

Distribution and Density of Zebra Mussels (*Dreissena Polymorpha* Pallas, 1771) and Related Some Environmental Properties in Euphrates River, Iraq

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Abstract
The present study was carried on the Euphrates river /middle of Iraq, from October 2011 to September 2012 between Al-Musayyib city and Twereej City. Sampling were monthly from three sites in study area for studying some physical and chemical properties to river water (air &water temperature , p H , EC , TDS ,TSS , Dissolved oxygen , transparency ,Total alkalinity , Total hardness, calcium , magnesium) , also measured the concentration of chlorophell -a as indicator of biomass and primary productivity in Euphrates river. This study include collected the samples of zebra mussel from study sites to calculated the density and distribution of the species.The results showed the impact of spatial and temporal variation of environmental properties under study on the distribution and density of *D.polymorpha* .The species was recorded during most of time and sites of study and this species being invasive species was recorded for the first time in this region. Fluctuation was observed in the total density of *D.polymorpha* and the highest values were recorded in the sites (3) (23.7 individual /m2) during March 2012 and absente during October 2011 and September 2012 . Statistical analysis was done using the canonical correspondence analysis (CCA).
Keywords: Zebra mussel; Biodiversity; Invasive species; Euphrates River; Iraq.

1.Introduction

The zebra mussel, Dreissena polymorpha, is a freshwater bivalve mollusk; look like small clams with a yellowish to brownish shell shaped like the letter “D” (ENSR, 2005).

Zebra mussels are usually found in freshwater lakes, ponds, and rivers, typically live 3 to 5 years, but some specimens have lived as long as 15 years (Ludyanskiyet al. 1993). Unlike most freshwater mussels, the zebra mussel grows in clusters containing numerous individuals,

Zebra mussels apparently preferentially settle on submersed aquatic plants, or on the underside of substrates (Ackerman *et al*., 1994),and later move to other substrates. (Wainman*et al* .,1996)

The native range of the zebra mussel includes river basins; and estuarine reservoirs along the Bulgarian, Romanian, Ukrainian, and Russian Black and Azov sea coasts and in zones of these seas influenced by freshwater (Son, 2007).

Zebra mussels reach sexual maturity after one or two years and exhibit external fertilization(Ludyanskiy*et al*., 1993). The optimal temperature forspawning is 12-14 C°. In temperate climates, peakspawning often occurs at 15-17 C° during the earlysummer (Claudi& Mackie, 1994).

Releasing eggs or sperm after being stimulated by environmental factors including temperature, rates of temperature change, fooddensity, and the effects of neighboring mussels (Ram *et al*., 1996).Zebra mussels have caused major environmental changes due to their physical community structureand their filtering capabilities.Their excellent filtering capabilities may be reduce the amount of phytoplankton and suspended particulates in the water column, resulting in increased water clarity, and due to increased productivity of submerged aquatic vegetation, Zebra mussels can out-compete native filter feeders and may reduce the abundance of native species, this species can create large reef-like colonies, altering the physical habitat as well as biological energyflow(ENSR, 2005).

Zebra mussels may alter nutrient cycling ina water body (Makarewicz*et al*., 2000),Some Europeanand North American freshwater communitieshave experienced profound ecological changessubsequent to invasion by zebra mussels (Minchin *et al*., 2003). Its ability to attach to hard surfaces with abyssal threads makes the Zebra mussel, a major macrofouler and a serious threatto water supplies, industrial processing, power stations,transportation and recreation. Problems created by theZebra mussel in Europe have occurred for more than 100years(Bobat*et al*., 2004).The economic impacts of zebra mussels can be extreme, due to their biofouling characteristics(Moser, 2002). This biofouling is usually experienced by industrial and municipal entities using intakepipes and screens for water withdrawal. Al-Nakib (2004) was the first author studied this species in Euphrates river near electrical power plant in Al-Musayab city- middle of Iraq. This aimed to investigation the distribution and density of Zebra mussel in Euphraytes river ,also to determine some physical and chemical properties of the study area.

2.Material and methods

2-1- Study area:

Samples were collected monthly from Euphrates River in the middle of Iraq from October 2011 to September 2012at three selected sites in the river (fig. 1); the first is located in Al-Musayyib city, the second in Saddat Al-hindya city and the third in Twereej city. Water samples were collected at 30cm depth (sub surface layer) by using clean polyethylene bottle (5L) with three replicates, while the Zebra mussels individuals were obtained by hand collecting from hard substrata in shallow waters or from stones and rocks or from aquatic plants in the near shore. Soft substratum and plant material on Zebra mussels was removed by washing it in river water, and then put in plastic bag and when brought to laboratory, washed with tap water and Distilled water to remove any residue.

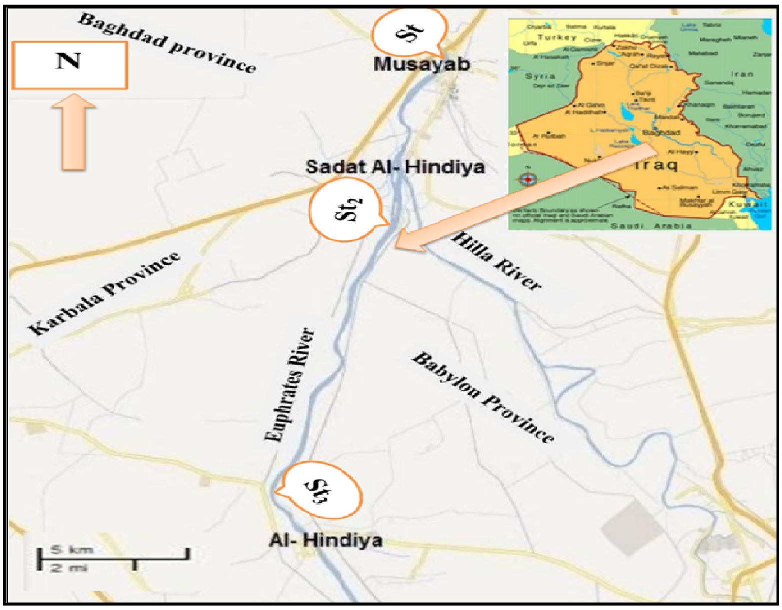

Fig. (1): A map of study sites

2-2- Field measurement

Air and water Temperature directly measurement by using mercury thermometer (0C°-100 C°). pH, elcatrical conductivity as well as TDS values were measured by using‘’Hanna, model”Multi meter.Dissolved oxygen meter(Oakton) ,U.S manufacturing was used to determine the concentration of dissolved oxygen (DO) (Mg/L).The transparency of water was measured in the field, using secchi-disc (diameter 25 cm).

2-3- Laboratory measurement

The total suspended solids (TSS) and total alkalinity were measured by depending on procedure which described by (APHA , 2003).Total hardness,Calcium and Magnesium concentrations weredetermined according to (Lind , 1979). Chlorophyll- a concentration was determined according to (Aminot& Rey, 2000).

2-4-Total density of zebra mussel

The total density of zebra mussel was collected in each stations for all months by determine the number of individual within the space provided by sampler grape and expressed on the total density by the unite (individual /m^2).

2-5- Statistical analysis

The Analysis of Variance (ANOVA) was used for determine the Least Significant Difference (LSD), as well as the standard deviation and mean values were determined by using the computer program (SPSS.Ve.20).The correlation coefficient matrix (r) was calculated using computer program (Cononical Correspondence Analysis CCA).

3.Results and Dissections

Table (1) was showed the physico-chemical parameters of water during the period of study, table (2) was showed the total density of zebra mussel and figure (2) was showed the correlation between the total density of zebra mussel and physico-chemical parameters of wateraccording to Canonical Correspondence Analysis (CCA).

Table (1): physico-chemical parameters in the study stations during the period (October 2011- September 2012).(Range in the first line ; Mean ± SD in the second line.)

Parameters	**Site**		
	1	**2**	**3**
Air temp (C^o)	11.7 - 39.27 22.27 ± 7.76	9 -38.2 23 ± 9.34	13.33-43.5 26.53 ± 8.86
Water temp (C^o)	11.54-30.37 19.73±6.69	9.06-29.96 20.08±6.85	13.03-31.43 21.09±6.23
pH	7.6-8.7 8.26 ± 0.34	8.7-7.3 8.18±057	7.6-8.7 8.29±0.34
E.C (µ.S/cm)	798.7 - 1167.6 961.17 ± 127.16	811.1- 1168.6 974.6 ± 114.36	903 – 1149 1011.4 ± 95.33
Transparence (Cm)	48.6 – 229 112.8 ± 51.22	37.6 - 234.6 117.1 ± 58.1	43.83 – 269 120.5 ± 69.7
TDS (Mg/L)	540.22-758.44 641.1 ± 68.71	502.33-739 624 ± 64.81	572-789.3 651 ± 76
TSS (Mg/L)	0.0104-0.0443 0.0226 ± 0.0209	0.06-0.323 0.0172 ± 0.0069	0.063-0.031 0.0176 ± 0.00754
DO (Mg/L)	6.9-11.38 8.69 ± 1.4	6.27-11.59 8.96 ± 1.52	6.63 - 10.78 8.44 ± 1.3
Total Hardness ($MgCaCO_3$/L)	446.33-749.44 548.9 ± 96.55	446.6-700 529.6 ± 81.23	423.33-773.3 550 ± 101.3
Calcium ($MgCaCO_3$/L)	56.17- 173.64 103.5 ± 40.36	76.48 -215 106.1 ± 41.1	87.9 - 180.3 143.07 ± 169.6
Chlorophyll- a (µg/L)	1.22 - 18.84 6.75 ± 5.57	0 -13.29 5.6 ± 4.84	0 - 24.37 7.99 ± 8.24

Table (2): the total density of zebra mussel during the period of study.

Months	**Sites**		
	1	**2**	**3**
October 2011	0	0	0
November 2011	0	0	0.88
December2011	0	0	0.88
January 2012	0	0	1.92
February 2012	0	0	20.29
March 2012	0	0	23.7
April 2012	0	2.22	2.81
May 2012	0.44	2.37	9.77
June 2012	0.59	1.62	3.55
July 2012	4.29	0.44	1.33
August 2012	0	1.18	1.33
September 2012	0	0	0

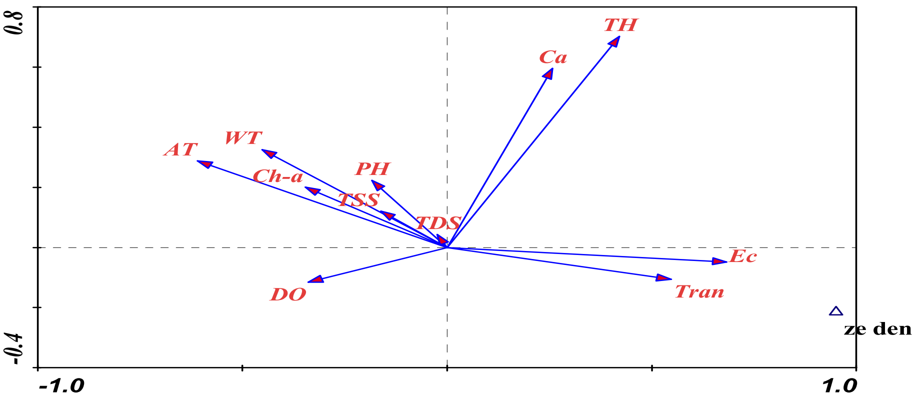

Figure (2) the correlation between the total density of zebra mussel and physico-chemical parameters
[AT: air temperature, WT: water temperature, DO: Dissolved oxygen, Ch-a: chlorophyll-a, pH, TDS : Total dissolved solid, TH: Total hardness ,Tran: transparency, EC: electrical conductivity, Ca: calcium, TSS: Total suspended solid, ze den: zebra mussel density.]

3-1-Air and Water temperature

Air temperature was ranging between highest values (43.5 ºC) in station (3) and lowest values (9 ºC) in station (2). The highest water temperature values(31.43 ºC) were observedin station (3) and the lowest values were observed (9.06 ºC) in station (2).The results show significant deference ($p<0.01,p<0.05$) between month. According to Canonical Correspondence Analysis (CCA**),** the results of the current study were showed a negative correlation between air temperature, water temperature and the total density of Zebra mussel.Zebra mussels have both a lower and upper lethal threshold limits for temperature. They cannot tolerate freezing and are rare in Europe, where mean annual air temperatures are below 3–6°C (McMahon, 1996). In Europe zebra mussels were absent where mean annual air temperatures were above 18°C or where the highest mean monthly air temperatures were above 27°C (Strayer, 1991).The threshold temperatures for growth and reproduction apparently vary considerably among populations of zebra mussels.

The upper lethal threshold level for zebra mussels has been an issue of some debate largely because of discrepancies between observations in laboratory experiments and observations of occurrences and abundances in nature. In addition, most of the observations in the literature are based on lakes at low altitudes and/or high latitudes. Among the variables that affect the lethal threshold value are the rate of acclimation (in the lab) or acclimatization (in nature), the duration of the exposure, the frequency and extent of temperature variations, and the source or "previous experience of mussels to thermal extremes(Mackie &Claudi, 2010).

There is a strong selection pressure for an increased heat-tolerance in the southern range of the zebra mussel but this has not resulted in an adaptation. The lack of adaptation at this stage may be due to gene flow being too strong or due to insufficient genetic variation for selection to act on (McMahon, 2002).

3-2 - pH

The highest PH values(8.74) were recorded in station (3) and the lowest values(7.54) were recorded in station (2). The results show significant deference in the values of PH ($p<0.01,p<0.05$) between months. The PHwas showed slightly alkaline trend. Generally PH of water is influenced by geology of catchments area and buffering capacity of water(Shyamala*etal*., 2008).Zebra mussels have both a lower and an upper lethal threshold to Ph. For lower PH thresholds a PH of <7 is generally considered either lethal to zebra mussel veligers and adults, or is insufficient to support a reproducing population based on field or laboratory studies or a preponderance of evidence (Hincks & Mackie, 1997). Zebra mussels have distinct PHtolerance limits. In the laboratory, a PHrange of 7.3 to 9.4 is required for veliger development, and development success is greatest at PH ~8.5 (Sprung, 1993). In the field, Ramcharan *et al*., (1992) found that a PH of 7.3 was the lower limit of zebra mussel occurrence in 76 European lakes (Cohen & Weinstein, 2001). Adult zebra mussels are more tolerant of lower PH than are larvae(Bartell*et al*., 2007).

3-3-Transparence

In the current study water transparency values were ranged from (37.6 Cm) as lowest values in station (2) to (269 Cm) as highest values in station (3).The results show significant deference ($p<0.01,p<0.05$) in the valuestransparency of between months.

The Secchi depth is a measure of the relative depth of light penetration, or its relative transparency. It is a relative measurement because the readings usually vary from one individual to the next, from one day to the next, and even from one hour to the next(Mackie &Claudi, 2010).

In general, invasions by zebra mussels are quickly followed by increases in water clarity (Secchi depth) (Barbiero& Tuchman, 2004) and a decrease in phytoplankton abundance (Caraco*et al*., 2006; Depew *et al*., 2006) This was confirmed by the positive correlation between water transparency and the total density of zebra mussel. The clarity of water is related to the clearance rates of dreissenids. Collectively, zebra mussels are unrivaled in their capacity to clarify water (Claudi& Mackie, 1994). However, compared to other freshwater bivalves, the zebra mussel's filtration rate (10–100 mL/individual/h) is intermediate between Sphaeriidae (0.6 to 8.3mL/individual/h) and Unionidae (60–490 mL/individual/h) (Stanczykowska *et al*., 1976).

As water clarity increases, zebra mussel growth can become limited by food availability. Subsequent zebra mussel population decreases have been reported (Strayer&Malcom 2006). Zebra mussels are not able to survive under the conditions of very high turbidity with corresponding Secchi disk depths <10 cm. Zebra mussels appear to grow rapidly under conditions where Secchi disk depth ranges between 40 cm and 200 cm (Cohen & Weinstein, 2001).

3-4- Electrical conductivity (EC)

The electrical conductivity In the current study was ranged from (789.7µ.S/cm) as lowest valuesin station (1) to (1168.8µ.S/cm) as highest values in station (2). The results show significant differences ($p<0.01,p<0.05$) in values of electrical conductivity between months.Conductivity represents the total amount of cations and anions in solution of which calcium and magnesium are important cations and carbonates and bicarbonates are among the most important anions for zebra mussels. It stands to reason that the most important criterion for survival is a minimal conductivity, the upper limit not being critical until salinity becomes a factor(Mackie &Claudi, 2010).

Bartell *et al*. (2007) examined 14 physical–chemical factors to determine habitat suitability for the Dreissenidae mussels; they recommend a conductivity of 62.5 mS/cm as the threshold value for survival for zebra mussels.Conductivity <22 µS/cm will limit zebra mussel distribution and greater than 83µS/cm will be greatly favor zebra mussel colonization (Cohen &Weinstein 2001). According to Canonical Correspondence Analysis (CCA**),** the results of the current study were showed a positive correlation between electrical conductivity(EC) and the total density of Zebra mussel.

3-5- Total dissolved solid (TDS) and total suspended solid(TSS)

The results of the current study were showed significant differences ($p<0.01,p<0.05$) in values of (TDS)between months and sites were ranging from the highest value (789.3mg/L) in station (3) and the lowest value (502.33 mg/L) in station (2).

Total Suspended Solid (TSS)fluctuated between the lowest values during February (0.006mg/L)in station (2) and the highest values during October (0.0443 mg/L) in station (1). The results show significant deference ($p<0.01,p<0.05$)between months. The distribution of TDS and TSS are relatively increase during drought period due to the decay and degradation of the most microorganism species in the lower water level.Both the TDS and TSS fractions contain inorganic and organic residues(Nkansah,2009).

The effect of zebra mussels filtering capacity on levels of TSS (also measured as turbidity and seston) consisting mostly of phytoplankton is well documented. Holland (1993) reported a decline in diatom abundance coincident with the arrival and establishment of the zebra mussel in western Lake Erie.While the impact of zebra mussels on TSS is well known, the reciprocal relation-ship has not been as well examined and little information exists on the effects of suspended solids and food concentrations on zebra mussel survival or even metabolic activities. Morton (1971) suggested but did not demonstrate that higher concentrations of suspended materials can depress growth rates by overloading the gut and gills with inorganic solids.

3-6- Dissolved oxygen (DO)

The dissolved oxygen (DO) values were ranging between lowest values (6.63 mg/L) in station (3) and the highest values (11.59 mg/L) in station (2). The results was showed significant deference ($p<0.01,p<0.05$) in the values of (DO) between months.The results obtained from the study were showed an elevated DO during winter and a decreased during summer ,this is expected since the solubility of gasses in liquids is inversely proportional with temperature(Durmishi,2008).

Zebra mussels are among the least tolerant to low oxygen levels of all freshwater bivalves. DO concentrations less than 2–4 mg/L are lethal to zebra mussels and DO greater than 8 mg/L are favorable to zebra mussel growth (Cohen &Weinstein 2001). Oxygen depletion associated with respiration of zebra mussels has been documented in two large rivers, as evidence that DO is critical to zebra mussels' growth and survival (Caraco*et al*. 2000).

3-7- Total hardness (TH)

Total hardness (TH) was found to be in the range between the lowest values (423.3 mg/L) in station (3) and the highest values (773.3 mg/L)in station (3).The results show significant deference ($p<0.01,p<0.05$) between months.The TH considered a good indicator for the presence of some dissolved solid substance in water such as the Ca^{2+} and Mg^{2+}(Wurts& Durborow,1992)

Total hardness is defined as the sum of calcium and magnesium concentrations expressed as calcium carbonate

(Eaton *et al*., 1995). There are significant curvilinear relationships between juvenile growth rates and each of the buffer variables (calcium, alkalinity, and total hardness). As total hardness decreased below 25 mg/L, zebra mussels grow poorly; zebra mussels grow well when total hardness exceeds 90 mg/L (Cohen &Weinstein, 2001)

3-8- Calcium

During the study period calcium concentration was fluctuated between (56.15 mg/L) as lowest values and (215Mg /L). The results was showed significant deference ($p<0.01, p<0.05$) in values of calcium between months.Calcium concentration is considered by most researchers as the key factor for assessing the potential of zebra mussel colonization(Mackie &Claudi, 2010).

The minimum level for survival of adults zebra mussel appears to be between 8 and 9 mg Ca/L (Kozlowski, 2002). Veligers appear to require 11–12 mg Ca/L to survive for at least a few days (Hincks and Mackie, 1997) and 15–22 mg Ca/L to develop (Baldwin *et al*., 1997).There is considerable disagreement on the level of calcium required for establishment of a population of zebra mussels, particularly because of differences in reported values between the European and North American literature(Mackie &Claudi, 2010).

Occurrence and abundance of zebra mussels are high and unrelated to calcium levels above 30 mg/L (Stanczykowska, 1977).Growth of mussels will occur at calcium concentrations of greater than 35 milligrams per liter (mg/L), but growth is inhibited at concentrations <4 mg/L (Mackie &Claudi, 2010).Twelve to fifteen mg/L appears as a minimum calcium concentration for reproduction and growth (Cohen and Weinstein 1998a). In laboratory studies, zebra mussels did not survive calcium levels below 15 mg/L (Vinogradov*et al*., 1993). In tests ofrearing success, the number of deformed larvae decreased at >34 mg/Lof calcium (McMahon 1996).

3-9- Chlorophyll-a

Chlorophyll-a values were ranging between the lowest values (0µg/L) in station (2) and highest values (24.37µg/L)in station (3).The results show significant deference ($p<0.01, p<0.05$) in values of chlorophyll-a between months.

Chlorophyll-a levels can be used to assess the trophic status of a lake.The European literature indicates that the trophic status of surface waters often dictates the presence and abundance of zebra mussels. Growth rates correlate well with chlorophyll-alevels in the range 10–40 mg/L and not at all in the range 34–106 mg Chl a/L (Smit*et al*., 1993).

Stanczykowska and Lewandowski (1993) examined relationships between occurrence of mussels and trophic status of lakes in Poland and noted lowest densities in shallow, highly eutrophic, polymictic lakes; in general, densities were highest in mesotrophic lakes.zebra mussel was associated with a 60% decline in chlorophyll concentrations and a 60% increase in water clarity in Saginaw The survival potential of zebra mussels in the hypothetical lake based on chlorophyll a levels is low.

Zebra mussel growth and body condition were weakly correlated with phytoplankton biomass, which can be represented by the concentration of chlorophyll-a(Strayer&Malcom, 2006). Filtration rate reduced when chlorophyll-adecreased from 7.4 µg/L to 2.2 µg/L (Fanslow*et al*., 1995).

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References

Ackerman, J.D.;B. Sim, S.J; Nichols, and Claudi,R. (1994). A review of the early life history of zebra mussels (Dreisssenapolymorpha): Comparisons with marine bivalves. *Canadian Journal of Zoology 72: 1169–1179.*

Baker, S.M.; Levinton, J.S.; Kurdziel, J.P. and Shumway, S.E. (1998) .Selective feeding and biodeposition by zebra mussels and their relation to changes in phytoplankton composition and seston load. *Journal of Shellfish Research. 17 (4):1207–13.*

Baldwin, B.S., P. Filippetti, and Sanderson, S. (1997). A test of the potential spread of zebra and quagga mussels from the St. Lawrence River to inland waters of northern New York (abstract). Presented at the 2nd Northeast Conference on Nonindigenous Aquatic Nuisance Species, Burlington, USA.

Barbiero, R.P. and Tuchman, M.L.(2004). Long-term dreissenid impacts on water clarity in Lake Erie. *Journal of Great Lakes Research 30: 557–565.*

Bartell, S.M.; Y. Wu; S.K. Nair, J. Orr; and Ragland, J. (2007). Risk assessment and decision analysis support for invasive mussel management for the St. Croix Basin and adjacent Upper Mississippi River. Final Report for U.S. Army Corps of Engineers, St. Paul District, Contract No. W912ES-05-D-0002, Task Order 07.

Caraco, N.F., J.J. Cole, and Strayer, D.L. (2006). Top-down control from the bottom: Regulation of eutrophication in a large river by benthic grazing. *Limnology and Oceanography 51: 664–670.*

Claudi, R. and Mackie, G.(1994). Practical Manual for Zebra Mussel Monitoring and Control, Lewis Publishers, Boca Raton, FL.

Claudi, R.; and Mackie, G.L. (1994). Practical manual for zebra mussel monitoring and control. *Journal of the*

North American Benthological Society 13(3):411−412.
Cohen, A.N.; and Weinstein, A. (2001). Zebra Mussel's Calcium Threshold and Implications for its Potential Distribution in North America. San Francisco Estuary Institute,San Francisco, California. pp.47. http://www.dfg.ca.gov/quaggamussel/docs/2001-Zebramusselcalcium.pdf.
Depew, D.C., S.J. Guildford, and Smith, R.E.H. (2006). Nearshore-offshore comparison of chlorophyll a and phytoplankton production in the dreissenid-colonized eastern basin of Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences63: 1115–1129.*
Eaton, A.D.; Clesceri, L.S.; and Greenberg, A.E.(eds.). (1995). Standard Methods for the Examination of Water and Wastewater. 19th Edition. American Public Health Association, American Water Works Association and Water Environment Federation, Washington, DC. pp. 1,541.
Fanslow, D.L.; Nalepa, T.F.; and Lan, G.A. (1995). Filtration Rates of the Zebra Mussel (Dreissena polymorpha)on Natural Seston from Saginaw Bay, Lake Huron. *Journal of Great Lakes Research 21(4):489–500.*
Hincks, S.S. and Mackie, G.L.(1997). Effects of pH, calcium, alkalinity, hardness, and chlo-rophyll on the survival, growth and reproductive success of zebra mussels (Driessena polymorpha) in Ontario lakes. *Canadian Journal of Fisheries and Aquatic Sciences 54: 2049–2057.*
Kozlowski, S., C. Page, and Whetstone, J.(2002). Zebra Mussels in South Carolina: The Potential Risk of Infestation. South Carolina Department of Natural Resources, South Carolina Sea Grant Consortium and Clemson University.
Ludyanskiy, M. L.; McDonald, D. and. MacNeill, D. (1993). Impacts of the zebra mussel, a bivalve invader. *BioScience 43(8):533-544*.
Mackie, G.L. and Claudi, R.(2010). Monitoring and Control of Macrofouling Mollusks in Fresh Water Systems.2ed. Printed in the United States of America on acid-free paper.
Makarewicz, J.C.; Bertram, P. and Lewis, T.W.(2000). Chemistry of the offshore surface waters of Lake Erie: Pre- and Post-Dreissena introduction(1983–93). *Journal of the Great Lakes Research.26(1):82–93.*
McMahon, R.F. (1996). The physiological ecology of the zebra mussel, Dreissena polymorpha, in North America and Europe. *American Zoologist36: 339–363.*
McMahon, R.F.(2000). Invasive characteristics of the freshwater bivalve Corbicula fl uminea. In: Non-indigenous Freshwater Organisms: Vectors, Biology and Impacts, R. Claudi and J. Leach, eds, pp. 315–343. Boca Raton: Lewis Publishers.
McMahon, R.F. (2002). Evolutionary and physiological adaptations of aquatic invasive ani-mals: Selection versus resistance. *Canadian Journal of Fisheries and Aquatic Sciences, 59: 1235–1244.*
Minchin, D.; Maguire, C. and Rosell, R. (2003). The Zebra Mussel (*DreissenaPolymorpha*pallas) invades Ireland: human mediated vectors and the potential for rapid international dispersal.*biology and environment: proceedings of the royal irish academy, (103b) 1: 23 - 30.*
Ram, J.L.; Fong, P.P. and Garton, D.W. (1996). Physiological aspects of Zebra mussel reproduction: Maturation, spawning, and fertilization. *Am. Zool. 36: 326-338.*
Ramcharan, C.W., D.K. Padilla, and Dodson, S.I.(1992). Models to predict potential occurrence and density of the zebra mussel, Dreissena polymorpha. *Canadian Journal of Fisheries and Aquatic Sciences49: 2611–2620.*
Shyamala, R.; Shanthi, M.and Lalitha, p. (2008). Physicochemical Analysis of Borewell Water Samples of Telungupalayam Area in Coimbatore District, Tamilnadu, India. *E-Journal of Chemistry.5, (4) : 924-929.*
Smit, H., A. Bij de Vaate, H.H. Reeders, E.H. van Ness, and Noordhuis, R. (1993). Colonization, ecology and positive aspects of zebra mussels (Dreissena polymorpha) in the Netherlands. In: Zebra Mussels Biology, Impacts, and Control, T.F. Nalepa, and D.W. Schloesser, eds, pp. 55–78. Boca Raton: Lewis Publishers.
Son, M.O. (2007). Native range of the zebra mussel and quagga mussel and new data on their invasions within the Ponto-Caspian region. *Aquatic Invasions2: 169–179.*
Sprung, M., (1993). The other life: An account of present knowledge of the larval phase of Dreissena polymorpha. In: Zebra Mussels: Biology, Impacts, and Control, T.F. Nalepa, and D.W. Schloesser, eds, pp. 39–53. Boca Raton: Lewis Publishers.
Stanczykowska, A. and Lewandowski, W. (1993). Thirty years of studies of Dreissena poly-morpha ecology in Mazurian lakes of northeastern Poland. In: Zebra Mussels Biology, Impacts, and Control, T.F. Nalepa and D.W. Schloesser, eds, pp. 3–38. Boca Raton: Lewis Publishers.
Stanczykowska, A.(1977). Ecology of Dreissena polymorpha(Pall.) (Bivalvia) in lakes. *Polish Archives of Hydrobiology 24: 461–530.*
Stanczykowska, A., W. Lawacz, J. Mattice, and Lewandowski, K. (1976). Bivalves as a factor affect-ing the circulation of matter in Lake Mikolajskie (Poland). Limnologica10: 347–352.
Strayer, D.L.(1991). Projected distribution of the zebramussel, Dreissena polymorpha, in North America. *Canadian Journal of Fisheries and Aquatic Sciences48: 1389–1395.*
Strayer, D.L.; and Malcom, H.M. (2006). Long-term demography of a zebra mussel (Dreissena polymorpha)

population. *Freshwater Biology 51:117–130.*

The European Network for Social and Economic Research (ENSR).(2005). Rapid response plan for the Zebra mussel (Dreissena polymorpha) in Massachusetts. Prepared for the Massachusetts Department of Conservation and Recreation.

Vinogradov, G.; Smirnova, S.; Sokolov, V.; and Bruznitsky, A.(1993). Influence of chemical composition of the water on the mollusk Dreissena polymorpha. In T.F. Nalepa and D.W. Schloesser, (eds.), Zebra mussels: biology, impacts, and control. Lewis Publishers, Ann Arbor, Michigan. pp. 810.

Wainman, B.; S. Hincks, N.; Kaushik, and Mackie, G.L. (1996). Biofilm and substrate preference in dreissenid larvae in Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences 53: 134–140.*

Wurts , W.A. and Durborow , R.M. (1992).Interaction of pH , carbon dioxide,alkalinity and hardness in fish ponds.Southern Regional Aquaculture Center of Kentucky State University,USA, 464 : 2- 5.