Study of the Biological Diversity of Benthic algae in the Tigris River, Baghdad - Iraq

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Abstract. The present work included a study of benthic algae on two substrates: rocks and clay on a section of the Tigris River at the Al-Atifiyah site in the fall of 2018. The result of this study was recorded 89 species belong to 50 genus of benthic algae on both substrates and composed of Bacillariophyceae (59.6%, 61.2%), Chlorophyceae (25.8%, 20.4%) and Cyanophyceae (14.5%, 18.3%) respectively on epilithic and epipelic algae. The present study was recorded the highest total algae cell density (1173.2 cells *10³/cm²) on epilithic algae while the lowest total algae cell density was recorded on epipelic algae (76.95 cells *10³/gm). For measure diversity, four indices of diversity are used: Margalef index, Shannon and Weaver Index, Evenness Index and Simpsons Index. The study showed that benthic algal communities are of high diversity with different distribution and spread of adherent algae on different natural surfaces in the aquatic environment. 62 species of epilithic algae were recorded belonging to 39 genus, while epipelic algae were recorded 49 species belonging to 34 genus. Bacillariophyceae was recorded the highest number of species compared with other classes of benthic algae (59.6%, 61.2%) respectively on epilithic and epipelic Chlorophyceae recorded second ordered after diatoms in importance 25.8%, 20.4%, Cyanophyceae recorded third orders 14.5%, 18.3% respectively on epilithic and epipelic algae.

1. Introduction
The term Benthic algae refer to algae present at the bottom of the water surface and growing on submerged surfaces [1], but the most common term is periphyton, which includes algal communities that made submerged surfaces their home by modifying these surfaces and adding a mucilaginous substance or special enzymes that work to adhere algae to submerged surfaces and reservation organic and inorganic materials in the water or close to these surfaces [2].

The term Periphyton includes algae that is sticking up to the rocks called Epilithic, algae that are sticking up to the clay called Epipelic, and algae that are sticking up on the aquatic plants’ Epiphytic algae [3]. The advantage of Phytoben those algae over Phytoplankton algae is that it is more effective in obtaining its food from the bottom and is more tolerant to the speed of water currents because it has the property of adhesion to submerged surfaces [4]. The underwater layers of silt and rocks represent natural substrates for adhesion and a source of nutrients in addition to their important ecological role as a refuge for many organisms [5].

The algae are attached to the surfaces submerged in the water by adhesive gum materials produced by the algae or by a mixture of bacteria and fungi whose growth is associated with the growth of algae [3]. The forms of algae adherence to natural substrates in water differ according to different types of algae, as some types of algae are pressed tightly on the surface of the host forming the shape of the cortex, or the basal cell specializes into a cell with a fixed function of sticking the algae from its base, while some algae have a long or short stem that helps it to adhere or it may have gel pads that protrude the algae cell singly, and some moving species may adhere nearby to the submerged surfaces [6].
Benthic algae are a basic component in the aquatic environment, it represents the base in the aquatic food chain and the main source of food for aquatic organisms, in addition to its ability to produce oxygen as a by-product of the photosynthesis process \([4, 7]\) so a quantitative and qualitative study became necessary to determine the productivity of the water body.

2. Materials and Methods
The study was conducted on a section of the Tigris River at the Al-Atifiyah site adjacent to the city center of the Al-Karakh side of Baghdad, which is a residential area surrounded by the Tigris river from the north and east. The location was determined by GPS device at longitudes 44˚ 37 55.58 E and latitudes 33˚ 34 32.43 N. The river is affected by human activities because there are many Casinos and restaurants on the riverside in this area (Figure 1).

2.1. Collection of Samples
Seasonal samples of algae attached to mud and rocks were collected in the fall of 2018 and the method described by \([8]\) was followed to collect and isolate the algae from the mud by scraping the top layer of mud under the water surface near the river’s edge by a sharp-edged blade, the clay was placed in sterile plastic bottles with a little river water. It was taken to the laboratory and placed in a dark place without moving for 5 hours the excess water got rid, the mud was mixed well, 40 grams of it was taken, after that spread it on a petri dish well and cover it with lens cleaning papers, then place it near the window and leave it for the next day. Remove the leaves and the algae that is attached to them and put them in containers and add 10 ml of distilled water with some drops of the Lugols solution to the sample, while Epilithic algae were isolated by taking a rock below the water surface using a rubber delimiter to isolate 12.5 cm² area from rocks and brush to separate the algae from the rocks and wash it with distilled water \([9]\). The species of Epipelic and Epilithic algae have been diagnosed by preparing permanent and temporary algae slides \([10]\). These slides were examined with a light microscope by using magnified power 100x, 400x, 1000x and was adopted in the diagnosis of algae on some global and local references: \([11-16]\).

![Figure 1. Tigris River section and study area Al-Atifiyah site.](image)
2.2. Biological diversity index

2.2.1 Margalef Index. Use richness index to clarify the relationship between the number of species and number of individuals with their spread according to their abundance and calculate the value of the richness index from the equation developed by Margalef [17] in the following formula:

\[ M = \frac{(S-1)}{\ln N} \]

M = Margalef Index
S = The number of species in the sample
N = The total number of individuals in the sample

2.2.2 non and Weaver Index. It is a cursor to the number of all species in that community, and the value of diversity was calculated as follows:

\[ H = \sum_{i=1}^{S} P_i \log_2 P_i \]

H= Diversity Index (Shannon and Weaver Index)
S= The total number of species
Pi= The proportion of type i in a sample consisting of N individuals

2.2.3 Evenness Index. It is a cursor to the number of all species in that community, and the value of diversity was calculated as follows:

\[ J = \frac{H}{\ln S} \]

J = Evenness Index
Ln= Logarithm of natural number
S= The total number of species

2.2.4 Simpsons Index. It is used to estimate the dominance of species in each sample, it is calculated from the following equation:

\[ D = \frac{1}{\sum (p_i)^2} \]

D= Simpsons Index
Pi= number of individuals of type (i) in the sample whose number is N

3. Result and Discussion

The result of this study of Benthic algae on two substrates was shown in Table (1) and Figures (1-4).

| Table 1: Species of Benthic algae in Tigris River at Al-Atifiyah site. |
|-----------------|-----------------|-----------------|
| **Taxa**       | **Epipelic algae** | **Epilithic algae** |
| **Cyanophyceae** |                 |                 |
| Aphanocapsa sp. | +               |                 |
| Chroococcus limneticus Lemmerman | +              |                 |
| C. turgidus (Kütz.) Nägeli |                 | +               |
| Gloeocapsa sp. | +               |                 |
| Merismopedia convulata de Brebisson |                 | +               |
| M. minimum Beck | +              |                 |
| M. punctate Heyen |             | +               |
| Oscillatoria limentica Lemmermann | +          | +               |
| O. limosa (Roth.) Agardh | +             |                 |
| O. princeps Vaucher | +            |                 |
| O. prolifica (Crev.)Gomont |                 | +               |
### Table 1: Species of Benthic algae in Tigris River at Al-Atifiyah site. (Continue..)

| Taxa                                      | Epilithic algae | Epipelic algae |
|-------------------------------------------|-----------------|----------------|
| O. tenuis Agardh                          | +               | +              |
| Phormidium sp.                            | +               |                |
| Spirulina laxa G.M.Smith                  | +               |                |
| S. major (Witr.) Kirchner                 | +               |                |
| S. nordestestedtii Goment                 | +               |                |
| S. subsalsa Oersted                       |                 |                |
| **Chlorophyceae**                          |                 |                |
| Actinastrum gracilimum G.M.Smith          |                 |                |
| Cladophora glomerata (L.) Kützing         | +               |                |
| Chlamydomonas sp.                         | +               |                |
| Closterium diana Ehrenberg                | +               |                |
| Coelastrum microporum Nägeli             | +               |                |
| Coleochaeta pulvinata A.Braunin           | +               |                |
| Mougeotia scalaris Hassal                 | +               |                |
| Oedogonium sp.                            | +               |                |
| Oocystis elliptica West                   | +               |                |
| O. solitaria Wittrock                     | +               | +              |
| Pediastrum boryanum (Trup.) Meneghini     | +               |                |
| Scenedesmus abundens (Lag.) Chodat        | +               |                |
| S. acuminatus (Lag.) Chodat               | +               |                |
| S. acuta Meyen                            | +               |                |
| S. quadricauda (Turp.) de Brébisson       | +               | +              |
| Spiragrya sp.                             | +               |                |
| Stigeclonium tenue (A.C.Ag.) Kützing      | +               |                |
| **Bacillariophyceae**                     |                 |                |
| A-Centrales                               |                 |                |
| Actinocyclus granulate (Her)              |                 | +              |
| Coscinodiscus lacustris Grunow            | +               | +              |
| C. curvatulus Grunow                      | +               | +              |
| Cyclotella catenata (A.Braun.) Bachmann   | +               |                |
| C. comensis Grunow                        | +               | +              |
| C. operculata (Ag.) Kützing               |                 | +              |
| Melosira granulate (Ehr.) Ralfs           | +               |                |
| M. roeseana Rabenhorst                    | +               |                |
| Thalassionema nitzchioides Hestedt        | +               |                |
| T.nitzchioides Heiden                     | +               |                |
| Thalassiosira eccentric (Ehr.) Cleve      | +               |                |
| B-Pennales                                |                 |                |
| Achnanthes effinis Grunow                 | +               | +              |
| A.delicatula (Ktz.) Grunow                | +               | +              |
| Amphipora paludosa W.Smith                | +               | +              |
| Anomoeoneis exilis (Kütz.) Cleve          | +               |                |
| Bacillaria paradoxa Gmeline               |                 | +              |
| Centronella reicheltii Voiget             | +               |                |
| Caloneis amphisiaena (Bory.) Cleve        | +               |                |
| Cocconeis pediculus Ehrenberg             | +               |                |
| Taxa                                      | Epipelic algae | Epilithic algae |
|------------------------------------------|----------------|-----------------|
| C. placentula var. euglypta (Ehr.) Cleve |                | +               |
| C. placentula var. lineata (Ehr.) Cleve  | +              | +               |
| Cymatopleura solea (Breb.) W.Smith       |                | +               |
| C. solea var. apiculata (W.Smith) Raifs   | +              | +               |
| Cymbella affinis Kützing                  |                | +               |
| C. cistula (Hemp.) Grunow                |                | +               |
| C. cymbiformis (Kütz.) Van.Heurck         | +              | +               |
| C. gracilis (Rabh.) Cleve                |                | +               |
| Denticula tenuis Kützing                  |                | +               |
| Diatoma aniceps (Ehr.) Grunow            | +              | +               |
| D. vulgare Bory                          |                | +               |
| Diploneis elliptica (Kütz.) Cleve        | +              | +               |
| D. puella (Schum.) Cleve                 |                | +               |
| Fragilaria capucina Desmazieres          |                | +               |
| Gomphonema paravalum (Kütz.) Grunow      |                | +               |
| G. ventricosum Gregory                   |                | +               |
| Gyrosigma acuminatum (Kütz.) Rabenhorst  |                | +               |
| Hantzschia amphioxys (Ehr.) Grunow       |                | +               |
| Navicula anglica Ralfs                    |                | +               |
| N. exilissima Grunow                     |                | +               |
| N. gracilis Ehrenberg                    |                | +               |
| N. hungarica Grunow                      |                | +               |
| N. radiosa Kützing                       |                | +               |
| N. spicula Cleve                         |                | +               |
| Nitzschia acuta Hantzsch                 |                | +               |
| N. gracilis Hantzsch                     |                | +               |
| N. palea (Kütz.) W.Smith                 |                | +               |
| Pinnularia leptosome Grunow              |                | +               |
| Surirella linearis W.Smith               |                | +               |
| S. ovalis Berbisson                      |                | +               |
| **Dinophyceae**                          |                |                 |
| **Peridinium sp.**                       |                | +               |
The result of the qualitative study was recorded 89 species belong to 50 genus of benthic algae on both substrates 62 species of epilithic algae were recorded belonging to 39 genus while epipellic algae were recorded 49 species belonging to 34 genus (Figure 2).

Bacillariophyceae was recorded the highest number of species compared with other classes of benthic algae (59.6%, 61.2%) respectively on epilithic and epipellic algae this phenomenon is common in the Iraqi internal waters [18; 19] as well as the dominance of diatom species in a large number of water bodies in different regions of the world [5; 20] because diatoms are able to grow and reproduce within a wide range of environmental variables helped by its silicate frustule [21].

Chlorophyceae ranked second after diatoms in importance 25.8%, 20.4%, and Cyanophyceae ranked third 14.5%, 18.3% respectively on epilithic and epipellic algae we should be noted that Chlorophyceae is more dominant than Cyanophyceae in Iraqi waters [22]. Classes of other algae such as those of Dinophyceae were not significant as only one species was recorded (Figure 3).
The present study was recorded the highest total algae cell density (1173.2 cell *10³/cm²) on epilithic algae while the lowest total algae cell density was recorded on epipelic algae (76.95 cell*10³/gm) may be due to rocks were provided a good surface for sticking algae [23] or the competition for light and nutrients has diminished more for algae attached to rocks than clay.

The study showed a high value of Margalef index 12.419 on epilithic algae. This corresponds to recording the highest number of algae species attached to rocks. This may be due to the fact that algae preferred rocks as a more suitable medium for adhesion and securing their requirements of light and nutrients more than clay (Figure 4). Margalef index depends on the presence of species the regardless size of the sample [24].

![Figure 4](image-url)

**Figure 4.** Diversity Index for Epilithic and Epipelic algae on Tigris River at Al-Atifiyah site.

To measure the heterogeneity and the relative presence of species Shannon-Weaver Index adopted Figure (4). This is one of the most used pieces of evidence, it gives more space to the dominant species than rare species and measures the order of species in the sample and this arrangement is important in environmental studies. Shannon Index focuses on the number of individuals for each species in the sample and indicates the importance of the relative abundance of each species [24]. Shannon index was recorded close values ranging between 3.470 on epilithic algae and 3.085 on epipelic algae, due to the fact that most of the benthic algae populations are of high diversity with a difference in the distribution of adherent algae in different substrate in the aquatic environment [18, 25, 26].

Evenness index is one of the pieces of evidences that its calculation is based on the evidence of diversity taking into consideration the number of the diagnosed algae [24]. Values ranged from 0.841, 0.793 for epilithic and epipelic algae respectively. The increase in the number of diagnosed species in both substrate rocks and clay has contributed to a strong convergence of the Evenness index values (Figure 4).

Sampson Index was used to measure the bio version in ecological regions and is based on the relative abundances of different species [24]. The highest value of the index was recorded as 24.944 on epilithic algae. Rocks ranked first in numerical importance and recorded the highest total number of algae adherents to rocks. The presence of rocks within a numerical density provides a suitable environment.
for algae also works to preserve the nutrients and organic matter that come from the agricultural lands adjacent to the river [27].

4. Conclusion
This study shows that the Benthic algal communities recorded high diversity with qualitative and quantitative differences in the distribution and prevalence of algae with a preference for certain natural environmental media to adhesion than another substrate in the aquatic environment.

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