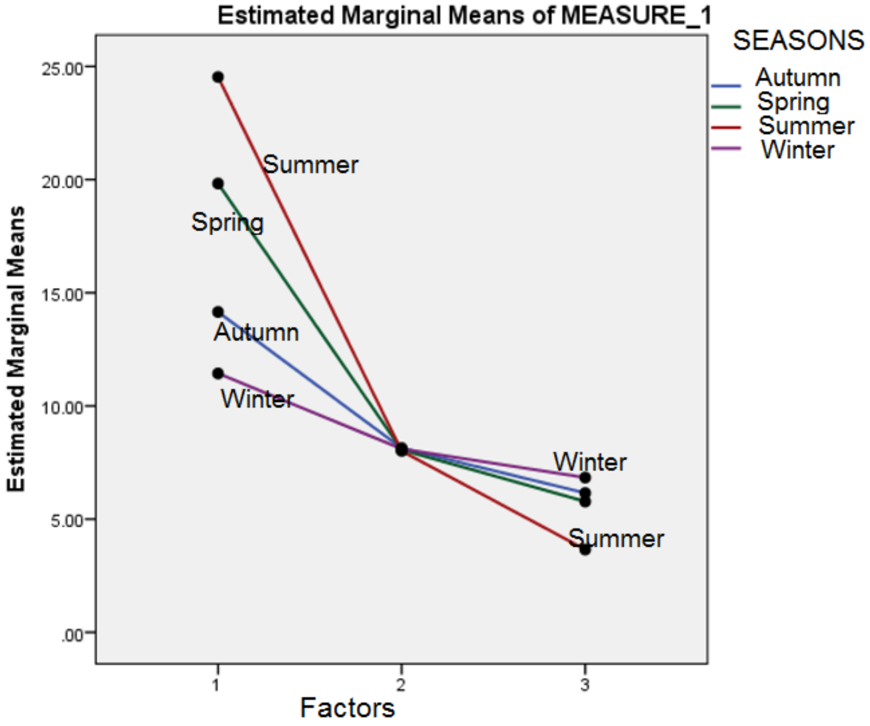


Figure 13. Estimated marginal means of MEASURE_1

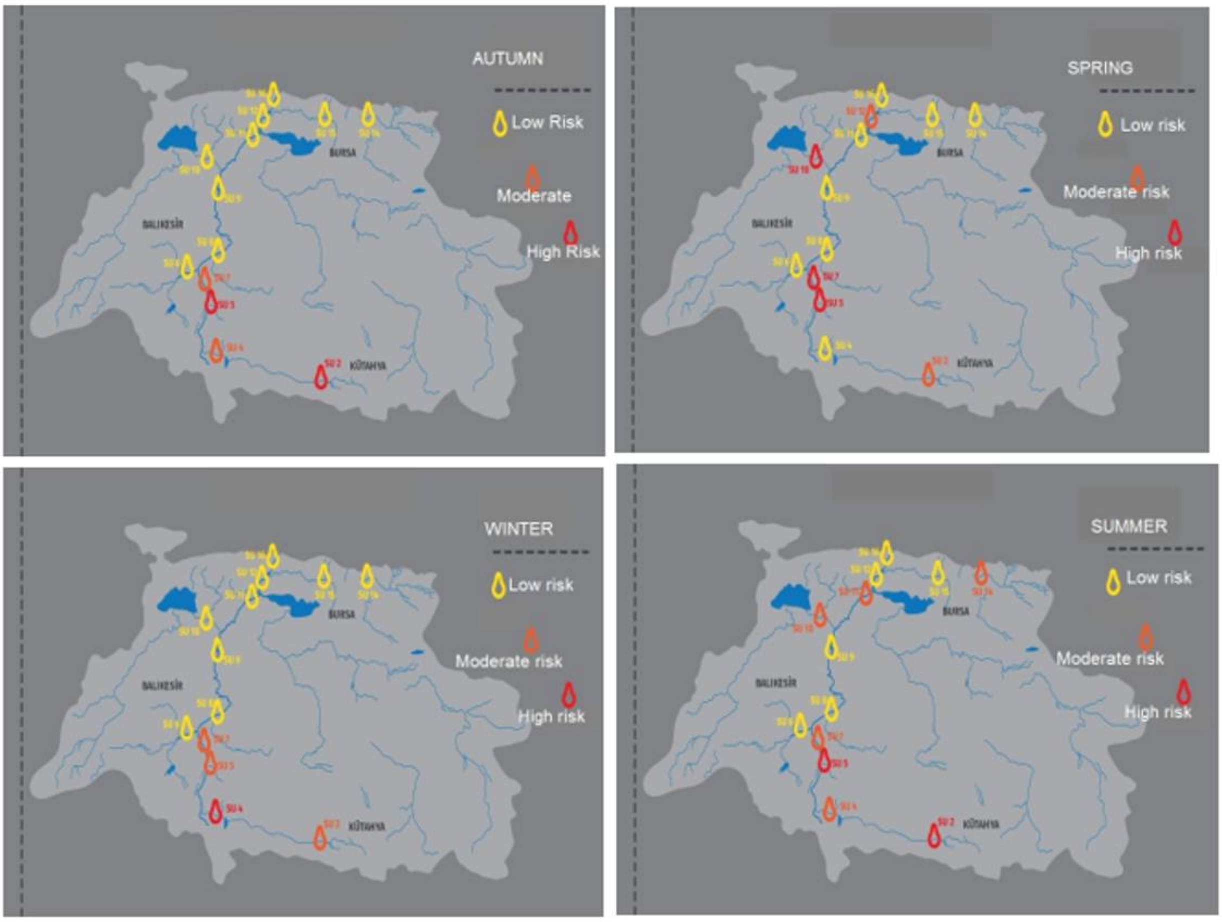


Figure 14. Risk potential scours obtained from the analyses in seasonal periods (Uyumaz 2016).

The water quality monitoring regions were studied according to pH, water temperature and dissolved oxigen data. A risk potential scoured map was produced by using these three parameters and given in Figure 14.

Obtained results showed that the upper reaches of rivers are under high infestation risk potential in every seasons in the year.This result confirmed the presence of Zebra Mussel shells in the dam reservoirs located in this region(İkizce tepeler and Çaygören dams).These results may suggest, that mainly during summer season moderate and high infestation risk potential of zebra mussel are shown in majority of the basin.

4.3.2.Çaygören Dam and İkizcetepeler Dam Cases in the Susurluk Basin

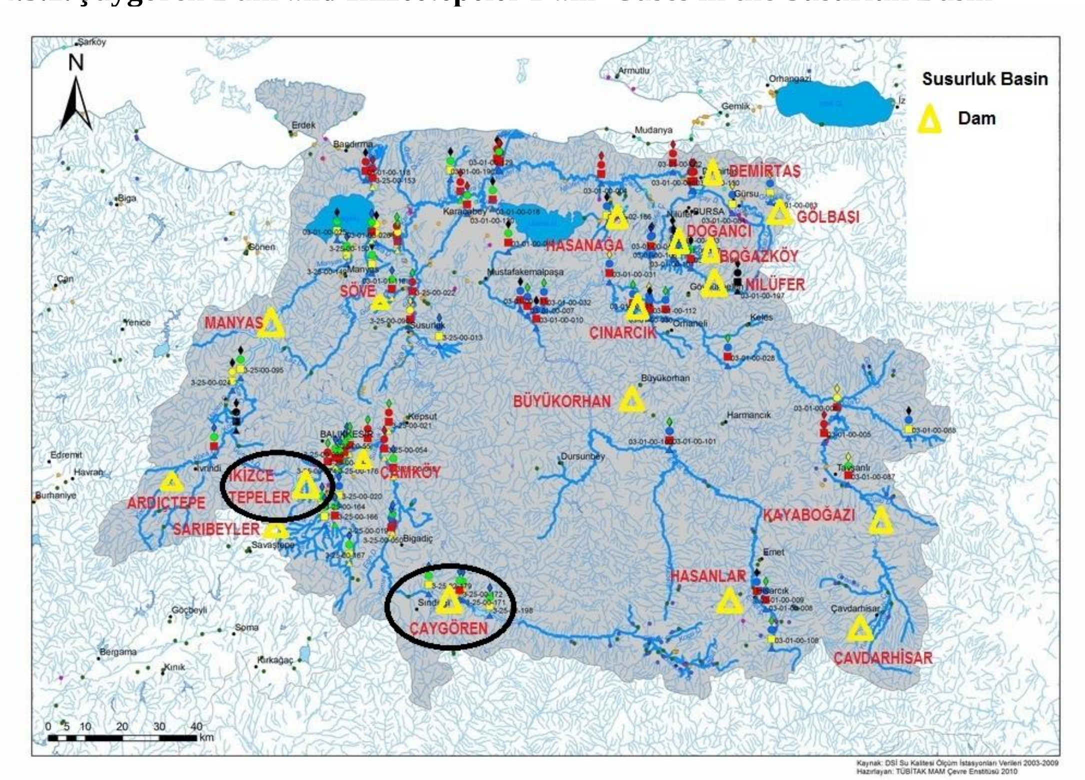


Figure 15.The Çaygören Dam and İkizcetepeler Dam Location.

In the worth-mentioning study made by Sevindik (Sevindik 2009), monthly sampling was carried out at 3 stations in the İkizcetepeler and Çaygören Reservoirs between February 2007 and January 2009. Mean values of measured parameters in İkizcetepeler Dam Reservoir were as follow: conductivity 0,336 mS/cm, TDS 0,256 g/L, pH 9,51, ORP 106,7 mV, temperature 15,47 °C, chlorophyll 4,56 µg/L, Secchi disk depth 164,4 cm, PO_4 0,251 mg/L, NO_3 1,61 mg/L, TN 5,03 mg/L, NH_4 0,098 mg/L, NO_2 0,0486 mg/L, Phenol 3,45 mg/L, SO_4 30,26 mg/L, COD 12,64 mg/L, BOD <4 mg/L, SS 11,22 mg/L.

Mean values of measured parameters in Çaygören Dam Reservoir were as follow: conductivity 0,431 mS/cm, TDS 0,330 g/L, pH 9,81, ORP 90,96 mV, temperature 14,8 °C, chlorophyll 13,26 µg/L, Secchi disk depth 105,83 cm, PO4 0,246 mg/L, NO3 1,62 mg/L, TN 5,38 mg/L, NH4 0,196 mg/L, NO_2 0,0267 mg/L, Phenol 9,13 mg/L, SO_4 59,3 mg/L, COD 15,03 mg/L, BOD <4 mg/L, SS 13,6 mg/L.

According to the Sevindik's study, Ikizcetepeler Reservoir is mesotrophic and Çaygören Reservoir is eutrophic based on physical and chemical parameters and dominant phytoplankton groups obtained .

Table 6. Physicochemical parameters in the reservoirs sampled in the Caygören and İkizcetepeler Dams (Mean values obtained between February 2007 and January 2009) (Sevindik 2009)

Reservoir	Depth, m	Water temp, °C	Secchi Disk transperancy, cm	Dissolved oxygen, mg/L	Oxygen saturation, %	pH	Electro conductivity, µS/cm	Phenol mg/L	COD mg/L	Total Dissolved Solids mg/L TDS	Chlorophyll µg/L	SO_4 mg/L	NO_3 mg/L	Presence of Zebra Mussel shells
Mean Values Feb 2007- Jan 2009														
Çaygören Dam	18	14,8	105,83	12	110	9,81	0,431	9,13	15,03	330	4,56	59,3	1,62	
İkizcetepeler Dam	16	15,47	164,4	7,8	71	9,51	0,336	3,45	12,64	256	13,26	30,26	1,61	Yes

Although the data was given as 2 years mean values in her study ,this mean values are used to obtain a general surviving and infestation risk potential of Zebra Mussel in the reservoirs.

Comparing the physical and chemical parameters given in Table 6 with suitability criteria given below, it may be said that these two dams are prone to infestation risk of zebra mussel.
In fact ,this assesement has been verified by previous observations that İkizcetepeler dam reservoir has been found to be infested by zebra mussel.(Table 1).

Table 7. Water Column Zebra mussel suitability criteria (Mackie and Claudi 2010).

Parameter	Risk: Low Little Potential for Larval Development	Moderate (survivable, but will not flourish)	High (favorable for optimal growth)
Calcium (mg/l)	8-15	15-30	>30
pH	7.0-7.8 or 9.0-9.5	7.8-8.2 or 8.8-9.0	8.2-8.8
Hardness (mg/L)	30-35	55-100	100-280
Alkalinity (mg/L)	30-55	55-100	100-280
Specific Conductance (umhos)	30-60	60-110	>110
Secchi depth (m)	1-2 or 6-8	4-6	2-4
Chlorophyll a (ug/L)	2.0-2.5 or 20-25	8-20	2.5-8
Total Phosphorus	5-10 or 35-50	10-25	25-35

4.3.3. Evaluation

It is now internationally recognized that invasive species are a major threat to habitat loss in terms of threats to biodiversity. Therefore this research presented here is not only important for the Susurluk Basin ,it is also important for international studies, on aquatic invasive species. Therefore research studies as well as infestation risk analyses , providing information-sharing towards future research and management will play an important role to find best suitable way to protect biodiversity.

4.4. Occurrence and abundance of zebra mussels in relation to physicochemical factors in the SUSURLUK BASIN

With a literatüre survey and personel contact ,we obtained some information about one infested reservoir (Çaygören Dam) and one reservoir (İkizcetepeler Dam) with evidence of previous infestation in the basin .The relation of zebra mussel occurrence and abundance to some of the environmental variables was first studied in available data obtained from different water quality monitoring stations located on main rivers in the basin.

The obtained water quality parameters and classes and results obtained a Multivaried Analyses of Variance and principle component analyses methods .

4.4.1 Surface area

In this theorotical infestation risk assesement study,reservoirs were selected with a surface area over 20 ha (0,20 km^2) (Table 4). The earlier investigation result showed that one of the the biggest in size reservoirs in the study region – Çaygören (with a maximum surface area of 850 ha) suffered infestation by zebra mussel.

The results of some studies on reservoirs showed that 46.2% of total variance of data was explained by the first principal component related to pH, calcium, bicarbonates and electroconductivity.
More alkaline and rich in nutrients reservoirs are also prone to heavy zebra mussel infestation. Another factors related to the size of the water body are the sources and pathways of zebra mussel introduction. It is assumed that larger water bodies are colonized more easily, presumably due to a greater number of access points and a larger number of human users (Kraft & Johnson 2000, Frischer et al. 2005).

The larger water bodies sometimes offer a higher substrate diversity which may additionally contribute to the more easily colonization of zebra mussel. the water bodies with larger surface areas should maintain more constant populations (Ramcharan et al., 1992).

4.4.2. Depth

According to Stanczykowska (1977) the abundance of zebra mussel populations is the highest in the littoral and sublittoral zones between 2 and 12 m. In the Black Sea coastal lakes Shabla and Ezerets, zebra mussels were found at depths 0.3-8.0 m being most abundant at about 3.5-4.5 m (Kaneva-Abadjieva & Marinov 1967, Valkanov et al. 1978, Liutzkanov 1981, 1983, Petrova & Stoykov 2002).

In the Danube, zebra mussels occurred at depths between 0.2 and 15.0 m and had highest biomass in the range of 4-7 m (Russev 1966, 1967, 1978).

Evidences of zebra mussel occurrence showed accumulation in reservoirs with higher depths. According to information about depth at construction, fourth of the reservoirs have maximum depth over 70 m, thirteen of reservoirs have maximum depth between 32 and 50 m, and one reservoir – below 10 m (Table 4).

4.4.3. Secchi Disk Transparency

As efficient filter feeders, zebra mussels are responsible for the considerable increase in Secchi disk transparency in the infested water basins (Fahnenstiel et al. 1995, MacIsaac 1996). But available data dosen't include this value in the Susurluk Basin.

4.4.4. Water temperature

Zebra mussels are typically considered a cool water species. Various studies in Europe and North America have reported low temperature limits for adult growth that are in the range of 10-12 ^oC (Stanczykowska 1977, Mackie 1991). In Europe, zebra mussels have become abundant where average winter temperatures are as low as 6^oC, but are less common in colder environments (Stanczykowska & Lewandowski 1993). The lower limit for survival of zebra mussels was accepted to be 0^oC (McMahon 1996).

Zebra mussel normally begin to spawn at 12 °C and above (Neumann et al., 1993), but limited spawning was reported at 10 °C (Sprung, 1993, McMahon 1996, Nichols 1996). Spawning peaks at about 12-18 °C, which is also roughly the optimum temperature for larval development (Sprung 1993). Juveniles and adults are able to grow at a wide range of temperatures, from about 12 °C to about 30 °C (Cohen 2005). Several authors reported 30 °C as the upper limit for efficient feeding and adult growth, and 31-33 °C as the upper limit for short-term survival (McMahon 1996, Cohen 2005). In analysis of potential distribution and abundance of zebra mussel in California, Cohen & Weinstein (1998a) used the following suitability temperature ranges:

- 15-31 °C and 10<max<31 °C for high potential,
- 0-15 °C and 10<max<31 °C for moderate potential,
- Max <10 or >31 °C for low-to-no potential distribution.

It should be analyzed distribution of the water temperature data from April-September (active reproductive months of zebra mussel.

4.4.5. pH

pH regulates calcium uptake in freshwater shellfish (Kozlowski et al., 2002). Zebra mussels are generally more vulnerable than other freshwater bivalves to disruption of ion metabolism from reductions in pH level (Vinogradov et al. 1993). They have distinct pH-tolerance limits (Cohen & Weinstein, 1998a). Different authors reviewing the literature have selected minimum pH requirements ranging from 6.5 to 7.5 and maximum pH requirements ranging from 9.0 to 9.5 (Cohen, 2005).

4.4.6. Calcium concentration

Zebra mussels require calcium for shell growth and osmoregulation (Vinogradov et al. 1993, McMahon 1996). This element was recognized as a key factor affecting the mussels' potential distribution, survival, growth and reproduction (Cohen & Weinstein 2001). Different calcium thresholds were reported in literature. Reviewing data for 70 European lakes, Strayer (1991) found zebra mussels mainly reported in lakes with calcium levels above 20-40 mg/l, and absent from lakes with <20 mg/l.

Ramcharan et al. (1992) analyzed 76 European lakes and found that zebra mussels are present only where calcium concentrations are at least 28.3 mg/l. In 527 lakes in Belarus, zebra mussels were found only in lakes with more than 25.4 mg/l of calcium (Karatayev, 1995). In North America, however, zebra mussels have been reported as present and sometimes abundant at calcium levels ranging from 12 to 25 mg/l (Cohen & Weinstein 2001).

After a detailed literature review study , Cohen & Weinstein (2001) summarized that ambient calcium concentration of 12 or 15 mg/l was the minimum threshold below which the establishment of a zebra mussel population was unlikely, and that abundant reproducing populations most probably would become established in concentrations between 20-28 mg/l and above.

Negative effect of high calcium levels was observed by Hincks & Mackie (1997), who found that adult mortality increased above 25 mg/l and maximum juvenile growth rates decreased above 32 mg/l.

4.4.7. Dissolved oxygen

Some authors reported that zebra mussels were usually found where dissolved oxygen was over 90% of saturation and become stressed at levels of 40-50 % of saturation; others reported 80-85% oxygen saturation as optimal (Cohen, 2005). The oxygen requirements of zebra mussel rose in warm water (25^{o} C and over), and decline in colder water allowing overwintering mussels to survive under ice (Cohen & Weinstein, 1998a). Low oxygen levels may in part account for the poor colonization success of zebra mussels in eutrophic lakes (McMahon, 1996).

The oxygen concentrations like pH also undergo significant diurnal and seasonal variations. They are usually higher in winter than in summer. During dry seasons, water levels decrease and the dissolved oxygen concentrations also decrease, while during rainy seasons, they tend to be higher.As a result of intensive photosynthesis of algae and macrophytes, supersaturation with dissolved oxygen occurred during the day. Most probably, concentrations of oxygen decrease significantly during the night, due to respiration. Dissolved oxygen concentrations are usually highest in the late afternoon, because of the all day photosynthesis. These variations, especially the decline of oxygen saturation during the night, can be stressful for zebra mussels.

5.POTENTIAL RISK OF INFESTATION

In order to evaluate the zebra mussel dispersal mechanisms in the region, we considered the following factors:

- Proximity of the reservoirs to already infested water bodies
- Accessibility of the reservoirs by human users

The study region was first classified according to water quality class and a map with three classifications was produced (Fig. 13 and 14).

In the major part of the territory ,available data shows that most of the river has IV class water quality as of physical and inorganic-chemical parameters.
According to the suitability ranges of zebra mussels given in table… we can say that the IV class of water shows a suitable water charecteristics to survive fort he zebra mussel larvae as well as high and fast infestation potential in the basin.

Moreover ,the İkizcetepeler Dams Reservoir located on the upstream part of the basin has been found to be infested by zebra mussel in 2005 (DSİ 2005).

Although we couldnt make our own measurement study in the basin , obviously the physical and inorganic-chemical parameters obtained from literature and other sources show that larval zebra mussels may well survive in the rivers that enter reservoirs and lakes and the infestation potential of the Zebra mussel may get higher as the months go by.
In this stage of the study , we we cant say that the lake and reservoirs in the basin will be full of Zebra Mussel in a certain time of period.But considering available data and obtained zebra mussel suitability criteria from literatures we can easily say that the rivers and lakes are prone to high infestation risk of zebra mussel.

The map given in Figure… with class of water quality according to the Turkish water pollution control regulation also indicates the survival and infestation potential of zebra mussel in the basin.

6. CONCLUSIONS AND RECOMMENDATION FOR FURTHER STUDIES

As a result of this Zebra Mussel assessment study , we reached the following conclusions

Based on water chemistry and environmental suitability ranges of zebra mussels during the larval and early growth stages, 75 % of the North and North-West Susurluk Basin territory was classified with high potential, 10 % - with moderate potential, and 15 % - with low potential for zebra mussel infestation. Thus, the North and North-West Susurluk Basin was identified as a region with very high risk of zebra mussel infestation.

In reservoirs, the large surface area (over 90 ha) and depth, high substrate diversity, moderate amount of nutrients and easy accessibility to human users, were additional factors that contributed to the increased risk of infestation by zebra mussel.As potential zebra mussel dispersal mechanisms in the region were identified the direct waterway connections with the rivers. As potential zebra mussel dispersal mechanisms were identified

Although it is difficult to make concrete conclusions because of the lack of enough data,obtained results with available data and the direct waterway connections with the rivers entering to the Manyas and the Uluabat Lakes show that this lakes can be considered under high risk of zebra mussel infestation.
Therefore it is strongly recommended that a more detailed zebra mussel investigation Project in the Susurluk Basin need to be started in soon.
We may conclude that this project scope shouldn't be limited with only to investigate the Zebra Mussel infestation risk but also to decide necessery measures before being late

To protect this and other vulnerable regions in Turkey from further zebra mussel invasions, it is recommended:

1-Interested governmental institutions (Ministry of Forestry and Water Work ,Ministry of Environment , , etc.) should be informed about the problem in order further actions be initiated.
These should focus on:

- Public education and awareness of zebra mussels biological, economic and social impact
- Understanding of the problem by local reservoir managers and interested private companies in order to guide sampling efforts and to assist in taking preventive measures
- Performing of regular water chemical and biological monitoring in the region
- Strong control on fishery, fish-farm and fish stocking activities

2. Continue the research activities by developing a Risk Management Plan which should be linked to the evaluation of potential biological and economic consequences of zebra mussel invasions.
This should include:

- Further development of the created GIS database by adding updated and more detailed data layers as data become available in the future
- Development of early warning system based on the continuously updating GIS database
- Development of risk management measures
- Directing efforts to preserve the biodiversity and natural ecosystems from invasions

Thus, a Risk Assessment and Decision Analysis guide to potential invasion sites in other regions of Turkey will be provided.

7.References

Aksu S.,Yıldız D.,Güngör P.A.,2017 "The Zebra Mussel in Turkey" .Report No: 7 Hydropolitics Association .Ankara-Turkey.

DSİ 2005 .Hidroelektrik Santrallarda Sorun Yaratan Zebra Midye Araştırmaları Raporu.2005. DSİ Genel Müdürlüğü İşletme ve Bakım Dairesi Başkanlığı .Ankara-Türkiye

DSİ, 1969. Kovada II.Hidroelektrik Santralında Midye Sorunu ve Su Mecralarının Midye Üremesinden ve Korozyondan Korunmasıyla İlgili Olarak Yapılan Elektroşimik Tecrübelerin Neticeleri. T.C.Enerji ve Tabii Kaynaklar Bakanlığı, DSİ Genel Müdürlüğü, İşletme ve Bakım Dairesi Başkanlığı, Ankara.

Bobat, A., Hengirmen, M.O. and Zapletal, W. 2001. Zebra Mussel Research Project in Birecik HPP. Second Progress Report. June -September 2001, 18 p.

DSİ 2012 DSİ AR-GE -ZEBRA MİDYE İLE MÜCADELEDE FİLTRASYON VE BOYA DENEMELERİ SONUÇ RAPORU (In Turkish with english summary and conclusion) 2012 Ar-Ge Yayın No: 1. Ar Ge Proje No: 2011/1 DSİ Teknik Araştırma ve Kalite Kontrol Dairesi Başkanlığı Mayıs 2012 ANKARA

Aksu, S., E. A. Baran, H. Çevlik, S. Üstündağ, İ. Şahin, M. S. İpek, Y. Ağan, 2007 . Zebra Midye İle Savaşımda Malzeme Denemesi Sonuç Raporu. DSİ Genel Müdürlüğü .(in Turkish)

Aksu, S., E. A. Baran, S. Üstündağ, İ. Şahin, M. S. İpek, Y. Ağan, 2008. Zebra Midyenin Kontrol Yöntemleri Üzerine Araştırmalar Projesi Çalışma Raporu. DSİ Genel Müdürlüğü (in Turkish)

TÜBİTAK MAM 2015 Çevre Enstitüsü (ÇE) Proje Adı: Havza Koruma Eylem Planlarının Hazırlanması-Susurluk Havzası Koruma Eylem Planı Raporu Toplam Sayfa: 446. 2015

Uyumaz Ç, Ekmekçi S .2016 Tatlısu Kirliliğinde Çağın Tehdidi; ZEBRA MİDYE . PPS in Statistical Collogium in the Eskişehir Anadolu University.

EXECUTIVE SUMMARY 2016 “Draft article 5 report for Susurluk Basin” December 2016 TR2011/0327.21-05-01-001. TECHNICAL ASSISTANCE FOR THE CONVERSION OF RIVER BASIN ACTION PLANS INTO RIVER BASIN MANAGEMENT PLANS

Sevindik, Tuğba Ongun 2009. Fitoplanktonik organizmaların ikizcetepeler ve çaygören barajlarında mevsimsel ve dikey dağılımlarının incelenmesi URI: http://hdl.handle.net/123456789/329 Date: 2009

Teodora A. Trichkova[1], Alexander A. Kotsev[2], Anton Popov[2], Mladen T. Zivkov[1], Dimitar S. Kozuharov[3], Ivan S. Botev[1], Zdravko K. Hubenov[1], Stelian Dimitrov[2], Svetoslav D. Cheshmedjiev 2007 “Assessment of Zebra Mussel (*Dreissena polymorpha*) Infestation Risk Using GIS for Water Basins in the North-West Bulgaria” Institute of Zoology, Bulgarian Academy of Sciences

Strayer,D.L. 1991 . Projected distribution of the zebra mussel, Dreissena polymorpha, in North America . Can. J. Fish. Aquat. Sci. 48: 1389-1395.

Whittier, T.R., A.T. Herlihy & S.M. Pierson, 1995. Regional susceptibility of northeast lakes to zebra mussel invasion. Fisheries 20 (6): 20-27.

Hayward, D., & E. Estevez, 1997. Suitability of Florida waters to invasion by the zebra mussel, Dreissena polymorpha. Available from: http://sgnis.org, reprinted from Mote Marine Laboratory Technical Report No. 495.

Cohen, A.N. & A. Weinstein, 1998a. Methods and data for analysis of potential distribution and abundance of zebra mussels in California. San Francisco Estuary Institute, Richmond, CA. Available from: http://www.sfei.org/bioinvasions/Reports/1998-ZebraMusMthd&Dta225.pdf.

Cohen A. 2005. A review of Zebra Mussels' environmental requirements. Report for the California Department of Water Resources, San Francisco Estuary Institute, Oakland, CA. Available from: http://www.sfei.org/bioinvasions/Reports/No420_2005-ZebraMusselRequirements.pdf

Neary, B.P. & J.H. Leach, 1992. Mapping the potential spread of the zebra mussel (Dreissena polymorpha) in Ontario. Can. J. Fish. Aquat. Sci., 49: 406-415. Neumann, D., J. Borcherding & B. Jantz, 1993. Growth and seasonal reproduction of Dreissena polymorpha in the Rhine River and adjacent waters. Pages 95-109. In: Nalepa TF, Schloesser DW. (Eds.) 1993. Zebra Mussels, Biology, Impacts and Control. Lewis Publishers, Boca Raton, Florida, 810 p.

Ramcharan, C.W., Padilla, D.K., & Dodson, S.I., 1992. Models to predict potential occurrence and density of the zebra mussel, Dreissena polymorpha. Canadian Journal of Fisheries and Aquatic Sciences, 49: 2611-2620.

Koutnik, M.A. & D.K. Padilla, 1994. Predicting the spatial distribution of Dreissena polymorpha (zebra mussel) among inland lakes of Wisconsin: modelling with a GIS. Can. J. Fish. Aquat. Sci., 51: 1189-1196.

Kozlowski S, Page C, Whetstone J. 2002. Zebra mussel in South Carolina: the potential risk of infestation. Report, S.C. Department of Natural Resources, S.C. Sea Grant Consortium, Clemson University, 1-14.

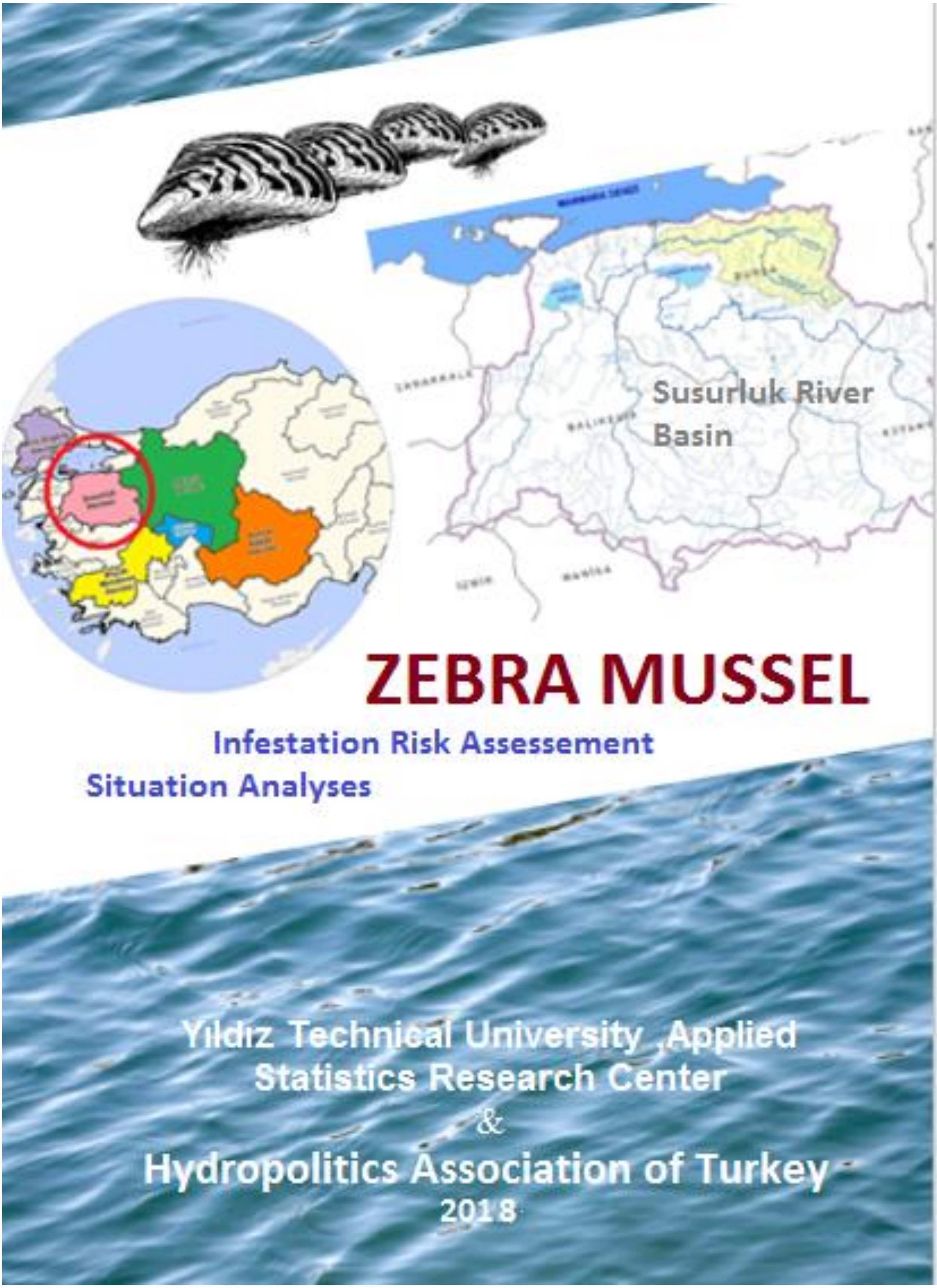
Murray, T., P. Rich & E. Jokinen, 1993. Invasion potential of the zebra mussel Dreissena polymorpha (Pallas) in Connecticut: predictions from water quality data. Special Report No. 36, Connecticut Institute of Water Resources, The University of Connecticut, Storrs. Available from: http://digitalcommons.uconn.edu/cgi/viewcontent.cgi?article=1033&context=ctiwr_specreports

Mellina E, Rasmussen JB. 1994. Patterns in the distribution and abundance of zebra mussel (Dreissena polymorpha) in rivers and lakes in relation to substrate and other physicochemical factors. Canadian Journal of Fisheries and Aquatic Sciences 51: 1024-1036.

Strayer, D.L. & L.C. Smith, 1993. Distribution of the zebra mussel (Dreissena polymorpha) in estuaries and brackish waters, pp. 715-728, In: Nalepa TF, Schloesser DW. (Eds.) 1993. Zebra Mussels, Biology, Impacts and Control. Lewis Publishers, Boca Raton, Florida, 810 p.

Mackie GL, Claudi R (2010) Monitoring and Control of Macrofouling Mollusks in Fresh Water System, CRC Press, 508 pp

Kraft CE, Johnson LE. 2000. Regional differences in rates and patterns of North American inland lake invasions by zebra mussels (Dreissena polymorpha). Canadian Journal of Fisheries and Aquatic Sciences 57: 993-1001.


Susurluk River
Basin
ZEBRA MUSSEL
Infestation Risk Assesement
Situation Analyses
Yıldız Technical University ,Applied
Statistics Research Center
&
Hydropolitics Association of Turkey
2018