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Effect of Hydraulic Flow on Phytoplankton Population Structure in Tajan River

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A B S T R A C T

The aim of present study was to investigate the relationship between hydraulic and ecological variables of the studied span and to investigate changes in living conditions of phytoplankton (*Amphora ovsalis* and *Navicula placentula*). According to the measurements and analysis of habitat fit curves, it can be concluded that the highest frequency of *Amphora ovsalis* and *Navicula placentula* occurred and specified at flow rate of 15.82 and 14.942 m^3/s, respectively. As can be seen, the lowest frequency of *Amphora ovsalis* and *Navicula placentula* in this measurement occurred at flow rate of 15.355 and 5.289 m^3/s, respectively. The best habitat conditions for Amphora ovsalis and Navicula placentula are in the range of 0.18 -0.31 and 0.18 - 0.265 of Froude number range respectively. The highest density and abundance of *Amphora ovsalis* and *Navicula placentula* was observed in the range of 0.017 - 0.055 and 0.017 -0.039 mg/l of phosphate demonstrating that the best growth and living conditions are predisposed in this range for these species had suitable habitat conditions for life in this range. The highest frequency of *Amphora ovsalis* and *Navicula placentula* is in the range of 0.019 - 0.071 and 0.047-0.071 mg/l nitrite, respectively. *Amphora ovsalis* and *Navicula placentula* had the highest frequency when nitrate ranges 4.48 – 5.16 and 4.48- 5.37 mg/l. The best habitat conditions for Amphora ovsalis and *Navicula placentula* were between the mean velocity values in the range of 1 -1.2 m/s.

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INTRODUCTION

Human population increases around the world, excessive use of water resources is inevitable. Rivers are one of the most important habitats for aquatic life such as fish, algae and etc. Construction of dams upstream of rivers is one of the most influential factors on the life of these aquatics. The construction of dams with various uses has many socioeconomic and environmental effects where environmental effects are controversial issue for the proper use of the environment and the survival of different aquatic species. The stated effects include loss of river self-purification, depletion of vital elements due to sedimentation behind dams, and insufficient growth of plankton and benthos in rivers, which play an important role in fish nutrition [1-3]. In any aquatic ecosystem, *phytoplankton* is important and valuable reserves in terms of organic matter production and being at the bottom of the energy pyramid, and other organisms in the food chain are directly or indirectly dependent on *phytoplankton*, regardless of their interdependence. Therefore, recognizing them in any water source is of special importance [4, 5]. *Phytoplankton*, as part of aquatic algae, also known as microscopic plants floating in water, are the basis of life and production in fresh and salt water [6-10]. These organisms are also of great importance in ecological, limnological and biological studies because other studies can provide a reasonable judgment about an ecosystem [11, 12]. A large number of aquatic algae are single-celled species and only a small percentage of them are multicellular algae that sometimes reach 50 meters or more in length [9, 13, 14]. The light, carbon dioxide and minerals in water are considered as the main factors for the growth and development of these algae. Therefore,

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their growth and development is exclusively limited to the area in which sunlight penetrates [11, 15-17]. The main factors result in reduced biodiversity in rivers can be mainly related to human activities including dam construction, industrial, agricultural, and rural pollution, as well as uncontrolled use of water for agricultural purposes. Industrial, agricultural, urban, and rural activities around Atrak River and effluents of such activities, which flows into this river, pollute it; the pollution which will derogate as the activities increase. Emergence and changes in the type and number of *phytoplankton* in each river should follow the general index of similar rivers. However, decreased diversity and number can indicate the pressure on the *phytoplankton* community in the rivers including Atrak River [18].

Grabowska et al. [19] studied the hydrological and hydrochemical effects on the structure of floodplain *phytoplankton* communities in Poland. Results obtained in this research showed that hydrological factors are strongly influenced by the abundance of *phytoplankton* in floodplains where the minimum density was observed in the body of white water and the maximum in stagnant water. Species diversity and richness are associated with changes in water levels. In the dehydration phase, diversity in stagnant waters was at its lowermost level and in white waters was the highest. Rising water levels promote interspecies exchanges and increase their Shannon index. Therefore, changes in the biodiversity of *phytoplankton* in the floodplain reflect the indirect effects of hydro-biotic factors on hydrological ones.

Poorgholam et al. [20] took samples in spring, summer, autumn and winter from 8 stations located in Astara, Bandaranzali, Sefidrood, Tonekabon, Noshahr, Babolsar, Amirabad and Bandar Turkmen on the south coast of the Caspian Sea and in depths of 5, 10, 20, 50 and 100 meters. Totally, they identified 7 branches of *Euglenophyta, Chlorophyta, Cyanophyta, Pyrrophyta, Bacillariophyta Xantophyta* and *Haptophyta* and 182 species of *phytoplankton*. Among the identified species, 81 species belonged to *Bacillariophyta*, 25 to *Pyrophyta*, 33 to *Cyanophyta*, 31 to *Chlorophyta*, 1 to *Chrysophyta*, and 1 to *Xantophyta*. Studies demonstrated that the *Bacillariophyta Pyrrophyta* and *Cyanophyta* branches are the predominant species of *phytoplankton* and the Shannon index (an index measuring species diversity taking into accounts the uniformity of species) is different for different branches of *phytoplankton* in different seasons and regions. Field measurements of this study were performed in three months of the spring. Along the river, near the Sarkat village, a span was selected where three sections were considered. The overall objective of this study was to analyze the impacts of hydraulic variables and chemical parameters (nitrite, nitrate and phosphate) on plankton community under environmental concentrations.

MATERIAL AND METHODS

This research was performed to study *phytoplankton* of Tajan River in Mazandaran Province in Sari. Shahid Rajaei Dam has been constructed on this river. In these study, hydraulic variables and chemical parameters (nitrite, nitrate and phosphate) have been measured onto phytoplankton Population Structure. The flow velocity was measured by current meter and the depth in each section, below sections at a distance of at least one meter. *Phytoplankton*, nitrite, nitrate and phosphate were then sampled at the same points. After data collection, hydraulic calculations and ecological tests were performed. Then, to create the TIN file of the region and locating the sections, topographic maps of the region were prepared by the Sari Regional Water Organization with a scale that includes two AutoCAD files. The current map was transferred to Arc GIS software. Then, the study dealt the relationship between *Amphora ovsalis* and *Navicula placentula* species and hydraulic variables and chemical parameters (nitrite, nitrate and phosphate) and the effect of their change on the population structure of these *phytoplankton*.

Field observations

The first observation was on Monday, 05.04.2021. It is worth mentioning that all field observations related to this research have been carried out in the area of Sarkat village in Kalijan Rastagh region, Sari city in Mazandaran Province. Data was collected at this field observation from 8:30 to 16:00 on Monday. First, a range of 270 meters of the length of the river was to be studied. This area starts from the bridge built on the river and goes downstream of the river. A tape measure was used to determine this range accurately.

Three sections were selected to sample *phytoplankton* chemical (phosphate, nitrate and nitrite) parameters, substrate and subsurface as well as to measure the flow rate. The sections were upstream at first and middle and then downstream with a total length of 270 m with approximately equal distance between them. Moreover, the geographical location of these sections was obtained using GPS. Table 1 briefs the geographical location of the studied sections in UTM system.

In addition to Table 1, Figure 1 shows the accurate geographical locations of theses sections. In Figure 1, the

Table 1. Geographical location of studied sections in UTM system (first observation on 05.04.2021)

Section No.	XUTM	YUTM
Profile – 1	693628	4031135
Profile – 2	693540	4031200
Profile – 3	693429	4031288

Figure 1. Location of studied sections on Google Earth (https://www.google.com/earth/)

sections are named according to the direction of flow from upstream to downstream. Flow rate measurements, *phytoplankton* sampling, phosphate, nitrite and nitrate were performed for each of the sections shown in Figure 1. The process is repeated foe the next observations on 05.05.2021 and 01.06.2021.

Phytoplankton testing method in laboratory

First, sampling containers were used for collecting 500 ml from the river in the studied sections in each field observation. After sampling, 4% formalin is added to each container. The samples are transferred to the laboratory and then store in the dark for 12 - 15 days to prevent the reproduction because *phytoplankton* probably reproduce in the light and storing status. Then the siphon is performed on 250 ml of water. The next step is centrifuge for 5 minutes. The approximately 40 ml remaining water is stored in a dark after centrifugation for 8-12 hours to precipitate.

The water left on the container is then removed by a device called Pasteur pipette, leaving approximately 15 ml at this step. This step should be done so that the container does not move. The remaining water is poured into a small graded beaker. The next step is to identify the species. Two drops of the remaining water are poured on a laboratory slide and the samples are identified by a microscope and it is repeated with two additional drops. After this operation, 0.1 ml out of 10 ml is tested on the slide by a sampler and the number of species is counted.

Types of *phytoplankton* branches in the study area of the river

phytoplankton and chemical parameters were measured in three observations in the spring simultaneously with the measurement of hydraulic variables in Tajan River in the study span for the mentioned sections. As the experiments were conducted in the laboratory in Caspian Sea Ecology Research Center of Sari showed *Bacillariophyta, Chlorophyta* and *Eglenophyta* branches were the existing branches in the study based on the measurement tables of *phytoplankton* in the first observation in April. *Bacillariophyta* branch with 30 species is the most affluent one. In the second observation in May, 4 branches of *Bacillariophyta*, *Chlorophyta*, *Eglenophyta* and *pyrophyta* were found, where *Bacillariophyta* branch with 25 species was the most common. In the third observation in June, *Bacillariophyta, Chlorophyta, Eglenophyta* and *pyrophyta* were the four existing branches with *Bacillariophyta* branch with 25 species as the most affluent.

Accordingly, given that *Bacillariophyta* branch was the most popular and affluent branch in all three observations, we examine the relationship between some different species of this branch that have the highest density and hydraulic variables as well as chemical parameters.

RESULTS AND DISCUSSION

Effects of hydraulic variables and chemical parameters on *phytoplankton*

Here, the relationship between hydraulic variables (flow rate, Froude number, and mean velocity) and chemical parameters (phosphate, nitrate and nitrite) on the life cycle of some of the largest branches and species of *phytoplankton* and their density and biomass was studied in this subsection. This is performed based on the experiments performed on *phytoplankton* in the studied span in Tajan River and chemical parameters measurement in the mentioned sections.

Changes in hydraulic and chemical variables

Amphora ovsalis and *Navicula placentula* are classified under *Bacillariophyta* species. The density of *Amphora ovsalis* was 3,800,000 units per cubic meter in April and 6,000,000 in May and 3,600,000 in June. *Navicula placentula* had a density of 1800000 units per cubic meter in April, 5400000 in May and 3800000 in June. The frequency of *Amphora ovsalis* and *Navicula placentula* were studied with hydraulic and chemical variables. As Figure 2 indicates, the flow rate increased from 4.981 to 15.877 m^3/s due to which there were changes in the abundance of *Amphora ovsalis* and *Navicula placentula* in the studied span. As seen, the highest frequency of *Amphora ovsalis* and *Navicula placentula* occurred and specified at flow rate of 15.82 and 14.942 m^3/s respectively. As we can see, the lowest frequency of *Amphora ovsalis* and *Navicula placentula* in this measurement occurred in flow rate of 15.355 and 5.289 m^3/s, respectively.

According to Figure 3, the best habitat conditions for *Amphora ovsalis* are in the range of 0.18 -0.31 of Froude number. The density of this species in this range shows a number associated to the Froude number and this species has suitable living conditions and growth in this range of Froude number. Also, the best habitat conditions for *Navicula placentula* are associated to Froude numbers ranging 0.18 - 0.265. The frequency of this species in this range related to Froude number can be at its best level where it has good conditions for life and growth. As seen in the diagram, as the Froude number increases, the abundance of this species of *phytoplankton* decreases. Therefore, in terms of lower Froude number, *Navicula placentula* species has better living conditions.

The highest density and abundance of *Amphora ovsalis* was observed in the range of 0.017 - 0.055 mg/l of phosphate demonstrating that the best growth and living conditions are predisposed in this range for the species *Amphora ovsalis* and this species of *phytoplankton* has suitable habitat conditions for life in this range (Figure 4). The highest frequency of *Navicula placentula* was measured in the range of 0.017 -0.039 mg/l phosphate. Therefore, the best growth and life conditions are provided for *Navicula placentula* in this range with suitable habitat conditions for life (Figure 4). Moreover, as the phosphate increases in river water, the frequency of this species decreases. It means that the lower the phosphate is; the better conditions are provided for *Navicula placentula*. Phosphorus is the primary nutrients that in excessive amounts pollute our lakes, streams, and wetlands. Phosphorus is a vital nutrient for converting sunlight into usable energy, and essential to cellular growth and reproduction of *phytoplankton*.

The highest frequency of *Amphora ovsalis* is in the range of 0.019 - 0.071 mg/l nitrite. Therefore, the best growth and living conditions can be provided for *Amphora ovsalis* in this range with suitable habitat conditions for life (Figure 5). *Navicula placentula* had the highest density when the nitrite amount ranges 0.047-0.071 mg/l. This demonstrate that the best growth and living conditions for the species *Navicula placentula* are provided in this range and this species of *phytoplankton* has suitable habitat conditions for life (Figure 5).

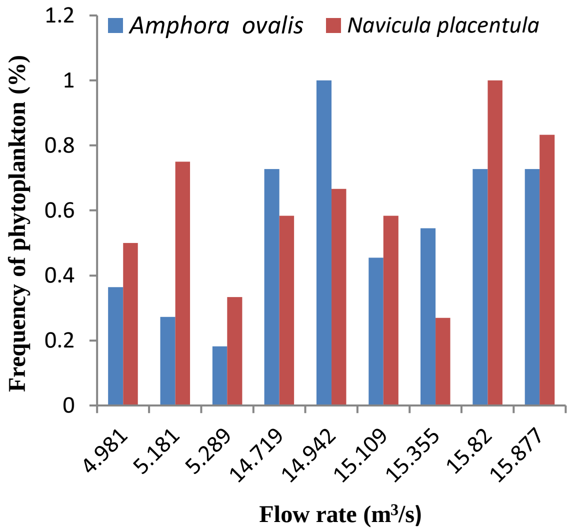

Figure 2. Flow rate changes with the frequency of *phytoplankton*

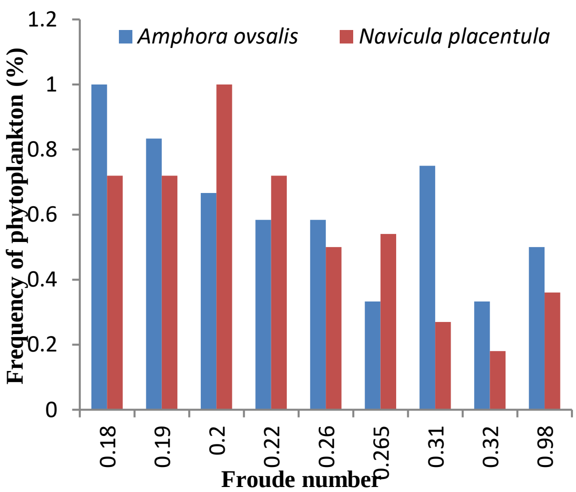

Figure 3. Effect of Froude number onto Frequency histograms of *phytoplankton*

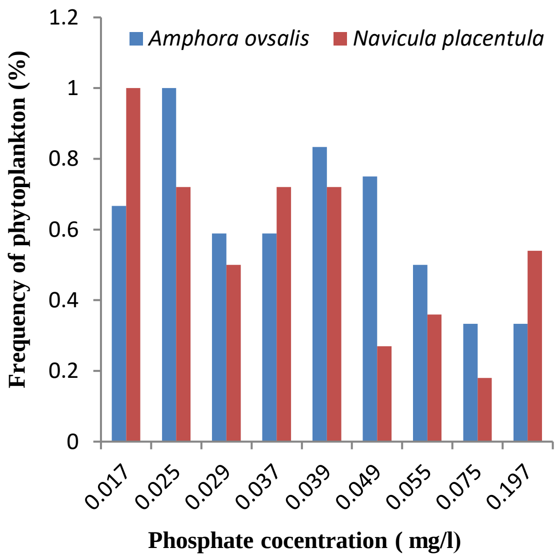

Figure 4. Effect of phosphorus concentrations onto Frequency histograms of *phytoplankton*

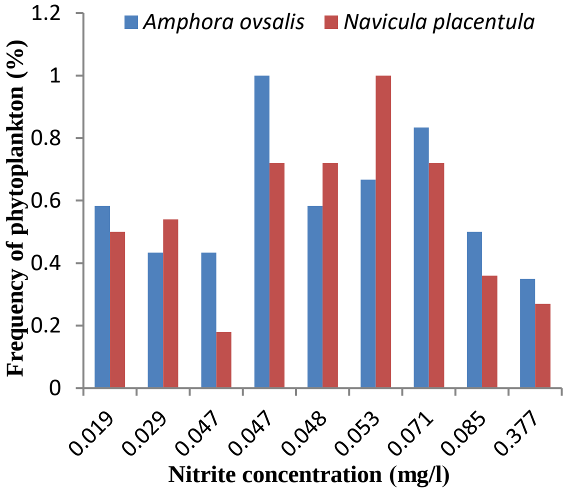

Figure 5. Effect of Nitrite concentrations onto Frequency histograms of *phytoplankton*

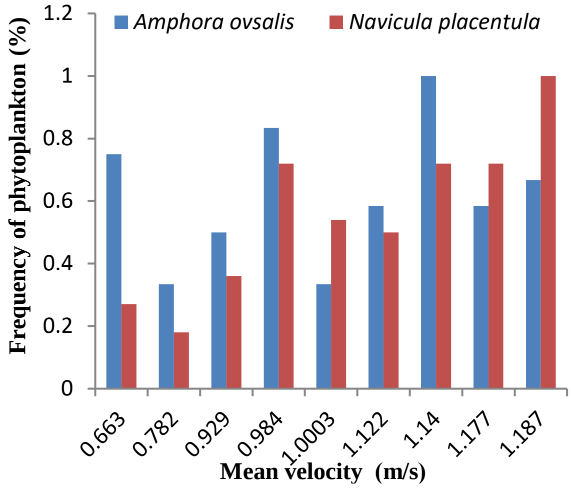

Figure 7. Effect of mean velocity onto Frequency histograms of *phytoplankton*

It was found that the highest density of *Amphora ovsalis* was in the range of 4.48 – 5.16 mg/l nitrate. Therefore, the best growth and living conditions can be supplied for the *Amphora ovsalis* species in this range with suitable habitat conditions for life in tis range of nitrate amount (Figure 6). *Navicula placentula* had the highest frequency when nitrate ranges 4.48- 5.37 mg/l. This indicates that the best growth and life conditions for the species *Navicula placentula* are provided in this range of nitrate and this species of *phytoplankton* has suitable habitat conditions for life in this range (Figure 6).

Figure 7 shows that the best habitat conditions for *Amphora ovsalis* and *Navicula placentula* are between the mean velocity values in the range of 1 -1.2 m/s. The density of *Amphora ovsalis* in this range associated with the mean velocity indicates favorable conditions for life and growth of the species in the study span. The

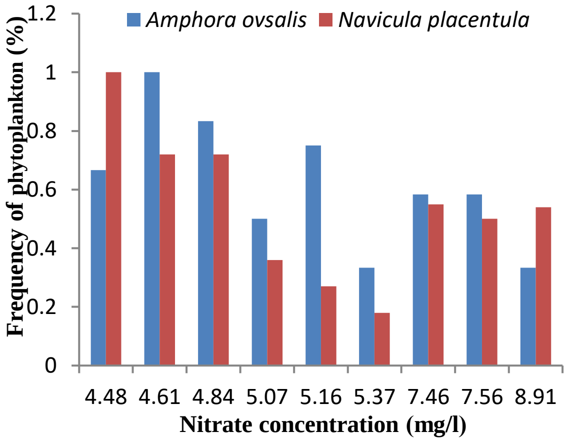

Figure 6. Effect of Nitrate concentrations onto Frequency histograms of *phytoplankton*

frequency of *Navicula placentula* in this range associated to the mean velocity can be at the best level, where this species has good conditions for life and growth. According to the graph, it can be concluded that as the mean velocity increases, the abundance of this species of *phytoplankton* increases, too. That is, the higher the mean velocity, the better these species can live.

CONCLUSION

According to the measurements and analysis of habitat fit curves, it can be concluded that *Amphora ovsalis* and *Navicula placentula* species are stream-friendly, viable at higher discharges and lower Froude numbers, and showed reversed correlation with nitrite concentration as an unstable toxic nutrient. However, regarding important nutrients (nitrate, phosphate) has been useful in the growth and reproduction of both two species. Although higher concentrations are considered, both species are from the low-expectation species group, which well adapted to lower concentrations for growth and reproduction.

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CONFLICT OF INTEREST

There is no conflict of interest.

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Persian Abstract

چکیده

هدف از این پژوهش، بررسی ارتباط بین متغیرهای هیدرولیکی و اکولوژیکی بازه مورد مطالعه رودخانه و بررسی تغییرات شرایط زندگی فیتوپلانکتون‌ها (گونه‌های *آمفورا اوسالیس* و *ناویکولا پلاکنتولا*) می‌باشد. با توجه به اندازه‌گیری‌ها و تجزیه و تحلیل منحنی‌های زیستگاه، می‌توان نتیجه گرفت که بیشترین فراوانی *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* به ترتیب در دبی‌های ۱۵/۸۲ و ۱۴/۹۴۲ متر مکعب بر ثانیه رخ داده است. همانطور که مشاهده می‌شود، کمترین فراوانی *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* در این اندازه‌گیری به ترتیب در دبی ۱۵/۳۵۵ و ۵/۲۸۹ متر مکعب بر ثانیه بود. بهترین شرایط زیستگاهی برای *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* به ترتیب در عدد فرود محدوده ۰/۳۱ — ۰/۱۸ و ۰/۲۶۵ — ۰/۱۸ بوده است. بیشترین تراکم و فراوانی *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* به ترتیب در محدوده ۰/۰۵۵-۰/۰۱۷ و ۰/۰۳۹-۰/۰۱۷ میلی‌گرم در لیتر فسفات مشاهده شد که نشان می‌دهد بهترین شرایط رشد و زندگی در این محدوده برای این گونه دارای شرایط زیستگاهی مناسب است. برای زندگی در این محدوده بیشترین فراوانی *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* به ترتیب در محدوده ۰/۰۷۱-۰/۰۱۹ و ۰/۰۷۱-۰/۰۴۷ میلی‌گرم در لیتر نیتریت می‌باشد. *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* بیشترین فراوانی را در محدوده نیترات ۵/۱۶-۴/۴۸ و ۵/۳۷-۴/۴۸ میلی‌گرم در لیتر داشتند. بهترین شرایط زیستگاه برای *آمفورا اوسالیس* و *ناویکولا پلاکنتولا* بین مقادیر سرعت متوسط در محدوده ۱/۲-۱ متر بر ثانیه می‌باشد.