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Aims and Scope

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Aquat Res 4(3), 214-232 (2021) • https://doi.org/10.3153/AR21017 *Research Article*

Analysis of shipboard fire/explosion accidents occurred in the Turkish search and rescue area

Fatih YILMAZ

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ABSTRACT

A shipboard fire/explosion may be occurred due to various causal factors such as actions, omissions, events or conditions. In this study, it is aimed to carry out an analysis focused on shipboard fire/explosion casualties. With this aim, the data on 127 shipboard fire/explosion casualties occurred in the Turkish Search and Rescue area, which were reported to the Main Search and Rescue Coordination Center between 2006-2015, have been analyzed. As a result of the statistical analysis (descriptive statistics), it has been observed that majority of the shipboard fire/explosion casualties were occurred on-board the Turkish flagged ships, on-board small passenger vessels/recreational vessels/private-commercial yachts among the classified ship types, in the regions of İstanbul, İzmir and Çanakkale, in the summer season, during the night-time, and in machinery spaces of the ships by described locations. It has been also observed that main events caused shipboard fires/explosion casualties were electricity contact/leakage, gas accumulation/leakage, cargo ignition, welding/hot works and other undescribed factors. Additionally, by examining the existing shipboard fire & explosion accident investigation reports of Transportation Safety Investigation Center between 2014-2020, it has been observed that the main possible causal/contributing factors for the shipboard fire/explosion casualties were related with the violations of the ISM-Safety Management System (SMS) requirements. Many previous studies in the relevant literature point out to the ISM/SMS-related causal/contributing factors as well. In conclusion, special attention should be paid to the effective implementation and continuous improvement of the ISM/SMS procedures related with shipboard fire safety for the prevention of shipboard fire/explosion casualties as well.

Keywords: Marine casualties, Shipboard fire/explosion, Maritime safety, Safety management, Accident analysis

Introduction

A fire, which is a chemical reaction, occurs when combustible substances combine with oxygen under sufficient heat. An explosion occurs when a substance flashes suddenly and turns into various gases, and its volume expands and forces its surroundings (MEB, 2016:5-7). According to the International Labour Organization (ILO), there are three basic requirements for a fire to be created and sustained (ILO, 2012:5).

a. The presence of fuel or flammable materials;

b. The presence of a source of ignition;

c. The presence of oxygen in the air to support the combustion.

The fuel/flammable materials may be any combustible substances or materials such as flammable liquids or gases, paper, rubber, wood or fabrics etc. The source of ignition, which is needed to preheat the fuel/flammable materials and keep the fire alight, may be open flames, hot surfaces, hot gases, sparks from mechanical or electrical equipment, static electricity, chemical reactions, lightning strike, electromagnetic radiation etc. Additionally, other sources of ignition (heat and spark sources) may also be oxy-acetylene flame, flames arising from ignition of leaks from flammable liquid and gas pipes, bare electricity cables, electric sparks, electrical heaters and devices, welding, grinding, metal cutting, scraper, steam/exhaust pipes, static electricity, and self-ignition that stored heat energy in substances starts to burn without any external effects (MEB, 2016:5-26).

The technical rules on construction-fire protection, fire detection and fire extinction of ships are basically established in Chapter II-2 of International Convention on Safety of Life at Sea (SOLAS) adopted by the International Maritime Organization (IMO). There are also many different international instruments on that issue. Instead of these instruments, marine casualties continue to be occurred due to human errors and/or technical failures. The IMO and its members attach a great importance to prevent marine casualties due to its negative effects on international shipping and trade. According to the IMO, *"marine casualty"* means an event, or a sequence of events, which has occurred directly in connection with the operations of a ship (IMO, 2020a). There have been different types of marine casualties such as collision, contact, grounding, capsizing, fire/explosion etc. that have negative consequences on human life, property and marine environment. The prevention of shipboard fire/explosion is also one of the most important issue in terms of maritime safety and environmental protection, as it may be resulted in severe damages and/or loss of life, loss of ships and pollution of marine environment (IMO, 2008). Table 1 includes some of very serious shipboard fire/explosion casualties in maritime history.

As also seen from the Table 1, a shipboard fire/explosion casualty may occur due to any internal causal factors, which include actions, omissions, events or conditions on a ship, or it may occur as a sequence of events such as collision, contact, grounding, and others (IMO, 2008). Determining the casual factors of a marine casualty is mostly possible with a very detailed investigation to be carried out by the Authorities such as flag States, costal States, port States etc. According to paragraph 7 of article 94 of United Nations Convention on the Law of the Sea (UNCLOS), regulation I/21 of SOLAS, articles 8 and 12 of MARPOL and article 23 of Load Lines Convention (LL 66), each Administration/State have responsibility to investigate serious and very serious marine casualties. The IMO adopted Resolution MSC.255(84) on "Casualty Investigation Code" in May 2008 in order to provide a standard approach to marine casualty and incident investigation (IMO, 2008). According to the IMO's Casualty Investigation Code, a very serious marine casualty means a marine casualty involving the total loss of the ship or a death or severe damage to the environment (IMO, 2008). A serious marine casualty was defined as a marine casualty other than very serious marine casualty that results in serious injury or substantial material damage that would render the ship unseaworthy according to the national "Deniz Kaza ve Olaylarını İnceleme Yönetmeliği/Regulation for Investigation of Marine Accidents and Incidents, 2019" of Turkey. According to the detailed definition of United Kingdom (UK) Merchant Shipping (Accident Reporting and Investigation) Regulations (2012), a serious marine casualty, which is an event or sequence of events that has occurred directly by or in connection with the operation of a ship but which does not qualify as a very serious marine casualty, that involves fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, or a suspected hull defect, resulting in any of the immobilization of the main engines, extensive accommodation damage, severe structural damage including penetration of the hull under water rendering the ship unfit to proceed, pollution or a breakdown that necessitates towage or shore assistance.

In accordance with the international requirements, marine casualties occurred in the Turkish SAR area should be reported to the Turkish Main Search and Rescue Coordination Center (MSRCC)/Ana Arama ve Kurtarma Koordinasyon Merkezi (AAKKM). The serious/very serious ones of those can be investigated by the Transportation Safety Investigation Center (TSIC)/Ulaşım Emniyeti İnceleme Merkezi (UEİM) of the Ministry of Transport and Infrastructure (MoTI). Preparation of each investigation reports, which include possible causal factors and other information related with the casualty, can take a long time depending on scope of the casualty. A retrospective analysis of a set of marine casualties provides a holistic view of past events, as well as some clues on which issues should be focused on for more studies that are detailed in the future. In this context, it is expected that this study will also contribute to better understanding of shipboard fire/explosion casualties in the Turkish SAR area and provide a future perspective for more detailed studies on this issue.

Table 1. Some of very serious shipboard fire/explosion casualties (Ece, 2011; AA, 2014; EPA, 2020; Akten, 2006; Kozanhan, 2019; İstikbal, 2020).

Year	**Name of Ship**	**Casualty**	**Location**	**Damages (to life, ships and/or marine environment)**
1960	**World Harmony** **Peter Zoranic (Tanker)**	Fire due to collision of ships.	İstanbul Strait	18.000 tons of oil spilled.
1963	**Lakonia** (Passenger ship)	Fire in the hair salon.	North of Madeira in the Atlantic	A total of 128 people, including 95 passengers and 33 crew members, died. Only 53 of those died due to fire, while others died from falling and injuries due to panic.
1966	**Lutsk** (Tanker) **Kransky Oktiabr** (Genel Cargo)	Fire due to collision of ships.	İstanbul Strait	1.850 tons of oil spilled.
1973	**Golar Patricia** (Tanker)	Explosions, during the tank cleanings	130 miles off the Canary Islands, Spain	The ship sank, 10.000 tons of bunker oil spilled and 43 people died.
1975	**Jakob Maersk** (Tanker)	Fire/explosion due to grounding	Porto/Portugal	80.000 tons of crude oil spilled.
1979	**Independenta** (Tanker)	Fire due to collision with another ship.	İstanbul Strait	95.000 tons of oil spilled and 43 crew members died.
1994	**Nassia** (Tanker)	Fire/explosion due to collision with another ship.	İstanbul Strait	20.000 tons of oil spilled and 30 crew members died.
1987	**Dona Paz** (Passenger/ferry ship)	Fire due to collision with another ship (tanker).	Tablas Strait	4.375 passengers and 11 of 13 crew members died.
2010	**Deepwater Horizon** (Mobile Offshore Drilling Unit)	Fire/explosion	Gulf of Mexico	4 million barrels of oil spilled and 11 workers died.

Literature Review

In the literature, there are many studies regarding marine casualties with different aims and scopes. Some of those are related with analysis of marine casualties in the Turkish SAR area as well. The difference of this study from others is that this study has specifically focused on shipboard fire/explosion casualties among different types of marine casualties. Therefore, the relevant previous studies which particularly cover shipboard fire/explosion casualties have been reviewed in parallel with aim and scope of this study. For example;

Akten (2006) stated in his study on shipping accidents that groundings and shipboard fires were dominant types of shipping accidents worldwide.

Arslan & Turan (2009) examined factors, which affect marine casualties including shipboard fire/explosion casualties by using a combination of SWOT and AHP methods, and developed a strategic action plan for minimizing shipping casualties at the Strait of Istanbul.

Ellis (2011) analyzed marine casualties of ships carrying packaged or containerized dangerous goods between 1998–2008 and concluded that self-ignition or ignition of incorrectly declared dangerous goods were identified as a contributing factor for the fatal accidents.

Özkan et al. (2012) examined 18 of fire & explosion accident investigation reports between 1998-2010 in oil tankers and concluded that the main factors causing fire & explosion accidents are inappropriate equipment use, hot working, combustible gas accumulation and cargo leakage, respectively.

Ece (2012) analyzed ships accidents occurred in the Strait of İstanbul between 1982-2010 and stated that 7.6% of analyzed accidents (785) were shipboard fires.

Erol & Başar (2015) analyzed marine accidents occurred in the Turkish SAR area between 2001-2009 and concluded that many of ship accidents (60%) were resulted due to human errors.

You & Chung (2015) analyzed many cases of ship fires/explosions between 2009-2013 and concluded that majority of reasons for ship fires/explosions were lack of safety awareness.

Silva (2016) examined 20 of shipboard fire & explosion investigation reports and concluded that the main causal factors were lack of knowledge and inadequate operation & emergency procedures.

Park et al. (2016) analyzed marine casualties of fishing vessels in Korea and concluded that the causes of fires/explosions were mainly due to poor inspection and maintenance the electric cord.

Uğurlu (2016) examined fire & explosion events between 1999-2013 in tankers transporting and concluded that the most significant causes of accidents were hot work, electric arcs, static electricity, and combustible gas accumulation in the cargo tank. And, the main causative factors were the violation of work permits and a lack of risk analysis.

Krystosik-Gromadzińska (2016) examined engine room fire safety in his study and stated based on DNV that more than 50% of all engine room fires (excluding yard repairs) were caused due to the combination of oil leakage with a hot surface. This study also emphasized importance of cleanness of engine room and checkpoints in the engine room with care.

Yılmaz & İlhan (2018) analyzed marine accidents and incidents resulting in death, injury or loss of life occurred on or involving the Turkish flagged ships between 2002-2014 and stated that 4.4% of analyzed accidents and incidents (182) were shipboard fires/explosions.

Ece (2019) analyzed marine accidents in the Strait of İstanbul between 1982-2018 in her study and stated that 7.2% of analyzed accidents (857) were shipboard fires.

Rothblum (2020) stated in her study that human error contributes to 75% of fires & explosions and poor maintenance is a leading cause of fires and explosions.

İstikbal (2020) carried out a detailed analysis of three major accidents occurred in the Strait of İstanbul, some of which resulted with fire and explosion, and discussed the long-term proceedings of Left-hand side navigation in the Strait of Istanbul.

Çakır & Kamal (2020) analyzed 535 of marine accidents, 26 of which were shipboard fire/explosion casualties, occured in the Strait of İstanbul between 2001-2016.

Material and Methods

This study is specifically focused on shipboard fire/explosion casualties occurred in the Turkish SAR area. It is expected that it will contribute to better understanding what is general profile of shipboard fire/explosion casualties occurred in the Turkish SAR area, and to determine what further measures can be taken for the future. With this aim, the data on 127 fire/explosion casualties occurred on-board ships in the Turkish SAR area between 2006 and 2015, which include ship flag, ship type, ship tonnage, casualty season, casualty time, casualty region, location of fire/explosion on board ship, event caused fire/explosion on board ship, have been provided from "accident/event statistics" database published on web site (https://aakkm.uab.gov.tr/kaza-olay-istatistikleri) of the MSRCC/AAKKM which is open to public access (MSRCC/AAKKM, 2020). Then, the data provided have been properly classified and descriptive statistics/frequency tables have been prepared by using a software. The maritime literature has been considered during the classification of ships' technical particulars such as ship type, ship tonnage. The same definition of the "night-time" on the national legislation "Gemiadamları ve Kılavuz Kaptanlar Yönetmeliği/Regulation for Seafarers and Pilots (2018)" of Turkey has been used. The MSRCC/AAKKM's own data have been considered during the classification of events caused shipboard fires/explosions. The locations of fires/explosions onboard ships have been generically classifed according to explanations in the accident/event statistics database of the MSRCC/AAKKM. Yearly statistics of the shipboard fire/explosion casualties occured in the Turkish SAR area between 2006-2015 are shown in Table 2.

As seen from the Table 1 and Figure 1, 789 people were recovered, 35 people were injured, and 7 people were died due to 127 fire/explosion casualties occurred on ships in the Turkish SAR area between 2006-2015.

In addition to the statistical analysis, the existing marine accident investigation reports related with very serious shipboard fire/explosion casualties (TSIC/UEİM, 2020a; 2020b; 2018; 2015; 2014) prepared by the TSIC/UEİM, which are open to public access from web site (https://ulasimemniyeti.uab.gov.tr/deniz) of the TSIC/UEİM, have been also examined and summarized in the Appendix – Table 1.

Table 2. Shipboard fire/explosion casualties in the Turkish SAR area (MSRCC/AAKKM, 2020).

Year	Number of Shipboard Fire/Explosion Casualties	Number of People Recovered	Number of People Injured	Number of People Died
2015	7	8	19	-
2014	13	63	9	1
2013	12	279	-	3
2012	15	92	-	-
2011	13	73	-	-
2010	10	40	7	1
2009	11	57	-	1
2008	19	64	-	1
2007	13	84	-	-
2006	14	29	-	-
Total	127	789	35	7

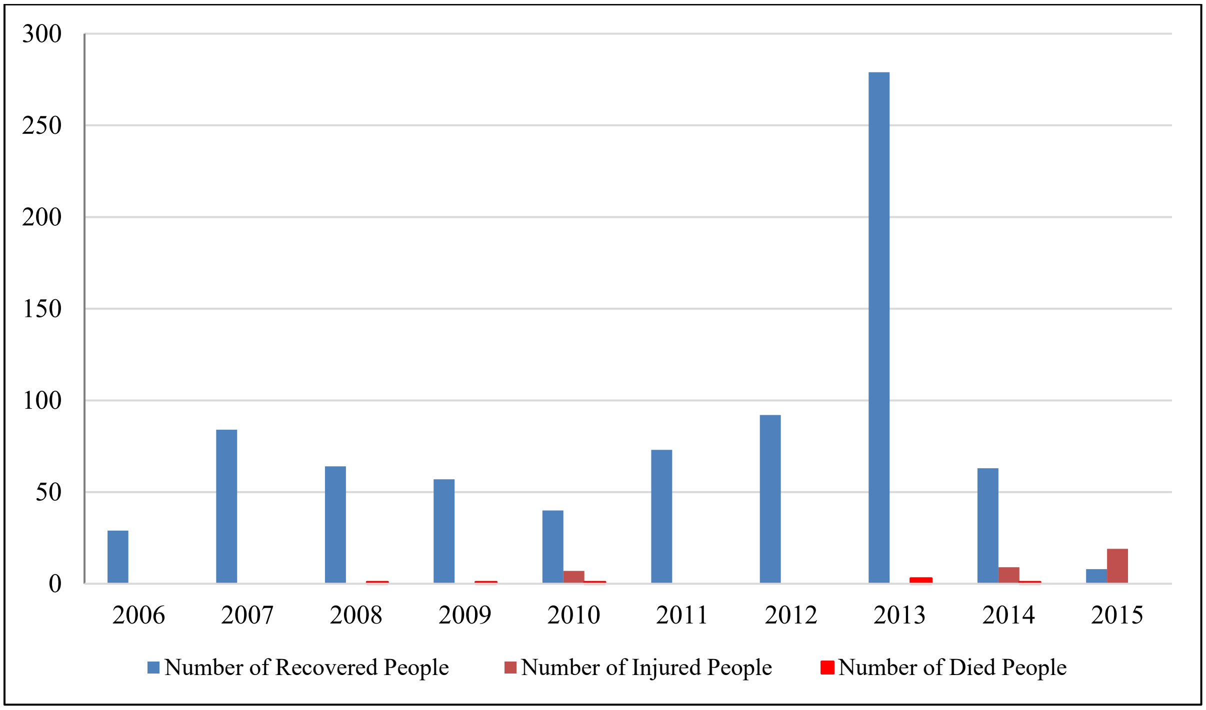

Figure 1. Number of people recovered, injured and died due to shipboard fires/explosions

Results and Discussion

Descriptive Statistics

As seen from Table 3, most of ships involved fire/explosion casualties between 2006-2015 were "Turkish flagged" with a share of 72.44% and "Foreign flagged" with 25.98%. The "Flag" data of some ships were undescribed or not described properly with 1.57%.

Table 3. Flags of ships involved fire/explosion casualties

Flag of Ship	Frequency (f)	Percentage (%)
Turkish	92	72.44
Foreign	33	25.98
Undescribed / Not described properly	2	1.57
Total	127	100.00

As seen from Table 4, most of ships involved fire/explosion casualties were "Recreational Vessels/Private-Commercial Yachts" with 33.07% and "Dry Bulk Cargo Ships" with 25.20%, respectively. The "Passenger Vessels/Ferries" with 17.32%, "Other types" with 7.87%, "Tankers (Oil, chemical etc.)" with 5.51%, "Fishing Vessels" with 5.51% and "Ro-Ro/Ro-Pax" with 3.94% were also involved in shipboard fire/explosion casualties, respectively. The "Type of Ship" data of some ships were undescribed or not described properly with 1.57%.

Table 4. Types of ships involving fire/explosion casualties

Type of ship	(f)	%
Passenger Vessels / Ferries	22	17.32
Recreational Vessels / Private-Commercial Yachts	42	33.07
Ro-Ro / Ro-Pax	5	3.94
Dry Bulk Cargo Ships	32	25.20
Fishing Vessels	7	5.51
Tankers (Oil, chemical etc.)	7	5.51
Other type of ships above	10	7.87
Undescribed / Not described properly	2	1.57
Total	127	100.00

As seen from Table 5, most of ships involved fire/explosion casualties were “less than 500 GRT” with a share of 47.24%. The ships between “500 – 2,999 GRT” with 18.11%, ships between “3,000 – 9,999 GRT” with 16.54%, ships “more than 10,000 GRT” with 7.87% were also involved in fire/explosion casualties, respectively. The “GRT” data of some ships were undescribed or not described properly with 10.24%.

Table 5. Grosstonnages (GRT) of ships involving fire/explosion casualties

GRT of ship	(f)	%
Less than 500	60	47.24
500 – 2,999	23	18.11
3,000 – 9,999	21	16.54
More than 10,000	10	7.87
Undescribed / Not described properly	13	10.24
Total	127	100.00

As seen from Table 6, most of shipboard fires/explosions were occurred in the region of “İstanbul” with 38.58%, in “İzmir” with 22.05% and in “Çanakkale” with 17.32%, respectively. Others were also occurred in “Antalya” with 9.45%, in “International Waters” with 4.72%, in “Mersin” with 3.15%, in “Samsun” with 2.36%, in “Trabzon” with 1.57%, respectively. The “Region” data of some shipboard fire/explosion casualties were undescribed or not described properly with 0.79%.

Table 6. Regions where shipboard fire/explosion casualties occurred

Region	(f)	%
Antalya	12	9.45
Çanakkale	22	17.32
İstanbul	49	38.58
İzmir	28	22.05
Mersin	4	3.15
Samsun	3	2.36
Trabzon	2	1.57
International Waters	6	4.72
Undescribed / Not described properly	1	0.79
Total	127	100.00

As seen from Table 7, most of shipboard fires/explosions were occured in the “Summer” season with 33.86%. Others were also occured in “Autumn” with 25.20%, in “Spring” with 23.62% and in “Winter” with 17.32%, respectively.

Table 7. Seasons of fire/explosion casualties

Season	(f)	%
March-April-May (Spring)	30	23.62
June-July-August (Summer)	43	33.86
September-October-November (Autumn)	32	25.20
December-January-February (Winter)	22	17.32
Total	127	100.00

As seen from Table 8, shipboard fires/explosions were occured during the “Nigthtime (20:00-06:00)” with 51.18% and “Daytime (06:01- 19:59)”, respectively.

Table 8. Time of fire/explosion casualties

Time	(f)	%
20:00- 06:00 (Night-time)	65	51.18
06:01- 19:59 (Day-time)	62	48.82
Total	127	100.00

As seen from Table 9, the locations where fires/explosions were occurred on-board ships were mostly undescribed or not described properly with a share of 51.18%. According to described locations, most of shipboard fires/explosions were mostly occurred in “Machinery Spaces” of ships with 25.20%. Others were also occurred in “Accommodation / Passenger Spaces” with 11.02%, in “Tanks / Enclosed Spaces” with 6.30% and in “Cargo Spaces” with 6.30%, respectively.

Table 9. Locations of fires/explosions on-board ships

Location of fire/explosion	(f)	%
Machinery Spaces	32	25.20
Undescribed / Not described properly	65	51.18
Accommodation / Passenger Spaces (Crew cabins, passenger longest, kitchens, bridges, etc.)	14	11.02
Tanks / Enclosed Spaces	8	6.30
Cargo Spaces	8	6.30
Total	127	100.00

As seen from Table 10, events caused shipboard fires/explosions were mostly undescribed or not described properly with 70.08%. According to described events, events caused shipboard fires/explosions were mostly related with "Electricity Contact/Leakage" with 18.11%. Others were related with "Gas Leakage/Accumulation" with 4.72%, "Cargo Ignition" with 4.72% and "Welding/Hot Works" with 2.36%, respectively.

The shipboard fire/explosion casualties may be resulted with loss of life, loss of ships and pollution of marine environment. Very serious shipboard fire/explosion casualties occurred in the maritime history, which are included in the Table 1, supports this view.

Table 10. Events caused shipboard fires/explosions

Event caused fire/explosion	(f)	%
Electricity Contact/Leakage	23	18.11
Gas Leakage/Accumulation	6	4.72
Cargo Ignition	6	4.72
Welding/Hot Works	3	2.36
Undescribed / Not described properly	89	70.08
Total	127	100.00

According to the retrospective analysis carried out in this study, 127 shipboard fire/explosion casualties occurred in the Turkish SAR area between 2006-2015 were mostly occurred:

- on-board "Turkish flagged ships"
- on-board "Recreational Vessels/Private-Commercial Yachts" and "Passenger Vessels"
- in the regions of "İstanbul", "İzmir" and "Çanakkale"
- in the "Summer" season
- during the "Night-time (20:00-06:00)"
- in "Machinery Spaces" of the ships (according to described locations)
- caused from "Electricity Contact/Leakage" (according to described events)

According to the statistical analysis, majority of the shipboard fire/explosion casualties in the Turkish SAR area were occurred on-board the Turkish flagged ships. On the other hand, Table 11 shows that total number of Turkish flagged cargo ship visits and total number of foreign-flagged cargo ship visits at Turkish ports are approximate.

Table 11. Total number of cargo ship visits at Turkish ports (DGM, 2020).

Year	Turkish flagged	(%)	Foreign flagged	(%)	Total
2019	20,991	38.0	34,311	62.0	55,302
2018	38,219	52.8	34,141	47.2	72,360
2017	38,263	52.2	35,043	47.8	73,306
2016	37,644	52.9	33,576	47.1	71,220
2015	38,397	52.1	35,288	47.9	73,685
2014	38,685	51.7	36,081	48.3	74,766
2013	39,835	52.3	36,295	47.7	76,130
2012	38,333	50.5	37,542	49.5	75,875
2011	37,234	49.6	37,900	50.4	75,134

The fact that approximately half (47%) of the total shipboard fire/explosion casualties were occurred on-board ships below than 500 GT points out that those were domestic small passenger/recreational vessels and private-commercial yachts which are mostly not subject to the international rules, in the Cabotage. Because other types of ships are generally more than 500 GT. Besides one third of the total shipboard fire/explosion, casualties were occurred on such ships. Therefore, it may be more beneficial to conduct further studies primarily in order to improve the fire safety of such ships. For example; as stated on the relevant marine accident investigation report (TSIC/UEİM, 2015), further studies can be conducted on the following issues:

- Effective inspection for marine type approval of portable electrical devices & equipment using on-board such vessels which are not under supervision of classification societies,
- Fixed fire pumps to be driven remotely,
- Control of periodical emergency drills.

Even though the summer season seems to be a little more prominent, seasonal changes did not make a significant difference for occurrence of shipboard fire/explosion casualties. The shipboard fire/explosion casualties were occurred at daytime or nigh time, irregardless of time.

Causal/Contributing Factors of Shipboard Fires/ Explosions

The causal factors of shipboard fire/explosion casualties are a combination of various factors such as actions, omissions, events or conditions. The fuel, oil, oily bilge water, sludge, oil absorbed materials, hot surfaces, damaged parts, heat-generating works, and self-igniting substances in the *engine rooms* of ships may cause a fire. The flammable liquids, heated oils for frying, hot surfaces, ovens, heated pans, damaged electrical installations in the *kitchens* of ships may cause a fire. The combustible materials, drapes, curtains, personal electrical devices, matches, cigarettes, electrical contacts, papers in the garbage in the *accommodation spaces* of ships may cause a fire. The self-heating cargo, oxidizable cargo, cargo that may spark by friction, organic substances, and accumulated/compressed gases in tanks/enclosed spaces, flares; explosives in the *cargo spaces* of ships may cause a fire. The shipboard fires usually occur due to human errors such as lack of knowledge, lack of care, lack of experience etc. (MEB, 2016:5-26)

According to the statistical analysis carried out in this study, electricity contact/leakage, gas accumulation/leakage, cargo ignition, welding/hot works and other factors undescribed/not described properly were main events caused shipboard fires/explosions. Of course, fuel/oil leakage is one of very important factors of shipboard fires/explosion casualties in general but there is no data on that issue in the "accident/event statistics" database of the MSRCC/AAKKM. Since the accident/event statistics between 2016-2020 had not been published on the web site of the MSRCC/AAKKM, this study was designed to cover a 10-year period from 2006 to 2015. Descriptive (frequency) analysis was possible but any correlation or root-cause analysis could not be carried out, as more than 70% of the data on "events caused fire/explosion casualties on board ships" had been undescribed or not described properly in the accident/event statistics of the MSRCC/AAKKM.

In order to better understand the main reasons and the advance of shipboard fires/explosions, the existing marine accident investigation reports of the very serious shipboard fire/explosion casualties (TSIC/UEİM, 2020a; 2020b; 2018; 2015; 2014) prepared by the TSIC/UEİM between 2014 – 2020 have been examined and summarized in the Appendix – Table 1 as well. By examining the results and recommendations stated on the reports, it has been observed that the possible causal/contributing factors of the shipboard fire/explosions were mostly related with some violations of the ISM-Safety Management System (SMS), such as improper cargo operation, improper supply operation, improper gas-free operation, improper hot work operation, insufficient procedure, insufficient audit/inspection, etc. Some reports also point out to the insufficient shipboard familiarization & awareness trainings about cargo operations, insufficient ship safety culture, and ineffectiveness of emergency fire and abandon ship drills on-board ships. Figure 2 contains a visual representation of those factors.

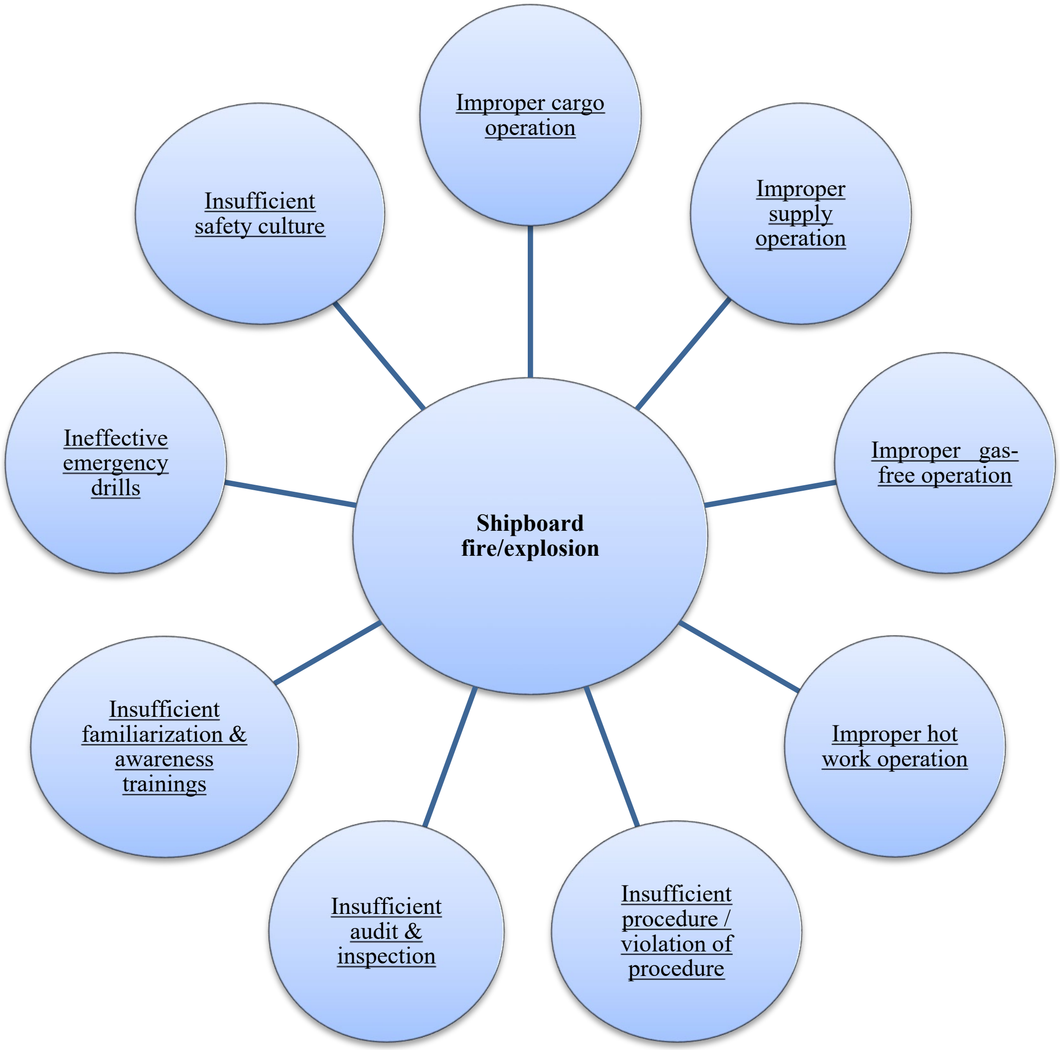

Figure 2. Possible causal/contributing factors of the shipboard fire/explosions according to the TSIC/UEİM's investigation reports examined in this study.

Those are the topics mostly related with the implementation of the ISM-Safety Management System (SMS). As seen from Table 12, many previous studies in the relevant literature also point out to some ISM/SMS-related causal/contributing factors of the shipboard fires and explosions.

Accordingly, the effective implementation and continuous improvement of the ISM/SMS are very important topics for the prevention of shipboard fire/explosion casualties as well. The International Management Code for the Safe Operation of Ships and for Pollution Prevention (International Safety Management (ISM) Code), which aims to provide the safe management and operation of ships and the protection of the marine environment, is based on general principles and objectives, which include assessment of all identified risks to one Company's ships, personnel and establishment of appropriate safeguards (IMO, 2020b). The Company should develop instructions and procedures to ensure safe operation of ships. The Company should periodically review and evaluate the effectiveness of the SMS in accordance with procedures established by the Company. Further, it is one of the master's responsibilities to review periodically the SMS and to report its deficiencies to the Company. Companies should carry out periodical internal shore-based and shipboard audits to verify whether shore-based and shipboard activities comply with the SMS. The Company should also continuously improve safety management skills of personnel ashore and on-board ships, including emergency preparedness, and ensure that all personnel have the qualifications, training and experience that may be required in support of the SMS. Master is responsible for implementing the safety and environmental-protection policy of the Company and motivating the crew in the observation of that policy. Master is also responsible for periodically reviewing the SMS and reporting its deficiencies to the Company (ISM Code, 2010; MEPC.7/Circ.8, 2013).

Table 12. Causal/contributing factors of shipboard fires/explosions in the literature

Causal/contributing factors	References
• Cleanness of engine room; fuel leakages in pumps, piping, generators, main engines • Electrical failures originating from the generators or switchboards	(Krystosik-Gromadzińska, 2016) (Lindgren & Sosnowski, 2009) (Silva, 2016)
• Violation of work permits • Lack of risk analysis • Hot working • Electric arcs, static electricity • Combustible gas accumulation in cargo tanks • Inappropriate equipment use	(Uğurlu, 2016) (Uğurlu, Başar & Köse, 2012)
• Poor inspection and maintenance the electrical installations/devices	(Park at al., 2016)
• Self-ignition or ignition of incorrectly declared dangerous goods	(Ellis, 2011)
• Lack of safety awareness • Crew's lack of knowledge • Inadequate operation • Inadequate emergency procedures/check lists	(You & Chung, 2015) (Silva, 2016)

Meanwhile, domestic recreational vessels/commercial yachts are subject to neither the SOLAS Chapter IX / ISM Code requirements nor the national technical rules, as such ships are mostly navigating in the Cabotage and less than 500 GT. On the other hand, some ISM Code requirements are being partly applied to the passenger ferries navigating in the Cabotage and their companies according to the national "Uluslararası Emniyet Yönetimi Kodunun Türk Bayraklı Gemilere ve İşletmecilerine Uygulanmasına Dair Yönetmelik/National Regulation on the Application of the ISM Code to Turkish Flagged Ships and Operators, 2009" of Turkey.

Globally, the training and certification of the seafarers are being conducted according to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 78/95). The Turkish seafarers are also being trained and certified in accordance with the national legislation "Regulation for Seafarers and Pilots (2018)" in line with the STCW 78/95. Of course, effectiveness of on-shore trainings is a very important topic but on the other hand, effectiveness of shipboard familiarization & awareness trainings of the seafarers to be carried out in scope of the SOLAS Chapter IX / ISM Code is also another important topic for providing the sustainability of the safety of ships and occupational safety of seafarers. Additionally, Regulation 4.3 of the Maritime Labour Convention (MLC, 2006) also requires that seafarers should be trained on-board ship in terms of health and safety protection and accident prevention. The Port State Control (PSC) provides the effective implementation of international maritime rules, together with flag State, Class and P&I inspections.

Fire Safety of Ship Engine Room

According to the statistical analysis carried out in this study, it has been observed that most of shipboard fires/explosions were occurred in the "machinery spaces" of the ships. According to Krystosik-Gromadzińska (2016), 50% of all engine room fires are due to the combination of oil leakage with a hot surface. Figure 3 also shows causes of engine room fires according to Krystosik-Gromadzińska (2016).

Lindgren & Sosnowski (2009) carried out a safety risk assessment for oil tankers and container vessels focused on fire & explosion in the machinery space and concluded that generators and leaking fuel pumps were the most critical components with respect to fires whereas boilers initiated the most explosions. In general electrical failures (usually originating from the generators or switchboards) and fuel, leakages in pumps, piping and the main combustion machinery (the generators and the main engine) were the most common sources of fire. Table 13 includes the most common sources of ignition and sources of oil leakages in the machinery spaces of the ships according to another study carried out by the United States of Coast Guards (USCG).

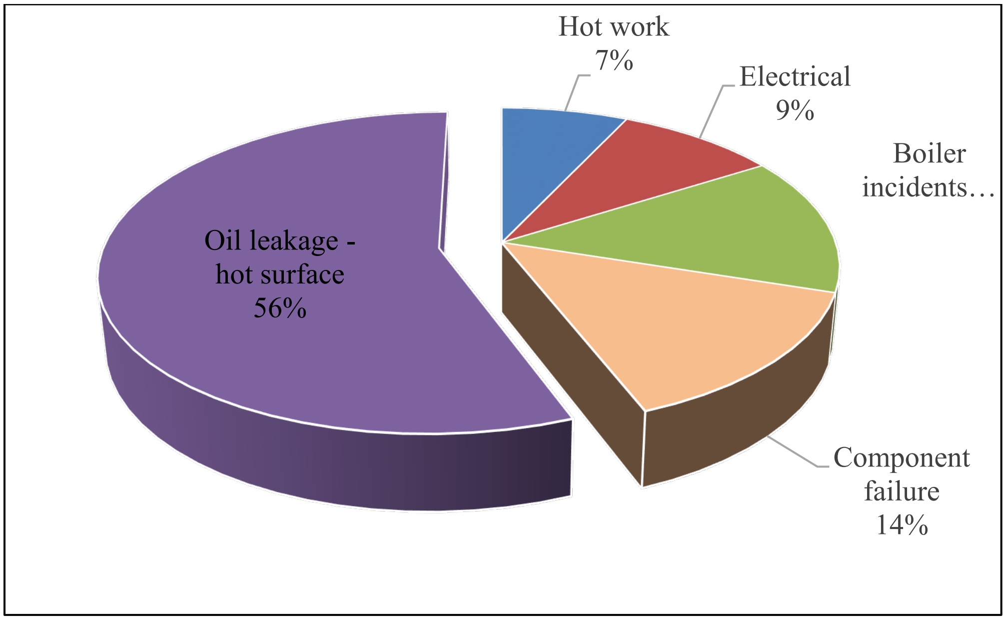

Figure 3. Causes of engine room fires (Krystosik-Gromadzińska, 2016)

Table 13. The most common sources of ignition and sources of oil leakage in the machinery spaces (USCG Research and Development Center, 1998; Lindgren & Sosnowski, 2009).

Source of ignition (component)	(%)	Source of oil leakage (component)	(%)
Boiler	0.7	Main engine	4.0
Explosion (other)	2.1	Pums	4.0
Hot surface (other)	52.5	Separator/purifier	1.1
Open flame	4.9	Turbocharger	1.7
Spark	1.4	Vents/pipes	61.7
Steam line	2.8	Other	17.7
Turbocharger	9.1	Onknown	9.7
Other/unknown	26.6		
Total	100.0	Total	100.0

As seen from the Table 13, the most common sources of ignition in the machinery spaces are hot surfaces (other), turbochargers, open flames, steam lines, sparks and boilers, respectively. The most common sources of oil leakage in the machinery spaces are related with some components such as vents/pipes, pumps, main engines, turbochargers and separators/purifiers, respectively.

Therefore, fire safety of engine room is very important issue. Figure 4 shows some major components of engine room fire safety that should be considered.

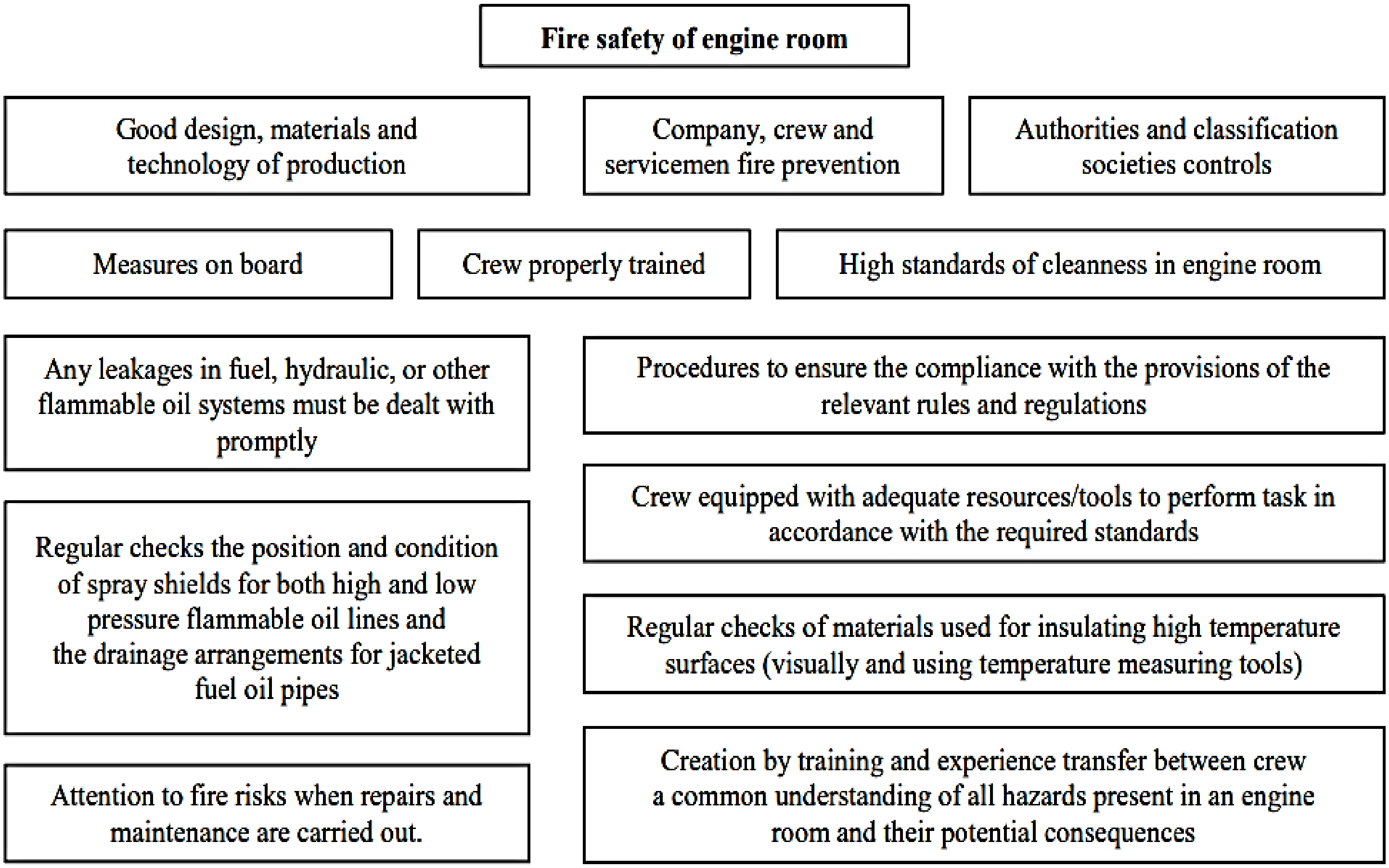

Figure 4. Components of engine room fire safety (Krystosik-Gromadzińska, 2016)

Fire safety of engine rooms starts from a good design, materials and technology of production. Accordingly, naval architects have also important roles and responsibilities for the proper design and construction of ship engine rooms in terms of fire safety. Company and ship crewmembers should have awareness of fire prevention. The inspections carrying out by authorities and classification societies provide the sustainability of fire safety of ships. The cleanness of an engine room is very important for prevention of shipboard fires/explosions. All fuel/oil leakages in the engine rooms should be monitored and checked regularly in accordance with ship's safety management procedures. Any violations of work permits should be avoided. The personal protective equipment should be provided by company to crewmembers and be used by crewmembers. The attention to fire risks, when repairs and maintenance are carried out, should be paid. A common understanding of all hazards and their consequences should be created by training and experience transfer between crewmembers. Experienced engine officers and ratings are also important to ensure the safe machinery operations.

In this study, an analysis focused on shipboard fire/explosion casualties occurred in the Turkish search and rescue (SAR) area has been carried out. Some descriptive statistics and possible causal/contributing factors of shipboard fires & explosions have been presented and discussed with previous studies in the section of "Results and Discussion" of the study.

As a result of the statistical analysis (descriptive statistics) of the shipboard fire/explosion casualties reported to the MSRCC/AAKKM between 2006-2015, it has been observed that majority of the shipboard fire/explosion casualties were occurred on-board the Turkish flagged ships, on-board small passenger vessels/recreational vessels/private-commercial yachts among the classified ship types, in the regions of İstanbul, İzmir and Çanakkale, in the summer season, during the night-time, and in machinery spaces of the ships by described locations. It has been also observed that main events caused shipboard fires/explosion casualties were electricity contact/leakage, gas accumulation/leakage, cargo ignition, welding/hot works and other undescribed factors.

By examining the existing shipboard fire & explosion accident investigation reports of the TSIC/UEİM between 2014-2020, it has been observed that the main possible causal/contributing factors for the shipboard fire/explosion casualties were related with the violations of the ISM-Safety Management System (SMS) requirements, such as improper cargo operation, improper supply operation, improper gas-free operation, improper hot work operation, insufficient procedure, insufficient audit/inspection, insufficient shipboard familiarization & awareness trainings about cargo operations, insufficient ship safety culture and ineffectiveness of emergency fire and abandon ship drills on-board ships, etc. Many previous studies in the relevant literature also point out to some SMS-related causal/contributing factors of the shipboard fires/explosion casualties.

Recommendations to Avoid from Shipboard Fire / Explosion Casualties

An effective fire safety management is very important issue for all ships. The technical rules on construction-fire protection, fire detection and fire extinction of ships engaged in international voyages are basically established in Chapter II-2 of SOLAS. As a recommendation, special attention should be paid for the fire safety measures and the effective implementation of the relevant ISM-SMS procedures of international cargo ships during the flag State and port State inspections as well as during the P&I and class inspections. Additionally, shipboard trainings of seafarers to be carried out in accordance with STCW 78/95, SOLAS Chapter IX / ISM Code and MLC 2006, emergency drills and audits should also be carefully inspected as well.

Of course, Companies should also fulfil their duties without waiting for the flag State, port State, P&I or class inspections. The Companies should also effectively inspect their ships in a close cooperation with the shipmasters. The Companies are primarily responsible to provide a ship safety culture to seafarers on their ships and effectively implement the ISM Code requirements. In this study context, whether the shipboard safety awareness trainings of seafarers, emergency drills and audits related with fire safety management are effectively performed or not should be carefully monitored and necessary corrective actions should be taken by the Companies. Special attention should be paid on cleanness of engine room, fuel leakages in pumps, piping, generators, main engines, electrical failures originating from the generators or switchboards, work permits, hot works, electric arcs, static electricity, combustible gas accumulation/leakage, periodical inspection maintenance of electrical installations/devices, self-ignition or ignition of incorrectly declared dangerous goods, operation and emergency procedures and risk analysis onboard ships. The recommendations stated on the accident investigation reports of the TSIC/UEİM should be monitored and considered by the Companies as well as by the other relevant parties.

Ship masters should also pay special attention to the effective implementation and continuous improvement of the ISM/SMS on-board ships in a close cooperation with the Company. They should pay special attention to reviewing the SMS and reporting its deficiencies to the Company, and motivating the crew in the observation of shipboard safety policy and procedures. Ship engine and deck officiers and ratings should pay special attention to the safe machinery and cargo operations, specially to the sources of oil/gas leakage and sources of ignition in the machinery spaces and other spaces, such as cargo holds, enclosed spaces, etc.

Meanwhile, there are also many domestic small passenger/recreational vessels and private-commercial yatchs involving the shipboard fire/explosion casualties in the Turkish SAR area. Such ships are subject to neither the SOLAS Chapter IX / ISM Code requirements nor the national ISM implementation. Therefore, focusing on improving fire safety of such domestic ships is of special importance. Accordingly, it can be recommended that the national technical rules may be further improved in terms of fire safety of such ships. This improvement action can be started from the effective inspection for marine type approval of portable electrical devices & equipment using on such vessels and providing fixed fire pumps to be driven remotely. Furthermore, some applicable ISM requirements, for example; emergency abandon ship drills etc., may be partly applied to the domestic small passenger/recreational vessels and commercial yachts, carrying more than 12 passengers, as well as to the domestic passenger ferries. Inspections to the domestic passenger ferries may be increased in terms of national ISM/SMS implementation including fire safety management. Some additional fire safety measures may be considered for both Turkish flagged and foreign-flagged private yachts as well.

Conclusion

Depending on the data available, this study was designed to cover all types of ships with the aim of better understanding what is general profile of shipboard fire/explosion casualties occurred in the Turkish SAR area. In the future, it would be useful to conduct further studies focusing on ship fire/explosion casualties for each types of ships with a detailed data set including each causal/contributing factors of shipboard fire/explosions, separately.

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Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: -

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Appendix – Table 1. A summary on possible causes of shipboard fires/explosions and recommendations according to the TSIC/UEİM's investigation reports (TSIC/UEİM, 2020a; 2020b; 2018; 2015; 2014).

TSIC/UEİM – Accident Investigation Report No	Serious/Very Serious Shipboard Fire/Explosion Casualties Investigated by the TSIC/UEİM	Possible Causes of Shipboard Fires/Explosions	Recommendations
41/DNZ-07/2020	Explosion & fire on-board an Italian flagged LPG tanker, on 01.07.2019 in İzmir, while cargo loading at an LPG terminal/platform.	• Gas leakage due to rupture of the hose used for connection between ship and shore, as a result of over pressure on the hose. • Static electricity. (possible ignition source)	• Within the scope of ISM "Cargo Loading Procedure", necessary measures should be taken to ensure effective tank level monitoring and/or a warning mechanism must be integrated into the system, against over pressure. • Periodical abondon ship drills sould be effectively carried out with participation of all crew members in accordance with the ISM. • Terminal should also take some measures in order to increase the efficiency of continuously monitoring of gas tranfer process & line pressure.
29/DNZ-04/2020	Capsizing due to a fire on-board a Turkish flagged wooden recreational vessel (gulet), on 16.09.2019 in Göcek, while at anchor.	• Overheating of electical caples connected with electrical devices in the kitchen of the vessel. (possible ignition source)	• A procedure should be developed for the effective inspection of the suaitability and adequacy of portable electrical devices & equipments used on-board vessels not under supervision of classification societies for marine type approval. • A regulation should be arranged so that the fixed fire pumps on such ships can also be driven remotely. • Especially in the certification process of such ships, effective measures sould be taken to control the fact that periodical emergency drills are carried out and recorded, including informing passengers about emergency situations.
DNZ-04/2018	Explosion & fire on-board a Turkish flagged LPG tanker, on 29.04.2017 in İzmit, while at an LPG terminal/platform.	• Gas leakage due to improper discharge of LPG vapor accumulated in cargo tanks. • Improper supply operation. (possible ignition source)	• ISM should be reviewed in order to rectify all non-conformities found during the accident investigation, in particular cargo operation related ones. • Deck Officers who are on duty for cargo operations should be given a refreshment training. • ISM internal audits should be done more frequently and ship fire drills should be done more effectively. • Terminal should review the compliance of its fire-fighting equipment on the LPG ship platform with international standards.

08/2015	A fire on-board a Togo flagged general cargo ship, on 14.01.2015 in İskenderun, while loading the cargo (straw) at a port.	• Burding of dry cargo (straw balls) due to cigaratte or self-ingition of cargo. (possible ignition source)	• Number of inspections and controls of dangerous cargo loading/unloading operations should be increased at ports. • Realistic drills should be carried out against fires and other similar emergency situations at ports. • A regulation should be arranged to measure the moisture content of the straw cargo before loading and to determine the straw transport conditions, especially on the deck.
01/2014	Explosion on-board a Turkish flagged chemical tanker, on 20.01.2014 in Tuzla- İstanbul, while at achor.	• Improper gas-free operation. Chemical (explosive) gas accumulation in enclosed spaces, cofferdams. • Improper hot work (spiral cutting) on the deck. (ignition source) (Without a hot work permission from Harbour Master Authority, without an on-board meeting about hot work planning, without informing the ship crews about their roles during the hot work, without completing the hot work permit forms, without gas measurement before hot work.)	• Company should give further trainings to its personnel and all crew members working on-board the ships managed by it in order to increase their ship safety culture. • Company should carry out internal ISM audits, which should also include gas-free and hot work operations, from time to time as possible, even while the ships are navigating. • Company should ensure that written permission must be obtained from itself before any "hot work" on-board ships under its management. • Company should check and monitor that the necessary records regarding explosive gas measurement of enclosed spaces are kept on-board ships under its management. • Company should establish and implement an ISM procedure in order to evaluate masters, officiers and engineers, before employment and boarding and after leaving the ships. • The efficiency of Administrative controls regarding ISM practices should be increased.

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Research Article

Phytoplankton diversity of a de-mineralized subtropical reservoir of Meghalaya state, northeast India

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ABSTRACT

This study monitors the spatio-temporal variations of phytoplankton of a soft-water and de-mineralized reservoir of Meghalaya state of northeast India. Phytoplankton assemblages of the littoral and limnetic regions reveal total 36 species and diverse desmids, and contribute dominantly to net plankton abundance. Our results record the quantitative importance of Charophyta > Bacillariophyta > Dinophyta and Charophyta > Dinophyta, and the 'specialist' nature of 11 and six species at the littoral and limnetic regions, respectively. *Staurastrum* spp. and *Cosmarium* spp. are notable taxa. Phytoplankton indicates moderate species diversity and depicts dominance and evenness variations. The individual abiotic factors exert differential influence on various taxa at the two regions and the canonical correspondence analysis registers 73.02 and 71.14% cumulative influence of 10 abiotic factors on the littoral and limnetic assemblages, respectively. The spatial differences of phytoplankton composition, richness, abundance, important groups and taxa, specialist species, diversity indices and the influence of individual abiotic factors are hypothesised to habitat heterogeneity amongst the sampled regions. This study records notable temporal differences of phytoplankton richness, abundance, diversity and the role of abiotic factors vis-a-vis the limited survey of November 1990–October 1991.

Keywords: Low conductivity, Primary producers, Spatio-temporal variations, Very soft-water

Introduction

Phytoplankton deserves importance as notable contributors to primary production and integral components of aquatic food webs in inland waters. Although these primary producers have been studied from the diverse aquatic environs since the inception of the Indian limnology, a large fraction of works from this country yet represent 'routine' ecology reports because of incomplete species lists and inadequate data-analysis (Sharma and Sharma, 2021). This generalization holds valid for phytoplankton assemblages of lakes and reservoirs of India and north India in particular. The studies from the Himalayan and sub-Himalayan regions of northwest India with variable extents of useful information are from the states of Jammu and Kashmir (Zutshi and Wanganeo, 1984; Wanganeo and Wanganeo, 1991; Baba and Pandit, 2014; Ganai and Parveen, 2014), Himachal Pradesh (Thakur *et al.,* 2013; Jindal *et al*., 2014a, 2014b; Gupta *et al*., 2018) and Uttarakhand (Sharma and Singh, 2018; Sharma and Tiwari, 2018). Referring to northeast India (NEI), the noteworthy studies (Sharma, 2004, 2009, 2010, 2012, 2015; Sharma and Hatimuria (2017) are limited to the floodplain lakes (*beels* and *pats*) of the states of Assam and Manipur. The detailed studies on phytoplankton diversity of the sub-tropical lacustrine environs of NEI in particular are, however, limited to the works of Sharma and Pachuau (2016), Sharma and Sharma (2021) from the reservoirs of Mizoram and Meghalaya states, respectively.

The present study aims at monitoring the spatio-temporal variations of phytoplankton vis-à-vis abiotic factors of a de-mineralized subtropical reservoir of Meghalaya state of NEI. The littoral and limnetic net plankton are analyzed with reference to species composition, richness, community similarities, abundance, dominant groups, important taxa, notable species, species diversity, dominance and evenness, and the individual and cumulative influence of abiotic factors on phytoplankton assemblages. The results are discussed in comparison with those from the tropical and subtropical lacustrine environs of India, and the floodplain lakes and reservoirs of NEI. Remarks are made on the spatio-temporal variations of phytoplankton diversity based on our results from the littoral and limnetic regions as well as on the temporal variations vs. our earlier preliminary survey (Sharma, 1995) undertaken at the limnetic region.

Material and Methods

The present study is based on January-December 2014 limnological survey of a small rainwater-fed reservoir (Figure 1, A-C; Latitude 25°34'N; Longitude 91°56'E, area ~10 ha; max. depth: 15m) located at a distance of about 10 km from Shillong city, the capital of Meghalaya state (refereed as 'Shillong reservoir'). This warm monomictic reservoir (Sharma, 1995) serves as drinking water storage basin and lacks any aquatic vegetation and fish fauna. It is surrounded by forest cover predominated by *Plnus kesiya* with *Cassia* sp**.,** *Cinnamomum gladulifercum, Rhus javanica* and *Mochilers khasyana*.

Water and the qualitative and quantitative net plankton samples were collected at monthly interval from the littoral and the limnetic regions (Figure 1C). Water temperature was noted using a centigrade thermometer and transparency was noted with a Secchi disc. pH and specific conductivity were noted with the field probes, dissolved oxygen (DO) was estimated by Winkler's method, and other abiotic factors: free carbon dioxide (CO_2), alkalinity, hardness, calcium (Ca), magnesium (Mg), chloride (Cl), dissolved organic matter (DOM), phosphate (PO_4), nitrate (NO_3) and sulphate (SO_4) were analyzed following APHA (1992). The rainfall data was collected from the local meteorological station. The qualitative net plankton samples were collected by towing nylobolt plankton net (#40 µm) and preserved in 5% formalin. All samples were screened with a Wild Stereoscopic binocular microscope; phytoplankton was observed with Leica stereoscopic microscope (DM 1000) and were identified following Islam and Haroon (1980), Fritter and Manuel (1986), Anand (1998) and John *et al.* (2002). The community similarities were calculated vide Sørensen index and the hierarchical cluster analysis was done using SPSS (version 20). The monthly quantitative samples were obtained by filtering 25 L of water each through nylobolt plankton net (#40 µm) and were preserved in 5% formalin. The quantitative enumeration of phytoplankton was done by using a Sedgewick-Rafter counting cell and abundance was expressed as ind. L^{-1}. Species diversity, dominance and evenness were computed vides Shannon-Weiner index, Berger-Parker index and E_1 index, respectively following Ludwig and Reynolds (1988). Two-way analysis of variance (ANOVA) was used to ascertain significance of variations of abiotic and biotic parameters between the sampled regions and months. Pearson correlation coefficients for the littoral and limnetic regions (r_1 and r_2, respectively) were calculated between abiotic and biotic parameters; p values (2-tailed) were calculated and their significance was ascertained after applying Bonferroni corrections. The canonical correspondence analysis (XLSTAT 2015) was done to observe cumulative influence of 10 abiotic parameters namely water temperature, rainfall, transparency, specific conductivity, DO, alkalinity, hardness, Cl, DOM and PO_4 on phytoplankton assemblages.

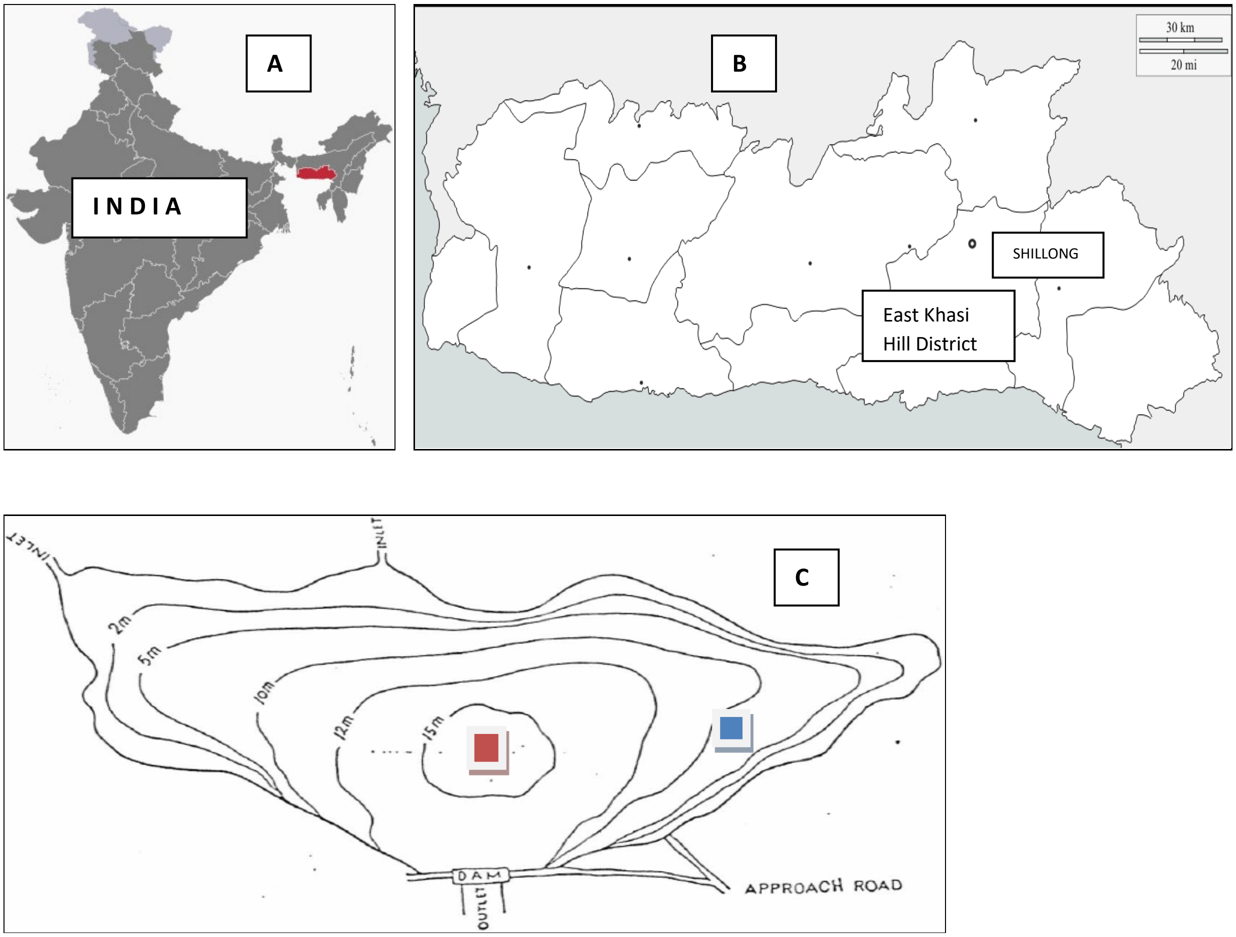


Figure 1(A-C). A, map of India showing Meghalaya state of northeast India (red color); B, map of Meghalaya indicating location of the capital city of Shillong; C, map of Shillong reservoir indicating the littoral (blue color) and limnetic (red color) regions

Results and Discussion

Our results highlight 'very soft, acidic, highly de-mineralized and distinctly calcium poor' nature of Shillong reservoir with oxygenated waters, low free CO2 and nutrients, and Cl indicates the limited human impact (Table 1). We report one of the lowest specific conductivity known till date from aquatic environs of the Indian sub-continent (Hickel, 1973; Sharma and Bhattarai, 2005; Sharma and Sharma, 2021). This notable feature is attributed to predominant effects of abundant rainfall in NEI coupled with the weathered and leached nature of rocks and soils of the catchment area and to the lowered buffering capacity of the de-mineralized waters (Sharma, 1995) of this rain-water fed reservoir. ANOVA registers significant variations of transparency, DO, Ca, Cl and SO_4 between the regions and months, while all abiotic factors register significant monthly variations (Table 2). This study records decrease in transparency and PO_4, and the relative increase in specific conductivity, alkalinity, hardness and Cl (Table 1) than the earlier survey (Sharma, 1995).

Total 36 species (Table 3) noted vide our study depict distinctly diverse phytoplankton than the earlier report of 16 species (Sharma, 1995), and the relatively diverse nature than the reports from lacustrine systems of Himachal Pradesh (Jindal and Thakur, 2014; Gupta *et al*., 2018,) and Uttarakhand (Negi and Rajput, 2015), and Meghalaya (Sharma and Lyngskor 2003), and the kingdom of Bhutan (Sharma and Bhattarai 2005). The richness broadly concurs with the reports from Assam (Devi *et al.*, 2016), Himachal Pradesh (Jindal *et al.*, 2014a), Tripura (Bharati *et al.*, 2020), Meghalaya (Sharma and Lyngdoh, 2003) and Uttarakhand (Goswami *et al.*, 2018) but is lower than known from Himachal Pradesh (Jindal *et al.*, 2013, 2014b), Meghalaya (Sharma and Sharma, 2021) and Mizoram (Sharma and Pachuau, 2016). The comparisons highlight fairly species-rich phytoplankton assemblage of 'very soft and highly de-mineralized' waters' of the sampled reservoir in particular. Charophyta, the speciose group, records higher richness than known vide the earlier survey (Sharma, 1995), and the reports from the floodplain lakes of NEI (Sharma, 2009, 2010, 2012, 2015; Devi *et al.*, 2016) and the lakes of Kashmir (Baba and Pandit, 2014) and Uttarakhand (Negi and Rajput, 2015; Goswami *et al.*, 2018; Sharma and Singh, 2018; Sharma and Tiwari, 2018).

Table 1. Variations of abiotic factors

	Present study				**Nov.1990-Oct.91**	
	Littoral region		**Limnetic region**		**Limnetic region**	
Factors	**Range**	**Average ± S.D**	**Range**	**Average ± S.D**	**Range**	**Average ± S.D**
Water temperature °C	11.0-21.0	17.1 ±3.5	11.0-20.5	16.8 ±3.3	12.0-21.5	17.7 ±3.6
Rainfall mm	0.6-780.5	211.6 ±223.7	0.6-780.5	211.6 ±223.7	1.0-652.0	196 ±206
Transparency m	1.6-2.2	1.88 ±0.16	1.6-2.2	1.93 ±0.16	2.0-3.25	2.55 ±0.35
pH	5.65-6.67	6.21±0.22	5.64-6.55	6.16 ±0.26	5.5-6.6	6.1 ±0.4
Sp. conductivity μScm^{-1}	11.5-19.2	15.8 ±2.5	12.0-19.0	15.8 ±2.2	6.0-12.0	8.2 ±1.8
DO $mg\ L^{-1}$	7.0-8.6	7.8 ±0.4	7.2-8.8	7.9 ±0.4	6.7-10.2	8.3 ±0.8
Free CO_2 $mg\ L^{-1}$	4.8-9.2	7.2 ±1.5	4.0-9.0	6.7 ±1.4	4.0-9.3	6.5 ±1.3
Alkalinity $mg\ L^{-1}$	9.0-16.8	11.8 ±2.3	9.2-16.4	11.7 ±2.1	5.6-11.8	8.5 ±1.8
Hardness $mg\ L^{-1}$	6.2-13.2	8.6 ±2.2	6.0-13.0	8.7 ±2.2	4.0-12.2	7.5 ±4.3
Ca $mg\ L^{-1}$	3.8-7.6	5.3 ±1.2	3.6-7.0	5.0 ±1.3	1.6-9.5	4.7 ±2.5
Mg $mg\ L^{-1}$	0.2-0.9	0.2 ±0.3	0.2-0.8	0.4 ±0.2	0.2-1.1	0.6 ±0.5
Cl $mg\ L^{-1}$	19.0-42.0	30.4±6.7	18.0-40.0	29.4 ±6.4	4.0-8.8	5.5 ±1.2
PO_4 $mg\ L^{-1}$	0.072-0.190	0.128 ±0.035	0.080-0.190	0.128 ±0.031	0.100-0.280	0.150 ±0.050
SO_4 $mg\ L^{-1}$	1.642-2.905	2.253±0.447	1.640-2.810	2.202 ±0.423	1.000-3.500	2.200 ±0.700
NO_3 $mg\ L^{-1}$	0.066-0.196	0.108±0.040	0.070-0.188	0.110 ±0.036	0.010-0.040	0.023 ±0.010
DOM $mg\ L^{-1}$	0.4-3.0	1.3±0.9	0.5-3.0	1.5 ±0.9	-	

Table 2. ANOVA indicating significance of abiotic factors

Parameters	**Regions**	**Months**
Water temperature	-	$F_{11,23}$=244.629, P < 0.0001
Transparency	$F_{1,23}$ = 17.742, P = 0.001	$F_{11,23}$ = 9.069, P = 0.0003
pH	-	$F_{11,23}$ = 196.986, P < 0.0001
Specific conductivity	-	$F_{11,23}$ = 66.715, P < 0.0001
DO	$F_{1,23}$ = 10.632, P=0.007	$F_{11,23}$ = 30.779, P < 0.0001
Free CO_2	-	$F_{11,23}$ = 6.372, P = 0.0024
Alkalinity	-	$F_{11,23}$ = 129.223, P < 0.0001
Hardness	-	$F_{11,23}$ = 342.936, P < 0.0001
Ca	$F_{1,23}$ = 27.770, P=0.0002	$F_{11,23}$ = 78.814, P < 0.0001
Mg	-	$F_{11,23}$ = 17.551, P < 0.0001
Cl	$F_{1,23}$ = 15.531, P=0.002	$F_{11,23}$ = 220.202, P < 0.0001
PO_4	-	$F_{11,23}$ = 157.459, P < 0.0001
SO_4	$F_{1,23}$ = 8.302, P=0.015	$F_{11,23}$ = 219.202, P < 0.0001
NO_3	-	$F_{11,23}$ = 195.429, P < 0.0001
DOM	-	$F_{11,23}$ = 189.7048, P < 0.0001

(-) insignificant variations

The soft, calcium-poor and de-mineralized waters are known for high desmid richness (Woelkerling and Gough, 1976; Payne, 1986). This generalization is affirmed by the rich desmid diversity noted vide our study which include five species each of *Staurastrum* and *Cosmarium*, and one species each of *Arthrodesmus*, *Closterium, Euastrum*, *Micrasterias, Netrium* and *Sirogonium*. Our results concur with the richness importance of *Staurastrum* = *Cosmarium* observed from a reservoir of Meghalaya (Sharma and Sharma, 2021). This trend, however, differs from the importance of *Staurastrum* (Sharma, 1995), and high richness of *Closterium* > *Cosmarium* > *Staurastrum* > *Micrasterias* > *Gonatozygon* (Sharma, 2009), *Closterium* > *Cosmarium* > *Micrasterias* > *Gonatozygon* (Sharma, 2010), *Staurastrum* > *Cosmarium* > *Micrasterias* (Sharma and Pachuau, 2016), and *Cosmarium* > *Staurastrum* > *Euastrum* (Sharma and Hatimuria, 2017) known from various aquatic environs of NEI.

Our study records higher phytoplankton monthly richness at the littoral than the limnetic region (Table 3). The differential variation, hypothesized to greater habitat heterogeneity of the former region, is affirmed by significant richness variations (Table 4) between the regions (vide ANOVA). Phytoplankton contribute to net plankton richness at the two regions (r_1= 0.746, p = 0.013; r_2= 0.735, p = 0.015). Peak richness is recorded during winter (January) and maxima during autumn-winter (November-December) at the littoral region, and the limnetic region indicates peak in May (Figure 2). The winter peak at the former region concurs with the reports Manipur (Sharma, 2010), Meghalaya (Sharma and Sharma, 2021) and Assam (Devi *et al*., 2016), while the peak richness at the limnetic region corresponds with the summer peaks vides Sharma (2004, 2012, 2015). A notable constellation of 30 phytoplankton species during January collection from the littoral region depicts the possibility of co-existence of a number of species in this small and relatively shallow reservoir due to high amount of niche overlap as hypothesized by MacArthur (1965). Charophyta (Table 3) contribute to phytoplankton richness (r_1= 0.688, p = 0.028; r_2=0.910, p= 0.0003) at the two regions. Phytoplankton register 66.7-92.0% and 54.0-91.7% community similarities at the littoral and limnetic regions (Table 3), respectively and thus indicate the relatively more heterogeneity at the latter region. This generalization is endorsed by the similarity values ranging between 71-90% in ~89% instances at the littoral region as against ~ 77% instances with similarities ranging between 61-80% at the limnetic region. The hierarchical cluster groupings (Figures 3-4) record peak affinity between February-November and April-May collections, while July > September > June communities record maximum species divergence at the littoral region. The limnetic phytoplankton, however, indicate peak affinity between April-May and maximum divergence during July.

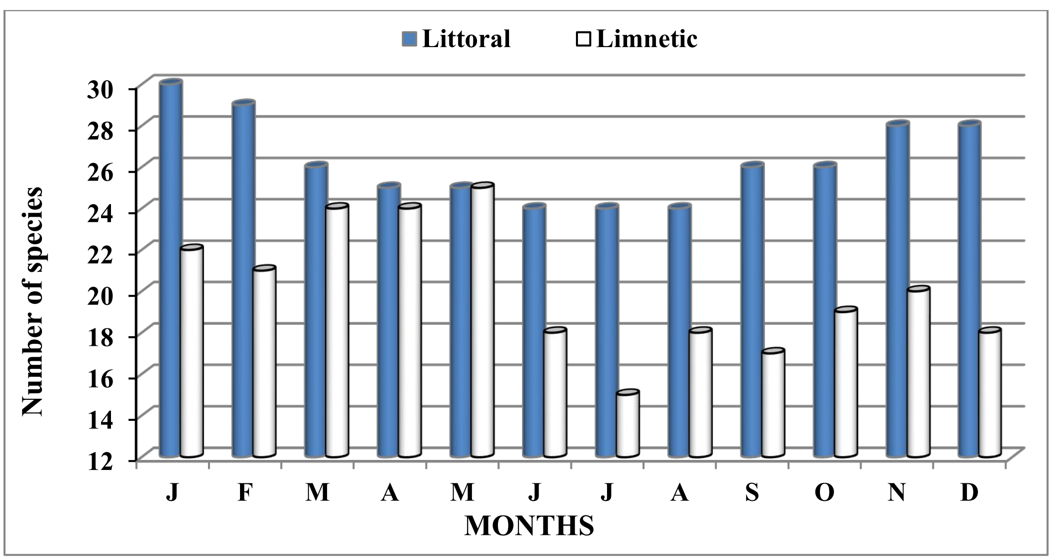


Figure 2. Monthly variations of phytoplankton richness

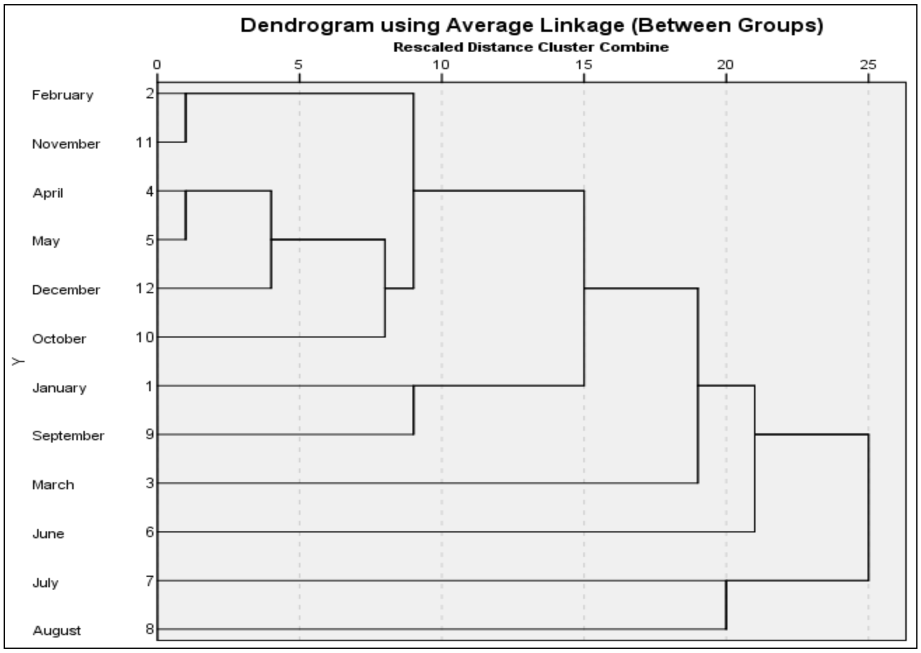


Figure 3. Hierarchical cluster analysis of phytoplankton assemblages (Littoral region)

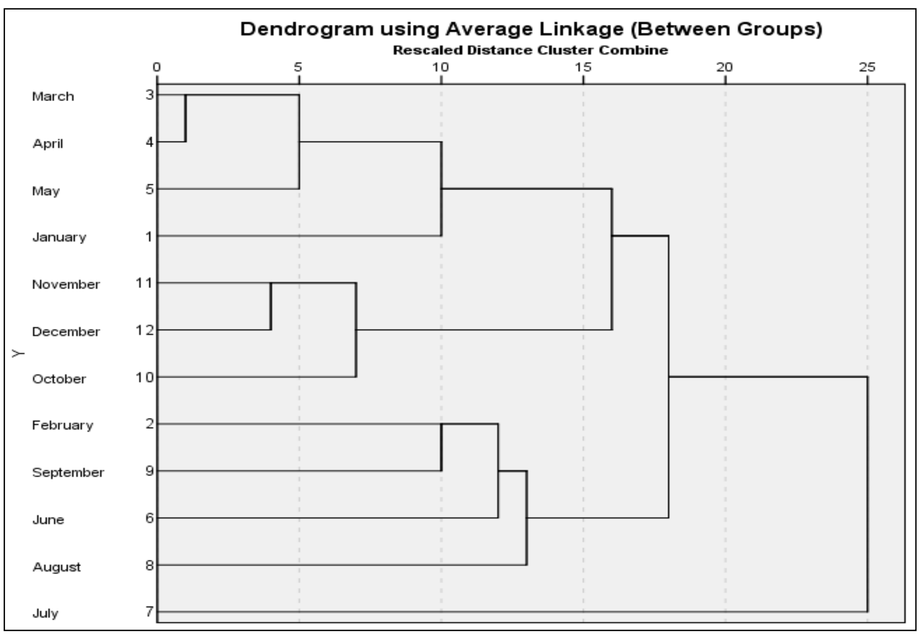


Figure 4. Hierarchical cluster analysis of phytoplankton assemblages (Limnetic region)

Table 3. Richness, abundance and diversity indices of phytoplankton assemblages

	Present study		Nov.1990-Oct.91
Qualitative	**Littoral region**	**Limnetic region**	**Limnetic region**
Net Plankton	72 species	67 species	28 species
Phytoplankton Monthly richness Community similarity %	36 species 24-30 26 ± 2 66.7-92.0	30 species 15-25 20 ± 3 54.0-91.7	16 species 3-14 8±3 -
Charophyta Monthly richness	19 species 11-15 14 ± 1	16 species 7-13 11 ± 2	9 species -
Quantitative			
Net plankton (ind. L^{-l})	189-1089 551 ±239	158-430 285±87	13-400 109±104
Phytoplankton (ind. L^{-l}) Percentage	95-887 429 ±230 44.8-90.0 73.7 ±14.4	74-364 216±93 46.8-86.9 73.0±12.4	7-318 98±100 53.9-95.8
Species Diversity	2.061-2.767 2.443 ±0.238	1.885-2.654 2.279±0.236	0.959-1.787 1.330±0.477
Dominance	0.156 - 0.408 0.285 ±0.099	0.187-0.464 0.278±0.093	0.265-0.883 0.542±0.212
Evenness	0.618 - 0.871 0.745 ±0.088	0.658 - 0.859 0.765±0.056	0.177-0.917 0.537±0.477
Charophyta (ind. L^{-l}) Percentage	30-636 174 ±191 11.8-71.7 37.4 ±16.6	49-219 100±50 46.8-86.9 47.1±11.4	2-275 51±79 2.4-85.1
Bacillariophyta (ind. L^{-l}) Percentage	29-312 140 ±50 11.7-58.1 35.6 ±14.8	8-66 34±20 6.4-23.6 15.0±5.3	1-8 2±2 -
Dinophyta (ind. L^{-l}) Percentage	11-299 105 ±90 10.1-39.7 24.7 ±11.6	12-130 72±34 13.3-52.3 32.8±12.8	4-102 42±39 8.5-96.0
Chrysophyta (ind. L^{-l})	0-38 8 ±2	0-47 9±13	2-8 1±2
Cryptophyta (ind. L^{-l})	0-3 2±0	0-3 2±1	-
Cyanobacteria (ind. L^{-l})	0-2 1±0	0-2 2±0	1-9 2±2
Euglenophyta (ind. L^{-l})	0-3 2±0	0-3 1±0	-
Important taxa (ind. L^{-1})			
Staurastrum spp.	14-570 135±150	31-204 73±45	0-90 20±28
Cosmarium spp.	4-38 19 ±12	2-54 15±17	-
Important species (ind. L^{-1})			
Peridinium cinctum	6-270 66±80	13-95 42±27	0-42 13±15
Staurastrum freemani	2-301 63±83	5-130 31±32	0-90 20±28
Staurastrum arctiscon	2-201 49±53	5-32 16±8	0-80 12±23
Navicula radiosa	6-242 61±68	2-51 21±15	-
Ceratium hirudinella	5-91 38±25	2-100 30±26	2-120 29±38
Tabellaria flocculosa	5-60 24±18	2-18 9±5	-
Staurastrum gutwinckii	2-41 17±11	8-43 24±11	0-100 16±30
Cosmarium decoratum	0-21 10±7	0-11 4±4	-
Pinnularia viridis	0-46 12±16	0-1 1±1	-
Frustulia rhomboides	2-27 11±7	0-7 2±2	-
Caloneis bacillum	0-40 10±12	0-1 1±1	-

Table 4. ANOVA indicating significance of phytoplankton assemblages

Parameters	Regions	Months
Phytoplankton richness	$F_{1,23}$ = 40.590, P < 0.0001	-
Charophyta richness	$F_{1,23}$ = 24.267, P = 0.0004	-
Phytoplankton abundance	$F_{1,23}$ = 19.260, P = 0.001	$F_{11,23}$ = 3.811, P = 0.018
Charophyta abundance	-	-
Bacillariophyta abundance	$F_{1,23}$ = 30.107, P = 0.0003	-
Dinophyta abundance	-	$F_{11,23}$ = 5.731, P = 0.0367
Chrysophyta abundance	-	$F_{11,23}$ = 5.099, P < 0.0001
Species diversity	$F_{1,23}$ = 4.163, P= 0.066	$F_{11,23}$ = 9.024, P = 0.0005
Abundance of Important taxa and species		
Staurastrum spp.	-	$F_{11,23}$ = 2.934, P = 0.043
Cosmarium spp.	-	-
Ceratium hirudinella	-	$F_{11,23}$ = 11.092, P = 0.0002
Cosmarium decoratum	$F_{1,23}$ = 10.329, P= 0.008	-
Navicula radiosa	$F_{1,23}$ = 5.638, P= 0.036	-
Peridinium cinctum	-	$F_{11,23}$ = 3.019, P = 0.040
Staurastrum freemani	-	$F_{11,23}$ = 4.422, P = 0.010
Staurastrum arctiscon	$F_{1,23}$ = 5.085, P= 0.045	-
Staurastrum gutwinckii	$F_{1,23}$ = 7.727, P= 0.018	$F_{11,23}$ = 6.563, P = 0.002
Tabellaria flocculosa	$F_{1,23}$ = 10.277, P= 0.008	-
Caloneis bacillum	$F_{1,23}$ = 7.176, P= 0.021	-
Frustulia rhomboides	$F_{1,23}$ = 20.502, P= 0.001	-
Pinnularia viridis	$F_{1,23}$ = 6.538, P= 0.027	-

(-) insignificant variations

Phytoplankton comprise dominant quantitative component and significantly influence net plankton abundance (r_1= 0.978, p < 0.0001; r_2= 0.982, p < 0.0001) at the littoral and limnetic regions (Table 3), and register significant density variations (Table 4) between the two regions (vide ANOVA). Phytoplankton dominance concurs with the reports from Assam (Sharma and Hatimuria, 2017), Himachal Pradesh (Jindal and Thakur, 2014), Meghalaya (Sharma, 1995; Sharma and Lyngdoh, 2003) and Mizoram (Sharma and Pachuau, 2016). The wider density variations and higher abundance (Table 3) at the littoral than the limnetic region are hypothesized to greater habitat heterogeneity of the former region. Our results depict three- and two-fold higher abundance at the two regions, respectively than the earlier survey (Sharma, 1995). This study records bimodal monthly phytoplankton density variations at the two regions (Figures 5-6) concurrent with the reports of Baba and Pandit (2014), Goswami *et al*. (2018) and (Sharma and Sharma, 2021). The peak abundance noted during October and winter maxima at the two regions deviate from the mid-monsoon peak (Sharma and Bhattarai, 2005) and from the autumn peaks reported from Kashmir (Baba and Pandit, 2014), Meghalaya (Sharma and Sharma, 2020), Mizoram (Sharma and Pachuau, 2016) and Uttarakhand (Sharma and Singh, 2018). The winter maxima concur with the results of Wanganeo and Wanganeo (1991), Sharma (1995, 2004, 2009, 2010), Sharma and Lyngdoh (2003), Sharma and Hatimuria (2017), Goswami *et al*. (2018), Sharma and Tiwari (2018) and Sharma and Sharma (2021). Phytoplankton indicate the differential spatial quantitative importance of Charophyta > Bacillariophyta > Dinophyta and Charophyta > Dinophyta at the littoral and limnetic, respectively (Table 3). Charophyta result in late-monsoon phytoplankton peak, Bacillariophyta > Charophyta contribute to winter maxima and Charophyta > Dinophyta result in high abundance during November-December at the littoral region (Figure 5). Charophyta > Dinophyta influence late-monsoon peak and Charophyta influence winter maxima at the limnetic region (Figure 6).

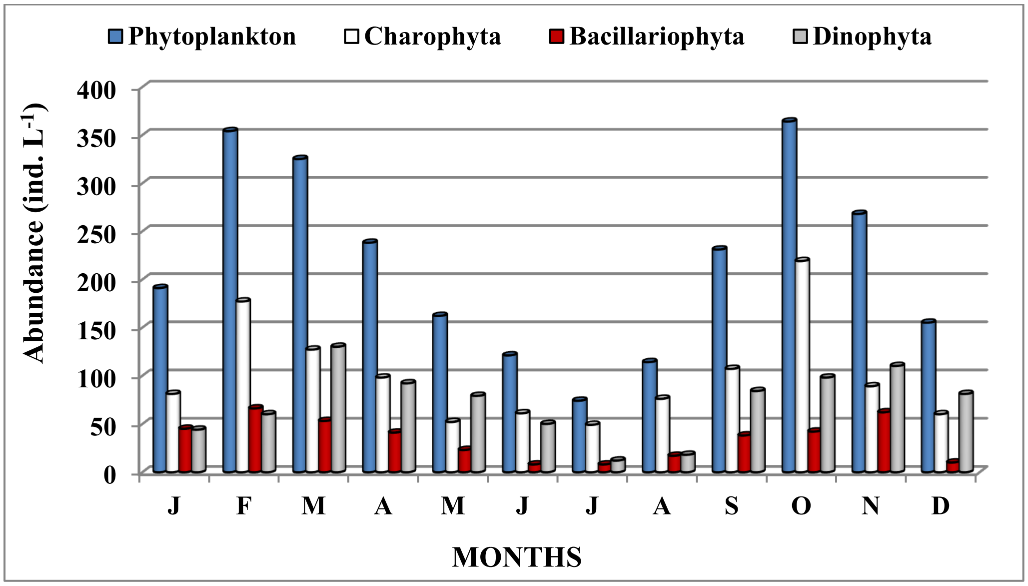


Figure 5. Monthly variations of abundance of phytoplankton and important groups (Littoral region)

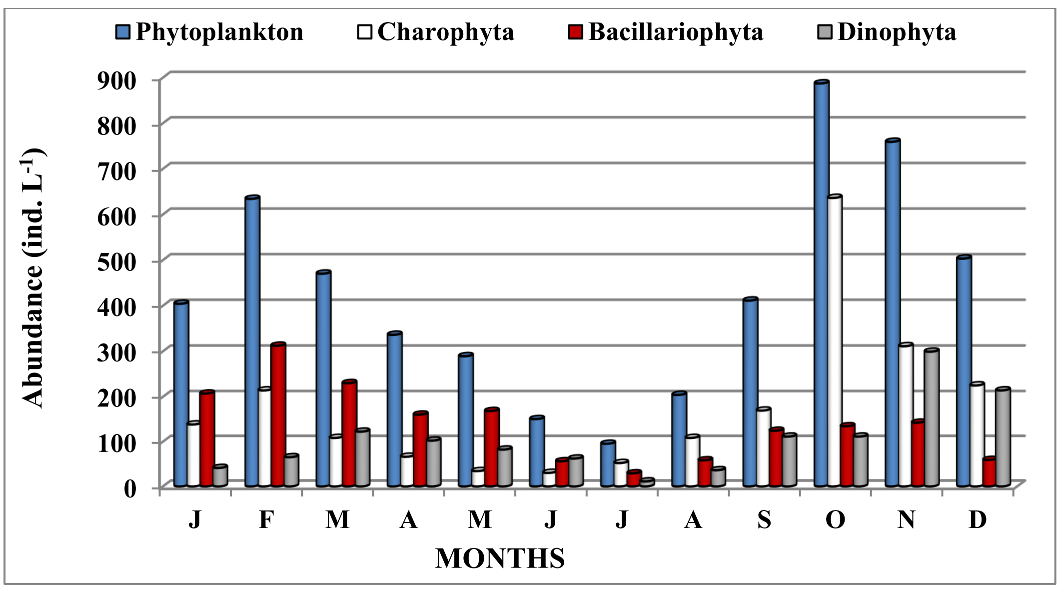


Figure 6. Monthly variations of abundance of phytoplankton and important groups (Limnetic region)

Peridinium cinctum > *Staurastrum freemani* > *S. arctiscon* > *Navicula radiosa* > *Ceratium hirudinella* > *Tabellaria flocculosa* > *S. gutwinckii* > *Cosmarium contractum* > *Pinnularia viridis* > *Frustulia rhomboides* > *Caloneis bacillum* indicate the stated order of the quantitative importance at the littoral region (Table 3). *Peridinium cinctum* > *Staurastrum freemani* > *Ceratium hirudinella* > *S. gutwinckii* > *Navicula radiosa* > *S. arctiscon* are notable at the limnetic region (Table 3). Our results categorize the 'specialists' nature of 11 and six species at the two regions, respectively and the 'generalist' nature of the rest of species with lower densities. Following MacArthur (1965) explanation, it is hypothesized that Shillong reservoir has resources for utilization both by the 'specialist' and 'generalist' species. The 'specialist' species collectively (84.0±8.1, 79.8±9.3%) influence phytoplankton abundance (r_1= 0.994, p < 0.0001; r_2= 0.941, p < 0.0001) at the two regions, respectively. Of these, *Staurastrum arctiscon* (r_1= 0.875, p= 0.0009), *S. freemanni* (r_1= 0.829, p= 0.003) and *Cosmarium decoratum* (r_1= 0.846, p= 0.002) individually influence phytoplankton abundance at the littoral region, while

Navicula radiosa (r_2= 0.840, p = 0.001), *Staurastrum arctiscon* (r_2= 0.955, p<0.0001) and *Tabellaria flocculosa* (r_2= 0.716, p= 0.020) exert influence at the limnetic region. *Staurastrum freemani* > *S. arctiscon* are main contributors to late-monsoon phytoplankton peak at the littoral region while the dominant *N. radiosa* contributes to winter maxima. The differential spatial importance of the 'specialist' species noted vide the present study concurs with the report of Sharma and Sharma (2021).

Charophyta (Table 3) contributes to the littoral and limnetic phytoplankton abundance (r_1 = 0.763, p = 0.010; r_2 = 0.892, p = 0.0005) and follows the bimodal monthly variations (Figures 5-6) identical with that of phytoplankton. The bimodal periodicity of the green algae differs from unimodal patterns reported by Baba and Pandit (2014) and Ganai and Parveen (2014). Charophyta indicates three- and two-fold higher abundance at the two regions (Table 3), respectively higher than the earlier survey (Sharma, 1995) and also records higher abundance than known from the reservoirs of Meghalaya (Sharma and Lyngskor, 2003; Sharma and Lyngdoh 2003) and Mizoram (Sharma and Pachuau, 2016) and the floodplain lakes (Sharma, 2004, 2009, 2010, 2012, 2015; Sharma and Hatimuria, 2017) of NEI. *Staurastrum freemani* > *S. arctiscon* influence late-monsoon Charophyta peak, while *Staurastrum arctiscon* > S. *freemani* contribute to the winter maxima at the littoral region. *Staurastrum freemani* > *S. gutwinckii* > *S. arctiscon* and *S. freemani* = *S. gutwinckii* > *S. arctiscon* > *Cosmarium contractum* result in late-monsoon peak and winter maxima, respectively at the limnetic region. ANOVA records (Table 4) significant variations of *C. contractum* and *S. arctiscon* abundance between the regions, *S. freemani* records significant density variations between the regions and months, and *S. gutwinckii* records significant monthly quantitative variations.

Staurastrum spp. (Table 3) contribute to Charophyta (r_1= 0.715, p = 0.020; r_2= 0. 918, p = 0.0002) and phytoplankton (r_1= 0.837, p = 0.002; r_2= 0.722, p = 0.018) abundance and influence their pre-monsoon peaks and winter maxima at the two regions, respectively. *Cosmarium* spp. contribute to Charophyta (r_1= 0.737, p = 0.015) and phytoplankton (r_1= 0.890, p = 0.001) abundance at the littoral region (Table 3). The importance of *Staurastrum* spp. > *Cosmarium* spp. concurs with the report of Sharma and Sharma (2021) but it differs from the quantitative significance of *Staurastrum* spp. (Sharma, 1995), *Staurastrum* spp. > *Xanthidium* spp. > *Cosmarium* spp. (Sharma and Pachuau, 2016), *Closterium* spp. > *Staurastrum* spp. > *Gonatozygon* spp. > *Micrasterias* spp. > *Cosmarium* spp. (Sharma, 2009); *Closterium* spp.> *Gonatozygon* spp.> *Micrasterias* spp. > *Staurastrum* spp. from Utra Pat (Sharma, 2010), and *Closterium* spp. > *Cosmarium* spp. > *Staurastrum* spp. > *Xanthidium* spp. from Waithou Pat (Sharma, 2010) known vide the different reports from NEI. *Staurastrum arctiscon* (r_1= 0.979, p <0.0001) and *S. freemani* (r_1= 0.996, p < 0.0001), and *S. arctiscon* (r_2= 0.735, p = 0.015), *S. freemani* (r_2= 0.968, p < 0.0001) and *S. gutwinckii* (r_2= 0.725, p = 0.018) influence *Staurastrum* spp. abundance at the two regions, respectively. *Cosmarium decoratum* (r_1= 0.846, p = 0.002) influences *Cosmarium* spp. abundance at the littoral region.

Bacillariophyta (Table 3) comprises an important quantitative component of phytoplankton at the littoral region but records sub-dominance at the limnetic region. The differential spatial importance is affirmed by significant density variations (Table 4) of the diatoms between the two regions (vide ANOVA). Our results mark a distinct contrast to very poor diatom abundance reported vide the earlier limnetic survey (Sharma, 1995). Bacillariophyta importance at the littoral region concurs with the reports from Assam (Sharma, 2015; Sharma & Hatimuria, 2017), Himachal Pradesh (Jindal *et al*., 2014b), Kashmir (Baba and Pandit, 2014) and Uttarakhand (Goswami *et al*., 2018). The diatom sub-dominance at the limnetic region, however, corresponds with the reports from Manipur (Sharma, 2009) and Uttarakhand (Sharma and Singh, 2018). The diatoms record peak abundance during winter (February) and maxima during autumn (November) at the two regions (Figures 5-6). The winter peaks concur with the reports from Kashmir (Wanganeo and Wanganeo, 1991; Baba and Pandit, 2014), Meghalaya (Sharma and Lyngdoh, 2003) and Manipur (Sharma, 2009) and autumn maxima agree with the report from Meghalaya (Sharma and Sharma, 2021). *Navicula radiosa* contributes to Bacillariophyta (r_1= 0.699, p = 0.024; r_2= 0.980, p < 0.0001) abundance and influences winter peaks and *N. radiosa* > *Tabellaria flocculosa* influence autumn maxima at the two regions. ANOVA (Table 4) registers significant density variations of *N. radiosa*, *T. flocculosa, Caloneis bacillum*, *Frustulia rhomboides* and *Pinnularia viridis* between the two regions.

Dinophyta (Table 3) contributes significantly to phytoplankton abundance at the limnetic region (r_2= 0.709, p = 0.022) and registers (Table 4) significant monthly density variations (vide ANOVA). Our results record distinctly higher Dinophyta abundance than the earlier survey (Sharma, 1995), while it differs from poor abundance reported by Sharma and Lyngdoh (2003), Sharma and Lyngskor (2003), Sharma (2010), Sharma and Pachuau (2016) and Sharma and Hatimuria (2017) from NEI. Dinophyta abundance depicts the differential spatial patterns (Figures 5-6) with peak in autumn (November) and maxima in spring (March) at the littoral region, and it records peak in spring and maxima in autumn at the limnetic region. Peaks and maxima differ from winter peaks (Sharma, 2009) and summer maxima (Sharma and Singh, 2018). Our study records importance of *Peridinium cinctum* > *Ceratium hirudinella*; the former contributes to autumn peak and autumn maxima at the two regions, respectively; *P. cinctum* influences Dinophyta abundance (r_2= 0.667, p=0.035) at the limnetic region, while *C. hirudinella* results in spring peak and autumn maxima at the two regions. ANOVA registers significant monthly density variations of the two species (Table 4).

Chrysophyta, represented by *Dinobryon sociale,* depicts limited quantitative importance (Table 3) with winter peaks at the two regions. This pattern differs from poor Chrysophyta abundance known from the floodplain lakes (Sharma, 2009, 2010, 2012, 2015) and reservoirs (Sharma, 1995; Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) of NEI. Amongst other phytoplankton groups, Cyanobacteria, Cryptophyta and Euglenophyta depict very poor abundance (Table 3). The present report differs from Cyanobacteria sub-dominance reported by Baba and Pandit (2014), Sharma (2015), Sharma and Pachuau (2016), Sharma and Hatimuria (2017) from the different parts of north India, while insignificance of Cryptophyta and Euglenophyta concurs with the results of Sharma (2009), Sharma, and Pachuau (2016).

Phytoplankton record moderate species diversity (Table 3) with oscillating monthly variations at the two regions (Figure 7); ANOVA affirms its significant variations between the regions and months (Table 4). This study records $H' > 2.5$ during five (March-July) and three (January, February and April) months at two stations, respectively. The relatively higher diversity at the littoral than the limnetic region is attributed both to higher richness and abundance at the former region. The notable diversity variations recorded in the present study vis-a-vis the earlier survey (Sharma, 1995) are attributed to distinct increase in the richness and abundance of phytoplankton during the present survey. The inverse influence of phytoplankton abundance on species diversity (r_1= -0.723, p = 0.018) at the littoral region is supported by concurrence of peak diversity during July (monsoon) with lowest abundance. The diversity is positively influenced by phytoplankton richness (r_2= 0.760, p = 0.011) and *Cosmarium* spp. (r_2= 0.757, p = 0.011) abundance at the limnetic region; it is inversely influenced by abundance of *Staurastrum* spp. (r_1= -0.738, p = 0.015), *S. arctiscon* (r_1= -0.708, p = 0.022) and *S. freemani* (r_1= -0.736, p = 0.015) at the littoral region. An inverse influence of species diversity vs. dominance (r_1= -0.787, p = 0.007; r_2= -0.755, p = 0.012) is affirmed by concurrence of the lower diversity with higher dominance at both regions. Further, the diversity is positively influenced by evenness (r_1= 0.986, p < 0.0001; r_2= 0.891, p = 0.0005) at the two regions.

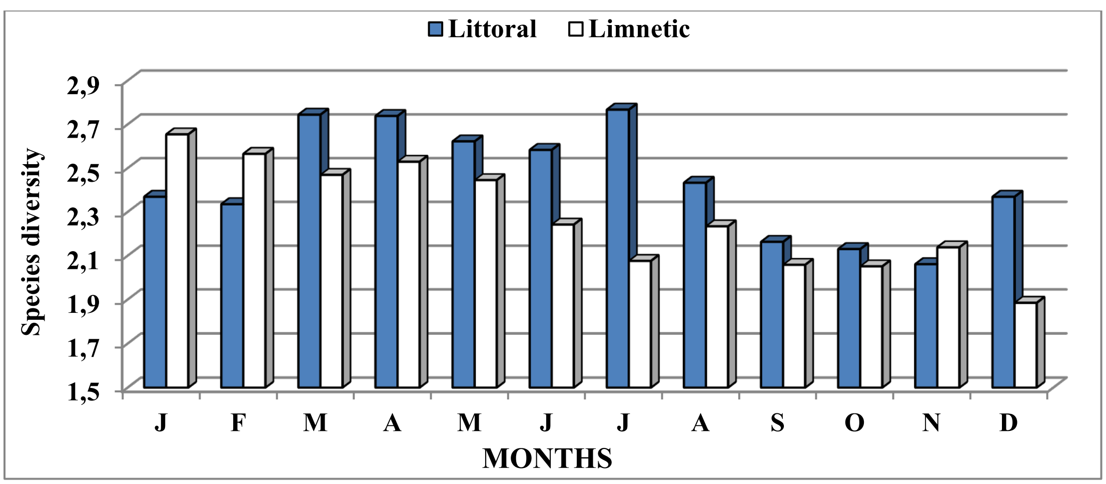


Figure 7. Monthly variations of phytoplankton species diversity

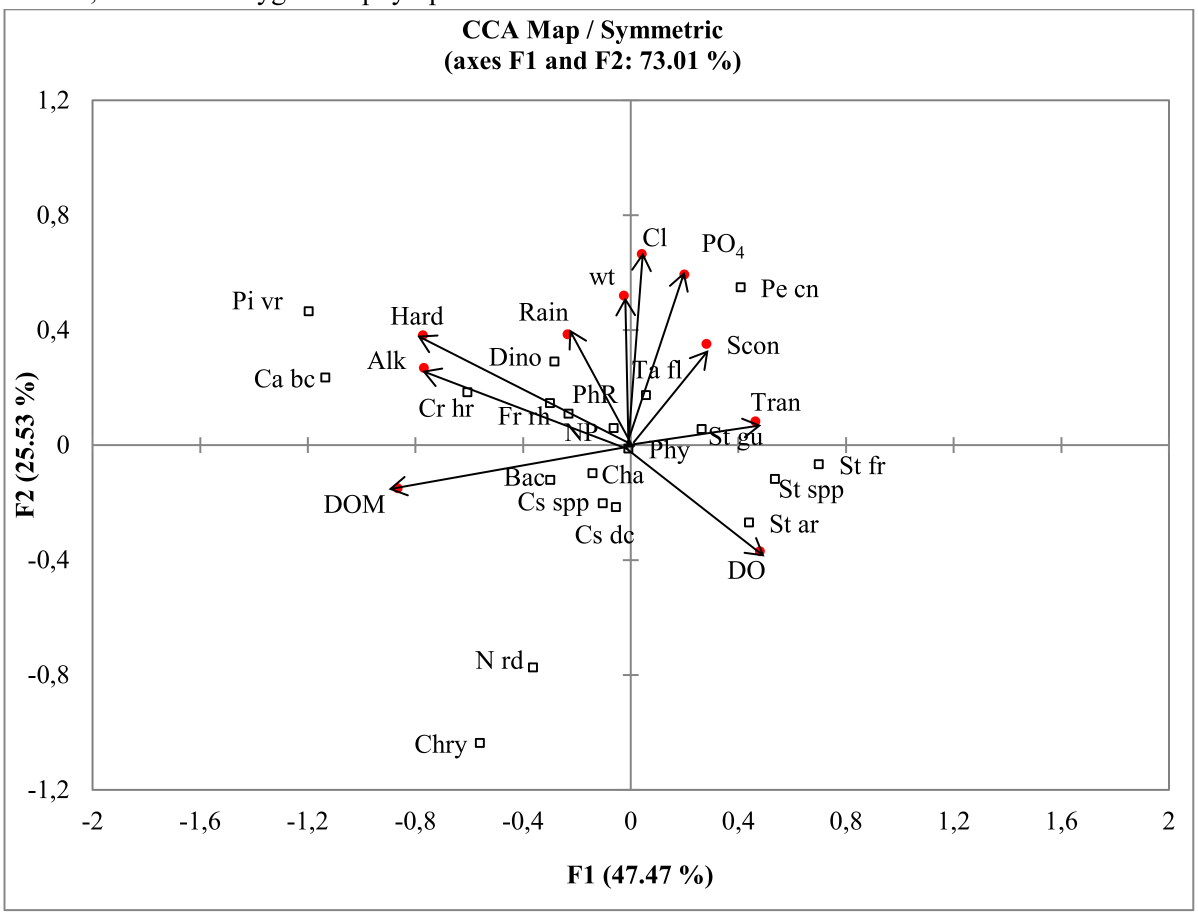
Phytoplankton dominance depicts the spatial differences at the two regions (Table 3); peak dominance and maxima at the littoral region are noted during autumn (November) and winter (February), respectively, while it records winter peak (December) and winter maxima (January) at the limnetic region. The 'specialist' species result in higher dominance during certain months, while low dominance during certain other months is concurrent with equitable abundance of the 'generalist' species. The dominance is positively correlated with abundance of *Cosmarium* spp. (r_1= 0.763, p = 0.020) and *C. decoratum* (r_1= 0.784, p = 0.020) at the littoral region. The extant of dominance variations broadly correspond with the reports of Sharma and Pachuau (2016), Sharma and Hatimuria (2017) but differs from low dominance reported from the reservoirs of Meghalaya (Sharma and Lyngdoh, 2003; Sharma and Lyngskor, 2003) and the floodplains of NEI (Sharma, 2004, 2009, 2010, 2012, 2015). Our results depict the spatial differences of phytoplankton evenness at the two regions (Table 3); high evenness noticed during several months is attributed to equitable abundance of majority of taxa while dominance of certain species results in moderate evenness. These remarks are affirmed by an inverse correlation of evenness vs. dominance (r_1= -0.846, p= 0.002; r_2= -0.694, p = 0.026) at the two regions. Further, evenness is inversely influenced by *Staurastrum* spp. (r_1= -0.732, p= 0.016), *S. arctiscon* (r_1= -0.726, p= 0.017) and *S. freemani* (r_1= -0.723, p= 0.018) and *Cosmarium decoratum* (r_1= -0.651, p= 0.041) at the littoral region, and *Peridinium cinctum* (r_1= -0.788, p= 0.007) at the limnetic region.

The present study registers the differential spatial influence of individual abiotic factors on phytoplankton assemblages. Inverse influence of water temperature (r_1=-0.941, p<0.0001), rainfall (r_1= -0.774, p= 0.0086) on phytoplankton richness at the littoral region is affirmed by lower richness during warmer months and rainy season and coincides with relatively high pH (r_1= -0.768, p= 0.0095), Cl (r_1= -0.875, p= 0.0009) and PO_4 (r_1= -0.797, p= 0.0058). The richness concurs with the periods of high alkalinity (r_2= 0.732, p= 0.0161), hardness (r_2= 0.713, p= 0.0206), Ca (r_2= 0.789, p= 0.0067) and DOM (r_2= 0.805, p= 0.0050) at the limnetic region. Higher phytoplankton abundance observed during January-March and again during October to December concurs with the relatively high transparency (r_1= 0.696, p = 0.0026) and photosynthetic activity of the primary producers resulting in high DO (r_1= 0.696, p= 0.0254), while lower abundance during monsoon season affirms inverse influence of rainfall (r_1=-0.695, p=0.0257) at the littoral region. The periods of high phytoplankton abundance result in increased DO (r_2= 0.759, p= 0.0109) at the limnetic region. This conclusion also holds valid for the positive correlations of Charophyta (r_1= 0.808, p= 0.0047; (r_2= 0.818, p= 0.0038) and *Staurastrum* spp. (r_1= 0.718, p= 0.0194; r_2= 0.825, p= 0.0033) abundance with DO at the two regions, and with Bacillariophyta (r_2= 0.856, p= 0.0047) at the limnetic region. High Dinophyta abundance concurs with high specific conductivity (r_1= 0.803, p = 0.0052) at the littoral region. Bacillariophyta abundance concurs with months of high Cl contents (r_2= 0.856, p= 0.0047) at the two regions; Chrysophyta abundance corresponds with high specific conductivity (r_2= 0.727, p= 0.0172) and Dinophyta indicate low abundance during periods of high DOM (r_2= -0.679, p= 0.0251) at the limnetic region. Overall importance of the individual abiotic factors is concurrent with the reports of Sharma and Sharma (2021) but deviates from the importance of only a few factors (Sharma and Lyngskor, 2003; Sharma and Lyngdoh, 2003; Sharma, 2010) and much limited role of the individual factors reported vide the various works from NEI (Sharma, 1995, 2012, 2015; Sharma and Pachuau, 2016).

Referring to important species, lower alkalinity (r_1= -0.723, p= 0.0181), hardness (r_1= -0.730, p= 0.0165), Ca (r_1= -0.812, p= 0.0043) and DOM (r_1= -0.821, p= 0.0036) favor *Staurastrum gutwinckii* abundance at the littoral region, while this desmid is inversely influenced only by Ca (r_2= -0.718, p = 0.0194) at the limnetic region. *Cosmarium decoratum* indicates lower densities concurrent with the periods of high temperature (r_1= -0.792, p= 0.0063), rainfall (r_1= -0.813, p= 0.0042), pH (r_1= -0.747, p= 0.0130) and Cl (r_1= -0.819, p= 0.0038) at the littoral region. *Navicula radiosa* is inversely influenced by water temperature (r_1= -0.718, p= 0.0194) and Cl (r_1= -0.725, p= 0.0177); *Tabellaria flocculosa* is positively influenced by DO (r_1= 0.694, p = 0.0181) and NO3 (r_1= 0.880, p = 0.0008); and *Ceratium hirudinella* is positively influenced by alkalinity (r_2= 0.771, p = 0.0090), hardness (r_2= 0.705, p = 0.0228), Ca (r_2= 0.719, p = 0.0191) and DOM (r_2= 0.817, p = 0.0040) at the limnetic region. *Peridinium cinctum* is positively influenced by NO3 (r_2= 0.684, p = 0.0292) and *Staurastrum arctiscon* is positively influenced by DO (r_2= 0.794, p = 0.0061) at the limnetic region. Our results thus endorse the differential spatial influence of the individual abiotic factors on notable phytoplankton species broadly concurrent with the report of Sharma and Sharma (2021). This generalization, however, marks departure from the results of

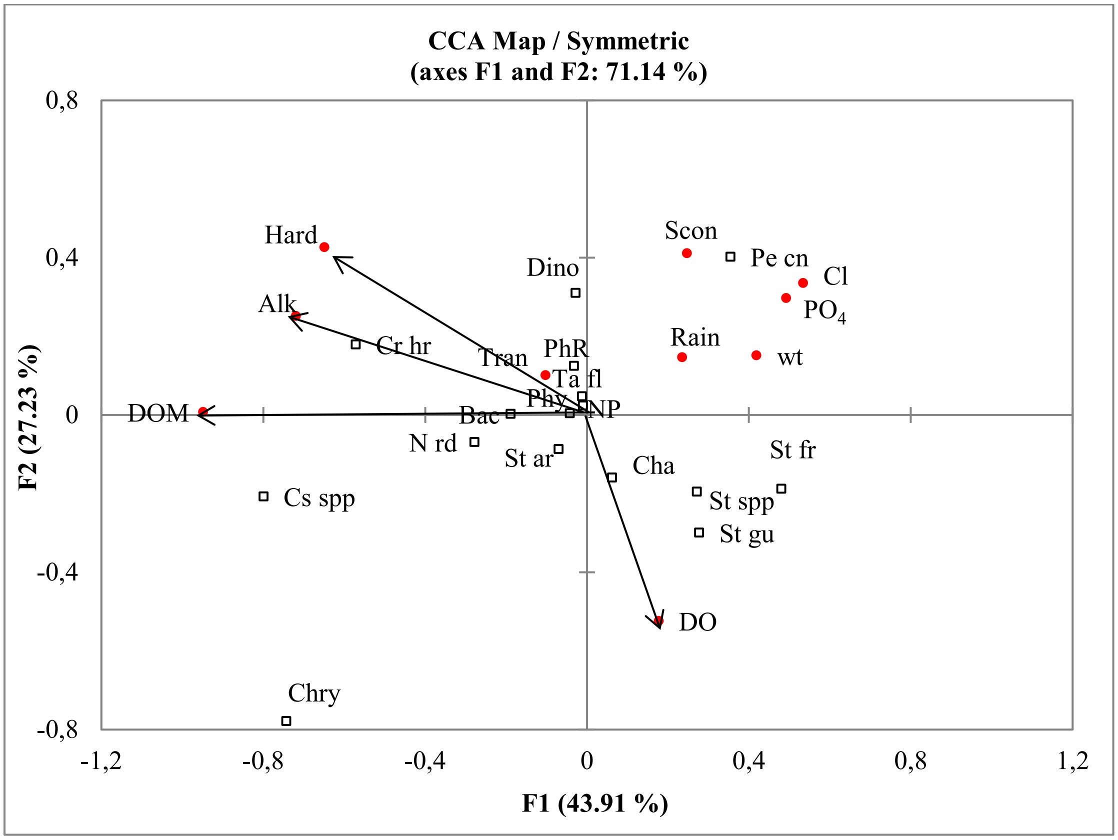
Sharma (1995, 2009. 2010, 2012, 2015), Sharma and Lyngdoh (2003) Sharma and Pachuau (2016) and Sharma and Hatimuria (2017) yielding little insight on influence of individual abiotic factors on important species.

The CCA registers high and broadly identical cumulative influence (73.01 and 71.14%) of 10 abiotic factors, along 1 and 2 axes, on the littoral and limnetic phytoplankton assemblages, respectively (Figures 8-9). The CCA co-ordination biplot indicates influence of alkalinity and hardness on abundance of *Ceratium hirudinella* and *Frustulia rhomboides*; rainfall on richness of phytoplankton and limited influence on Dinophyta abundance; PO_4 on *Tabellaria flocculosa* density; specific conductivity and transparency on *Staurastrum gutwinckii*; dissolved oxygen on phytoplankton abundance and limited influence on *Staurastrum* spp., *S. arctiscon* and *S. freemani*; and DOM on Charophyta and Bacillariophyta, and limited influence on *Cosmarium* spp. and *C. decoratum* at the littoral region (Figure 8). The CCA biplot registers influence of alkalinity and hardness on *Ceratium hirudinella*; alkalinity and DOM phytoplankton and Bacillariophyta abundance; DO on Charophyta abundance and limited influence on *Staurastrum* spp., *S. arctiscon* and *S. freemani* at the limnetic region (Figure 9). Higher overall cumulative influence of abiotic factors reported vide this study is concurrent with the reports from Khawiva reservoir of Mizoram (Sharma and Pachuau, 2016); Bhereki and Holmari beels (Sharma and Hatimuria, 2017) of the Majuli floodplains, and Deepor beel (Sharma, 2015) of Assam.



Abbreviations: Abiotic factors: Alk (alkalinity), Cl (chloride), Cond (specific conductivity), DO (dissolved oxygen), DOM (dissolved organic matter, hard (hardness), rain (rainfall), Trans (transparaency), PO_4 (phosphate), wt (water temperature):. **Biotic factors**: Bac (Bacillariophyta abundance), Ca sp. (*Caloneis bacillum*), Cha (Charophyta abundance), Chry (Chrysophyta abundance), Cs spp (*Cosmarium* species abundance), Cr hr (*Ceratium hirudinella* abundance), Cs dc. (*Cosmarium decoratum* abundance), Dino (Dinophyta abundance), Fr rh (*Frustulia rhomboides*), NP (net plankton abundance), N rd (*Navicula radiosa* abundance), Pe cn (*Peridinium cinctum* abundance), Pi vr (*Pinnularia viridis* abundance) PhR (phytoplankton richness), Phy (phytoplankton abundance), St spp (*Staurastrum* species.), St ar (*Staurastrum arctiscon*), St fr (*Staurastrum formosum* abundance), St gu (*Staurastrum gutwinckii* abundance). Tb fl (*Tabellaria flocculosa* abundance)

Figure 8. CCA coordination biplot of phytoplankton assemblages and abiotic factors (Littoral region)



Abbreviations: Abiotic factors: Alk (alkalinity), Cl (chloride), Cond (specific conductivity), DO (dissolved oxygen), DOM (dissolved organic matter), hard (hardness), rain (rainfall), Trans (transparaency), PO_4 (phosphate), wt (water temperature):. **Biotic factors**: Bac (Bacillariophyta abundance), Cha (Charophyta abundance), Chry (Chrysophyta abundance), Cs spp (*Cosmarium* species abundance), Cr hr (*Ceratium hirudinella* abundance), Dino (Dinophyta abundance), NP (net plankton abundance), N rd (*Navicula radiosa* abundance), Pe cn (*Peridinium cinctum* abundance), PhR (phytoplankton richness), Phy (phytoplankton abundance), St spp (*Staurastrum* species.), St ar (*Staurastrum arctiscon*), St fr (*Staurastrum formosum* abundance), St gu (*Staurastrum gutwinckii* abundance). Tb fl (*Tabellaria flocculosa* abundance)

Figure 9. CCA coordination biplot of phytoplankton assemblages and abiotic factors (Limnetic region)

Conclusion

The fairly diverse phytoplankton, rich Charophyta with diverse desmids, and peak constellation per sample of 30 species are notable features of very soft, acidic, highly calcium poor and one of the most de-mineralized waters of this small subtropical reservoir in particular. Phytoplankton dominance vs. net plankton abundance, the spatial differences of dominance of important groups, the reports 11 and 6 'specialist' species and *Staurastrum* spp. > *Cosmarium* spp. importance at the littoral and the limnetic regions are noteworthy. The differential spatio-temporal variations of species composition, richness, abundance, diversity, dominance, evenness and influence of the individual abiotic factors are hypothesised to habitat heterogeneity amongst the sampled regions. The CCA registers high cumulative influence of 10 abiotic factors on phytoplankton assemblages. Our results highlight distinct temporal differences of phytoplankton richness, abundance and species diversity vis-a-vis the limited survey of November 1990–October 1991. This study is an important contribution to the reservoir limnology and phytoplankton diversity of India and the subtropical reservoirs of NEI in particular.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: -

Funding disclosure: A part of research work of Department of Zoology, NEHU, Shillong

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Disclosure: -

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Research Article

Female fish farmers: How technically efficient are they? Evidence from Delta State Nigeria

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ABSTRACT

The study investigated the technical efficiency of female catfish growers in Delta State, Nigeria. Data have been obtained using questionnaires from 112 female catfish farmers who have been randomly selected. Descriptive statistics, cost and return analysis as well as the stochastic model have been used in the analysis of data. The results showed that the mean age, farming experience and household size of the female fish farmers were 42 years old, 8 years and 6 persons respectively. Most of the participants are married and educated. The gross margin and net farm income were N490,378.46 and N416,242.82k respectively. With a rate of return on investment and a BCR (Benefit Cost Ratio) of 0.64 and 1.64, fish farming was found to be profitable. The Stochastic frontier outcome showed that the size of the pond, fingerlings, feed and water supply had a significant and positive effect on fish production, while the cost of medication had an inverse relationship with fish production. Age, education and household size have been found to increase technical performance, while technical inefficiency is increased by distance from farm location and credit access. The finding further revealed that a female fish farmer had a technical efficiency of 53.5% in the area of study. This is a signal that by implementing the technologies practiced by the best farmers, fish productivity can be improved by about 46.5% by the farmers. The coefficient of elasticity was 0.567, which indicated that the female catfish farmers were in Phase II. The failure of farmers to reach the production frontier may however be due to certain factors, including insufficient funding, high feed costs, water supply and fingerlings shortages. On the basis of the results, female fish farmers should be supported by means of professional training in fish production practices to ensure that their resources are optimally utilized.

Keywords: Technical efficiency, Female farmers, Fish farming, Profitability

Introduction

Fish farming is one of the very important agricultural activities; hence, it holds a strategic role in the economy. Its contribution to the agricultural share of the gross domestic product (GDP) was estimated at 1.3% in 2010, with agriculture contributing 40.9% of the overall estimate to GDP (CBN, 2011).

Nigeria has substantial coastline of around 853 km contiguous the Atlantic Ocean and more than 14 million hectares of inland water with 75 percent being relatively suitable, and about 112,085 km2 are considered to be very suitable for development of aquaculture. The production of fish as a business has the potential to make a substantial contribution to the agrarian sector of the economy (FDF, 2007).

Observations showed that the demand of fish in Nigeria exceeds their availability. Despite the large number of water resources and manpower available, domestic production is very poor. Annual fish consumption and demand were estimated in Nigeria at over 1.3 million tons, and total domestic production was put at just approximately 407,869 tons per year (Tsadu et al. 2006).

Recently, over-exploitation of fisheries resources through heavy-duty fishing machines and capture equipment has become a serious issue, resulting in fish shortages and the need to increase fisheries production by fish farming (Eyo, 2003). Silvestre et al. (2003) argued that coastal fish stocks decreased through over-exploitation to 30% of their untapped levels. The effect is that poor coastal fishermen who depend solely on these services remain poverty-stricken. These concerns call for government response to sustainable fish availability to satisfy domestic demand by importing more than 288 billion naira per annum, which has not been reached **(**Central Bank of Nigeria, 2017). This gap needs to be covered hence the need to make up for the shortfall experienced.

Nigeria should replace fish importations by domestic production in order to bridge the gap between demand and supply with women's involvement in fish farming to build employment and minimize poverty (Shester and Micheli, 2011).

Further, it creates direct and indirect job opportunities for people engaged in the production of fish and for those engaged in other related enterprises, thus contributing to national income for all groups of folks engaged in fish farming. It takes less time, space, money and a higher feed conversion rate compared to livestock. Thus, fish farming has become a crucial endeavour, in particular for children, in order to ensure food security and to fight malnutrition (FAO, 2017).

Aquaculture is the fastest-growing food-producing sub-sector of the world, according to the World Fish Center (2009), with an annual growth of 8.9 percent since 1970. The major species cultured in Nigeria include tilapias, catfish and carp. However, the African catfish species *Clarias gariepinus* (Burchell, 1822) has been given much attention in Nigeria because of its prolificity and its quick growth potential to bridge the gap in demand. Adebayo and Daramola (2013) asserted that it is the largest species grown in Nigeria. Catfish (*C. gariepinus*) is highly resilient to disease and has a relative low production cost and feeding habit that makes it very easy to earn a huge profit on investment.

FAO (2003) was of the opinion that any nation's development process is decided by the development of its women and the extent of involvement of these women in the nations various farming activities, including fish farming.

The nation’s population provides an essential labour force which can turn fish farming in the nation into increased fish output in order to boost household and income generating jobs. It is generally agreed that, due to their social and economic positions, women participate strongly in the rural economy and are not left out of culture fish production.

Women folks are the mainstay of the labour force in agricultural production that generates about 40 percent of gross domestic product (GDP) and more than 50 percent of food produced in developing nations (Ani, 2004). This is confirmed by Adenugba and Raji-Mustapha (2013) found that women offer about 60-80 percent of agrarian labour and contribute approximately 80 percent of Nigeria’s food production.

Participation in this context connotes the physical involvement ‘of women in fish farming activities in order to increase efficiency in fish production and household income.

Women's involvement in aquaculture extends to all aspects of fish farming such as feed preparation, fish feeding, net/cage cleaning, pond maintenance and fish processing (Krushelnytska, 2015). Women's positions were either ignored or undervalued in fish farming (Cohen et al. 2016., Parks et al. 2015).

Unlike other enterprises, such as arable crop production and poultry production, which are engaging both male and female farmers, involvement of females in fish production is not known. Nevertheless, it is commonly conceived, with regard to fish production, that fish farming is culturally restricted to men. Thus, the involvement level of women folk in fish farming is far too low to meet the nation's protein needs.

It is estimated that 60% of the fish consumed are catfish and are gradually adding to the industry, which remains primarily a live fish market to date. According to Ekunwe and Emokaro (2009), a significant amount of fish farmers have recently concentrated on catfish because it can have 2-3 times the market value of tilapia in greater part of Nigeria owing to its market demand.

Furthermore, women's low fish production is due mainly to economic, financial, operational and technical obstacles, retarding the pace of development in the fishery sub-sector to the minimum level. It is suspected that their technical efficiency level is the major reason for the poor production level. A panacea for evaluating the capacity for sustainable aquaculture development would be to evaluate the technical efficiency level by identifying the significant factors related with efficient production systems (Gbigbi, 2019).

Recent studies in estimating women-in-agriculture and efficiency are centered on crop and livestock production with limited information on female catfish farmers technical efficiency (Adewale and Ikeola 2005, Ani 2004., Tulchan and Karki 2000). Similarly (Baruwa and Omodara 2019., Gbigbi, 2017 and Idoge et al. 2017) carried out investigation on catfish farming in Delta State. To the best of my knowledge, none of the researchers focus on technical efficiency and female catfish farmers in the area. Therefore, it becomes necessary to estimate the efficiency level of the women to see if the business is profitable and sustainable. Thus, this research was undertaken to bridge the knowledge gap by providing information on proper adjustment in resource utilization in catfish farming by women, which would in turn lead to increase in their income and standard of living.

The specific objectives are to:

i. Describe the socio-economic features of the female catfish farmers
ii. Examine the cost and return of female catfish farmers
iii. Estimate the determinants of technical efficiency of female catfish farmers
iv. Ascertain the technical efficiency level of female catfish farmers
v. Estimate the elasticity and return to scale of female catfish farmers
vi. Ascertain the constraints of female catfish farmers

Material and Methods

Study Area

Delta State is the study area for the research. For this study, primary data have been obtained. The key data were collected with a questionnaire from the field survey. The map of the study area is presented in Table 1. Data on the efficiency of females catfish production determinants, the structure of cost and return and inputs used in catfish production in the area under study were especially investigated.

Sampling Techniques

A three-stage sampling procedure was used in drawing the survey respondents. Delta State is demarcated into three agricultural zones namely: Delta north, Delta central and Delta south. Delta south and central agricultural zones have 8 extension blocks each, while Delta north agricultural zone comprises 9 extension blocks. Firstly, four agricultural blocks were randomly selected from each of the three agricultural zones. The second stage involved selection of two cells from each block. Finally, from each of the cells selected, 14 women folk in catfish production were carefully chosen. This will give us 112 respondents at the end.

Methods of Data Analysis

Both descriptive and quantitative tools were engaged in data analysis. While descriptive statistics were applied to encapsulate the socioeconomic attributes of the women in fish farming, gross margin analysis was used to examine the costs and return from fish farming enterprise. Determinants of technical efficiency and inefficiency of women in fish farming were estimated with stochastic frontier.

Model Specification

The specified production function is of the form:

$$\text{In}Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i) \ldots(1)$$

Where:

Y= Total fish output (kg)

X_1 = pond size (m2)

X_2 = labour used (mandays)

X_3 = fingerlings(Number of fingerlings)

X_4 = quantity of feed (kg)

X_5 = cost of medication ($)

X_6 = water supply(litres)

B_o = Intercept

Bs = Vector of the coefficients for the associated independent variables in the production function

U_i = one sided components, which captures deviation from frontier as a result of inefficiency of the firm V_i = effect of random stocks outside the firm control, observation and measurement error and other stochastic (noise) error term.

The inefficiency model is expressed as:

$$U_i = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Z_1 = age (years)

Z_2= education (years)

Z_3 = household size

Z_4 = farming experience (years)

Z_5 = distance of farm from residence (km)

Z_6 = access to credit obtained (yes=1, otherwise =0)

$\delta_1 - \delta_6$ = are the scalar parameters to be estimated

Profitability of female cattish farmers

The budgetary technique involves the cost and return analysis. It is used to assess the profitability of female catfish farmers. It is given as:

II=TRTC………………………………………………………………….. (3)

TR= PQ……………………………………………………………………. (4)

Where

II = Total Profit ($)

TR=Total revenue ($)

TC = total Cost ($)

P= Unit price of output ($)

Q= Total quantity of output (kg)

Benefit-Cost Ratio (BCR) = TR/TC.

Source: Facts about Delta State of Nigeria

Figure 1. Map showing the study area

Results and Discussion

Socioeconomic Characteristics of Female Fish Farmers

The distribution of the women's fish farmers by age indicates that 7.1% of them were 20 to 30 years old and 15.2% were over 50 years old. Most (42.9 percent) of female fish farmers were between 41 and 50 years of age, and 31-40 years of age were closely followed by 34.8 percent .. The fish farmers' average age is 42 years old, which indicate that most farmers are in their working age. The outcome is a strong contrast according to Olowosegun et al. (2004).

The marital status would affect the level of obligation of the farmers, which could have a positive influence on their ability to participate in economic activities like fish farming. Most (69.6%) of the women were married, 24.1% were single, while 2.7% were divorced and 3.6% were widowed. This is justified by the fact that the majority of women who participate in fish farming are married individuals. It also suggests that for these women, the means of subsistence is catfish farming. The implication is that married women will profit most from fish farming, as they tend to cater for their family. They can supply family labour easily.

The outcome indicates that 20.5% of female fish farmers had primary education, 60.7% had secondary education, and 12.5% had post-secondary education. Just about 6.3% were not formally educated. By implication, a reasonable number could understand and implement the advanced fishing technology available to achieve an improved in fish output. This implies that trained farmers predominantly engage fish farming and, for the most part, by those who are highly educated. This is because a great deal of technical and scientific knowledge is needed for fish production to be successfully carried out (Osondu et al. 2014). Thus, female catfish farmers would easily adopt new fishery technologies, which could improve their level of profit ceteris paribus.

It was evident that 43.8 percent of female fish farmers had been fishing for 1-5 years, 32.1 percent had 6-10years of experience, while 15.2 percent had 11-15 years of farming experience. The least constituted 1.8% with farming experience of above 20 years. The average farming experience is eight years. This is an indication that most female fish farmers have been involved in fish farming for a long time, which will have a positive impact on their production. This is due to the fact that the more experienced the farmers are, the more their ability to make decisions about fish farming as a measure of management ability. This is consistent with the finding by Onyekuru et al.(2019) that the more experience they have, the willingness to adopt the management methods of fish production become much easier.

From the result, about 57.1% of the female fish farmers had household size of 6-10 persons and 41.1% of fish farmers had household size of 1-5 persons. The lowest was 1.8% with a household size of 11-15 persons. The female fish farmers were noted to have an average household size of 6 individuals. This average is reasonably rational enough that most respondents in the study area would have necessitated the use of family labour. This is consistent with the findings of Gbigbi and Achoja (2020), who documented an average of 9 persons for backyard fish farmers in Nigeria (Table 1).

Table 1. Farmers socio-economic attributes (N =112)

Variables	Frequency	Percentage	Mean
Age (years)			
20-30	8	7.1	
31-40	39	34.8	42 years
41-50	48	42.9	
51-60	14	12.5	
61-70	3	2.7	
Marital status			
Married	78	69.6	
Single	27	24.1	
Divorced	3	2.7	
Widowed	4	3.6	
Education level			
No schooling	7	6.3	
Primary school	23	20.5	
Secondary school	68	60.7	
Post-secondary	14	12.5	
Experience (years)			
1-5	49	43.8	
6-10	36	32.1	8 years
11-15	17	15.2	
16-20	8	7.1	
Above 20	2	1.8	
Household size			
1-5	46	41.1	6 persons
6-10	64	57.1	
11-15	2	1.8	

Profitability Analysis of Female Fish Farmers

Table 2 presents the expenses and return of catfish production. It indicates that ₦646,065.78 was the total cost incurred by the female catfish farmers, of which the total variable cost accounting for the largest proportion, i.e. 88.5%, whereas the fixed cost was the lowest, representing 11.5% of the total cost of fish production. Feed costs also accounted for 48.6% of the overall cost, and also the highest. The result shows that the revenue of ₦1,062,308.60k was realized. About ₦490,378.46 and ₦416,242.82k were the gross margin and net farm profits. Positive net farm income infers that catfish farming is profitable.

It was estimated that the return on investment (ROI) and the benefit cost ratio were 0.64 and 1.64. As the BCR is greater than one, fish production is considered profitable. With about 64 per cent return on investment, the business is profitable.

The study suggests that $0.64 was made as a profit for each $1.00 spent on catfish farming. This finding is consistent with Gbigbi et al. (2019) assertion that aquaculture is a lucrative investment venture in cooperative fish farming, as supported by the BCR of N2.06.

Table 2. Profitability of female catfish farmers

Items	Amount ($)	Percentage
Variable cost		
Fingerlings cost	96949.16	15.0
Feed cost	313798.70	48.6
Drugs/medication	8423.96	1.3
Water cost	14100.00	2.2
Lime cost	13989.47	2.2
Fertilizer cost	10523.24	1.6
Labour cost	107345.61	16.6
Transportation	6800.00	1.1
Total variable cost	571,930.14	88.5
Fixed cost		
Land cost (depreciation)	49642.58	7.7
Pond construction (depreciation)	22648.74	3.5
Equipment (depreciation)	1844.32	0.3
Total fixed cost	74,135.64	11.5
Total cost	646,065.78	
Total revenue	1,062,308.60	
Gross margin	490,378.46	
Net farm income	416,242.82	
Return on investment	0.64	
Benefit cost ratio	1.64	

Stochastic Frontier Model of Female Fish Farmers

The Cobb Douglas production function's maximum probability estimate in Table 3 showed that total variance and gamma values were respectively 0.570 and 0.830. At the 5% level, the total variance of 0.680 is statistically significant, suggesting a good fit and the accuracy of the stated distributional assumption of the composite error term. The findings disclosed that size of pond, fingerlings, quantity of feed and water supply were positive and significant at 1% and 5%, while medication cost was negatively significant at 5%.

The estimated coefficient with respect to pond size was 0.152. This suggests that for every 1% increase in pond size, it would lead to 0.152% increase in output of fish. This shows that pond size must be increased to obtained increased efficiency level of fish farming. The explanation for this is that fish develop at varying rates and if the pond size were not expanded to accommodate the sizes then otherwise the fish would be excessively bigger which would in the long run lead to lower production. Increased pond size is thus a required prerequisite for increased fish production. This agreed with Gbigbi et al. (2017) findings.

The coefficient of fingerling stocking capacity was positively significant with a production elasticity value of 1.361. Therefore, a 1 % rise in stocking capability would raise fish production by 1.361%. This reveals that by expanding farmland, there is space for increasing production. With previous works by Gbigbi (2019), this outcome agrees that the greater the stock size, the more successful a farmer becomes. This means that as the fish farmer buys more fingerlings, the efficiency of catfish production increases.

The relationship between feed and fish output was positive. This is anticipated because output levels are largely dependent on the extent of feed used on the farm. This result agrees with that of Baruwa and Omodara (2019).

The coefficient for medication (-2.540) for fish production carried negative signs and is significant at 5%. This means that with every 1 percent increase in the cost of medication, the production output of fish will decrease by -2.540 percent.

The coefficient for water supply (0.232) had positive relationship with output at 1%. This indicates that increase in availability of water to the fishpond will lead to an increase in the output of fish. This agrees with Ekanem et al. (2012) study in Cross Rivers State that cost of water was significant in aquaculture production.

The inefficiency model showed that the age of the female fish farmers is negatively significant with efficiency at 5%. The negative sign of age implies that as the farmer increases in age, she would gain more experience in farming which could increase farm technical efficiency in other words farm inefficiency will be reduced. This disagreed with the work of Gbigbi (2019).

The coefficient for education was found to be negatively significant at 1%. It means that increase in educational status reduces female fish farmers' technical inefficiency. Educated female fish farmers will be able to readily adopt and utilize efficiently modern fish farming technologies, which results in higher productivity.

Household size had a negative coefficient, which was significant at 5%. This means large households could serve as reservoir of family labour. Families with large households could be more efficient when it comes to supply of labour to achieve critical fish farm operations. This may hold, if the household members are willing to support their family fish farm enterprise. This agrees with Gbigbi and Enete (2014).

The variable distance was positively significant at 5%. This implies that the farther the distance of farm from farmer's residence the higher the technical inefficiency. This support the findings of Gbigbi (2019).

Credit access had positive coefficient for the respondents. The positive signs recorded imply that the female fish farmers who have access to credit are more inefficient than those who do not have. This could be due to untimely access of the credit, which may lead to diversion of credit to other non-fishing activities. It was expected that if the credit is invested into fish production, it would have led to higher output level.

Technical Efficiency Scores Index

Table 4 presents the female catfish farmer's efficiency level. The efficiency level ranges from 36.5-89.1.' About 6.3% of catfish farmers had technical efficiency ranging between 0-20 while 12.5% had technical efficiency ranging between 21-40. About 50% of the catfish farmers had technical efficiency ranging between 41-60 and about 32.2% had technical efficiency above 60%. The average technical efficiency value was about 53.5%, indicating that the realized output could be increased by about 46.5% by adopting the fishing technologies of the best female fish farmers.

Table 3. Stochastic production function for female fish farmers

Variables	Parameters	Coefficients	Standard error	t-value
Production factors				
Constant	X_0	2.628	1.064	2.470**
Pond size	X_1	0.152	0.049	3.102**
Labour	X_2	0.340	0.194	1.753
Fingerling	X_3	1.361	0.247	5.510***
Feed	X_4	1.022	0.610	3.315***
Medication cost	X_5	-2.540	1.217	2.087**
Water supply	X_6	0.232	0.053	4.377***
Inefficiency factors				
Constant	Z_0	0.152	0.073	2.082**
Age	Z_1	-1.059	0.372	2.847**
Education	Z_2	-0.027	0.008	3.375***
Household size	Z_3	-0.232	0.103	2.252**
Fish farming experience	Z_4	0.414	0.520	0.796
Distance of farm	Z_5	0.249	0.108	2.306**
Credit access	Z_6	0.083	0.023	3.609***
Diagnostic statistics				
Sigma squared	σ^2	0.570	0.264	2.159**
Gamma	Γ	0.830	0.211	3.934***
Log likelihood function		64.104		
LR Test		9.320		

Table 4. Technical efficiency level of female fish farmers

Efficiency level	Frequency	Percentage
0-20	7	6.3
21-40	14	12.5
41-60	56	50.0
61-80	25	22.3
81-100	10	8.9
Total	112	
Maximum Technical efficiency	89.1	
Minimum Technical efficiency	36.5	
Mean	53.5	

Elasticities of Production Inputs and Return to Scale of Female Fish Farmers

Table 5 indicates the elasticity of inputs of output and the return to scale of female farmers. The sum of the input coefficients suggests a declining return to the scale of 0.567 and that women fish farmers are generally reasonably effective at using their input into output. However, the most productive use of variable inputs will be estimated by the relative unit prices of individual technical inputs. This indicates that there is a declining return to scale in catfish production.

The results are that each additional input unit leads to a marginal upsurge in the price of fish output compared to previous unit. In stage 2, the quantity of output elasticities is greater than zero but <1. This suggests that, in stage 2, production among fish farmers occurred at a reasonable stage of production. This implies that the higher the inputs used, the higher the output of fish, but at a lower cost. This finding is in consonance with Gbigbi (2019).

Challenges Encountered by Female Fish Farmers

The foremost constraints' limiting female catfish farmers is presented in Table 6. Inadequate finance (mean=2.9107), high cost of feed (2.8929), water supply(2.8839) and scarcity of fingerlings(2.8571) ranked 1st, 2nd, 3rd and 4th respectively as the most important areas where technical assistance is required by the respondents. This concurs with (Idoge et al 2017., Ohen and Abang 2009., Oyinbo et al. 2013., George et al. 2010) findings that fish production is affected by lack of adequate capital, high cost of feed, high cost of labour, inadequate water supply and theft.

Conclusion

The study concludes that by increasing pond size, fingerlings, feed quantity and water supply, there is potential for increasing female catfish farmers in Delta State, Nigeria. Technical efficiency ranged from 36.5 to 89.1 with a mean value of 53.5. This revealed that productivity can be improved further by 46.5 percent by raising awareness of modern fish culture technology and cost-efficient skills that will play a major role in improving female catfish farmers' fish productivity. The result indicates that insufficient financing, high feed costs, water supply and the shortage of fingerlings were the issues that made farmers' unable to hit the production frontier.

It was recommended that

i. More emphasis should therefore be placed on resource utilization to further sustain catfish production.

ii. Government should assist the female catfish farmers through soft loan

iii. Female catfish farmers should be encouraged through technical training on production practices that support the optimum use of their resources

iv. More female catfish farmers should also be encouraged to go into fish farming since it is profitable.

v. Government should provide subsidy to enable purchase feed at lower cost

vi. Government should embark on irrigation programme to facilitate water availability for sustainable production

vii. Government should assist the female farmers with consistent supply of fingerlings at subsidized rate

Table 5. Elasticities of production inputs and return to scale of female fish farmers

Variables	**Coefficients**
Pond size	0.152
Labour	0.430
Fingerling	1.361
Quantity Feed	1.022
Drugs cost	-2.540
Water supply	0.232
RTS	0.567

Table 6. Constraints faced by female fish farmers

Constraints	**Mean**	**Std. deviation**	**Remark**	**Ranking**
High cost of feed	2.8929	0.31068	Significant	2nd
Lack of modern technologies	2.8036	0.48098	Significant	5th
Water supply	2.8839	0.34863	Significant	3rd
Pond construction	2.5625	0.58172	Significant	9th
Inadequate finance	2.9107	0.28644	Significant	1st
Lack of fingerlings	2.8571	0.42143	Significant	4th
Cost of land	2.7768	0.49701	Significant	6th
Inadequate extension contact	2.6875	0.52042	significant	8th
High mortality rate	2.7589	0.45014	Significant	7th

Cut off point=2.00 Mean> 2.00=a problem, mean <2= not a proble

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: This research was conducted with the approval of the ethics committee, Department of Agricultural Economics and Extension, Delta State University Asaba Campus on 22/04/2020(Ethical committee approval number: AEE/2020/012).

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Research Article

Assessing water quality in the Kelebek Stream branch (Gediz River Basin, West Anatolia of Turkey) using physicochemical and macroinvertebrate-based indices

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ABSTRACT

This study was carried out in Kelebek, which is the most important stream in Gediz River Basin, Turkey, to determine water quality by using macroinvertebrate-based metrics and physicochemial variables. In addition, we also aimed to investigate the effects of anthropogenic pressure and dam construction on stream macroinvertebrates during the study period. In this study, following biotic indices are used: Saprobi Index (SI), Biological Monitoring Working Party (BMWP), Average Score per Taxon (ASPT), Family Biotic Index (FBI), Belgian Biotic Index (BBI), as well as diversity indices: Shannon-Weaver index (SWDI), Simpsons index (SDI) and Margalef index (MDI). Collection of macroinvertebrate samples and the physicochemical measurements were carried out monthly for a year. As a result of the identification, the most dominant macroinverterate group was Insecta. Our results show the presence of 9 taxonomic group in the stream which belong to nine groups: Oligochaeta, Mollusca, Crustacea, Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Diptera. Canonical correlation analysis (CCA) indicates importance of physicochemial variables in the distribution of different macroinvertebrates groups (total variance 88%), species (total variance 86.2%) and biotic indices (total variance 88.2%). The water quality along the Kelebek Stream show variation from good class in station #1, #2 and #5, to moderate in station #3 and #4. We conclude that BMWP (Original), BMWP (Spanish), BMWP (Greek) and ASPT indices are suitable for assessing stream health by macroinvertebrates.

Keywords: Gediz River Basin, Kelebek Stream, Macroinvertebrates, Biotic Index, Water Quality

Introduction

In today's world where sustainable growth and development strategies are made, the use of natural resources as a raw material and environmental pollution caused by production-consumption cause great ecological crises. Increasing damage to freshwater resources is just one of these crises. Water is an extremely valuable, economic and strategic resource both in our region and in the world. In underdeveloped and developing countries, as a result of the discharge of wastewater to water sources without treatment, 1.4 billion people in the world are still trying to continue their lives without the opportunity to use clean water (Girgin et al. 2004).

Streams cover 1% of freshwaters in the world and play a very important role in the water cycle (Wetzel, 2001). For this reason, streams must be managed well and pollution must be well detected and followed for sustainable water management. Stream polluting factors are regional and widespread pollutants such as sewage water, industrial waste, materials carried by surface runoffs, pesticides and fertilizers resulting from agricultural activities.

To determine the current status of streams, it is necessary to calculate the ecological status in the water bodies. Three basic quality elements (hydromorphological, physicochemical and biological) are used in the calculation of the ecological situation. Biological quality elements are determined using five organism groups such as benthic macroinvertebrates, macrophyte, fish, phytoplankton, and diatome (Akay et al. 2008). Among these groups, benthic macroinvertebrates get the most attention. Benthic macroinvertebrates are often preferred in water quality studies because they have a longer life cycle than macrophytes and algae, respond to environmental changes in a shorter time compared to fish. They are easy to collect and they are generally diagnosed at the level of genus and family (Bonada et al., 2006).

Biotic indices are the focus of biological monitoring studies based on benthic invertebrates. Many existing biotic indices were created according to specific geographic and climatic regions. Many European countries have created various indices with statistical variations of their diagnosis and counting on different organisms (Korycińska and Królak 2006; Yorulmaz et al. 2015). In this direction, the Saprobi Index (SI) (Kolkwitz and Marsson, 1902) in Germany, the BMWP and ASPT (De Pauw and Hawkes, 1993) in England, the BBI (De Pauw and Heylen, 2001) in Belgium, the FBI (Hilsenhoff, 1988) in USA, Danish Stream Fauna Index (DSFI) (Skriver et al., 2001) in Denmark, give the most reliable results specific to geographical regions. A lot of biotic indices have been used based on benthic macroinvertebrates to determine water quality in Anatolia (Kazancı and Dügel, 2000; Kalyoncu and Zeybek, 2009; Kazancı et al. 2010; Zeybek et al. 2014; Yorulmaz et al. 2015; Zeybek, 2017). Biological monitoring studies are conducted for 25 years in Turkey; however a biological water quality index specific to Turkey has not been developed.

The aim of this study is to determine the water quality of the stream and to compare the results of seven biotic indices and three-diversity indices accordance with physicochemical characteristics of Kelebek Stream in West Anatolia region of Turkey.

Material and Methods

Study Area and Benthic Macroinertebrate Sampling

This study was carried out on Kelebek Stream in the Gediz River Basin of west of Turkey (Figure 1). Kelebek Stream is located in Ahmetli plain of Ahmetli district of Manisa province. The length of the stream is 41 km^2. The Mediterranean climate prevails in the region. Summers are dry and hot, winters are mild and rainy. July-August are the hottest months and January-February are the coldest months.

Kelebek Stream is used as irrigation water source for the surrounding agricultural fields. The sampling stations were chosen based on stream source, dam construction, domestic areas and pollutant factors. The research was conducted during August 2019 and July 2020 at five monitoring stations that included the upstream of the stream (#1 and #2), and downstream (#3, #4 and #5). The sampling carried out monthly over a year in the stream. The characteristic of sampling stations are presented in Table 1.

In Kelebek Stream, the benthic macroinvertebrates were collected from each station by using a classic 50x30 size with a 250 μm mesh hand net. Macroinvertebrate sampling was done by moving downstream of the steam towards the upstream. Macroinvertebrates were obtained from the different substrate types such as rock, sand, and gravel present at the stations. Some sessile organisms adhering to the large stone, rock or any other substrate, collected by removing from the water was made with forceps (AQEM Consortium, 2002). The taken organisms were storage in 70% alcohol and 4% formaldehyde, and then brought to the Ege University Hydrobiology Research Laboratory. Brought samples from the stream were categorized and diagnosed to the lowest possible taxonomic level such as genus or species, under a ZEISS stereomicroscope.

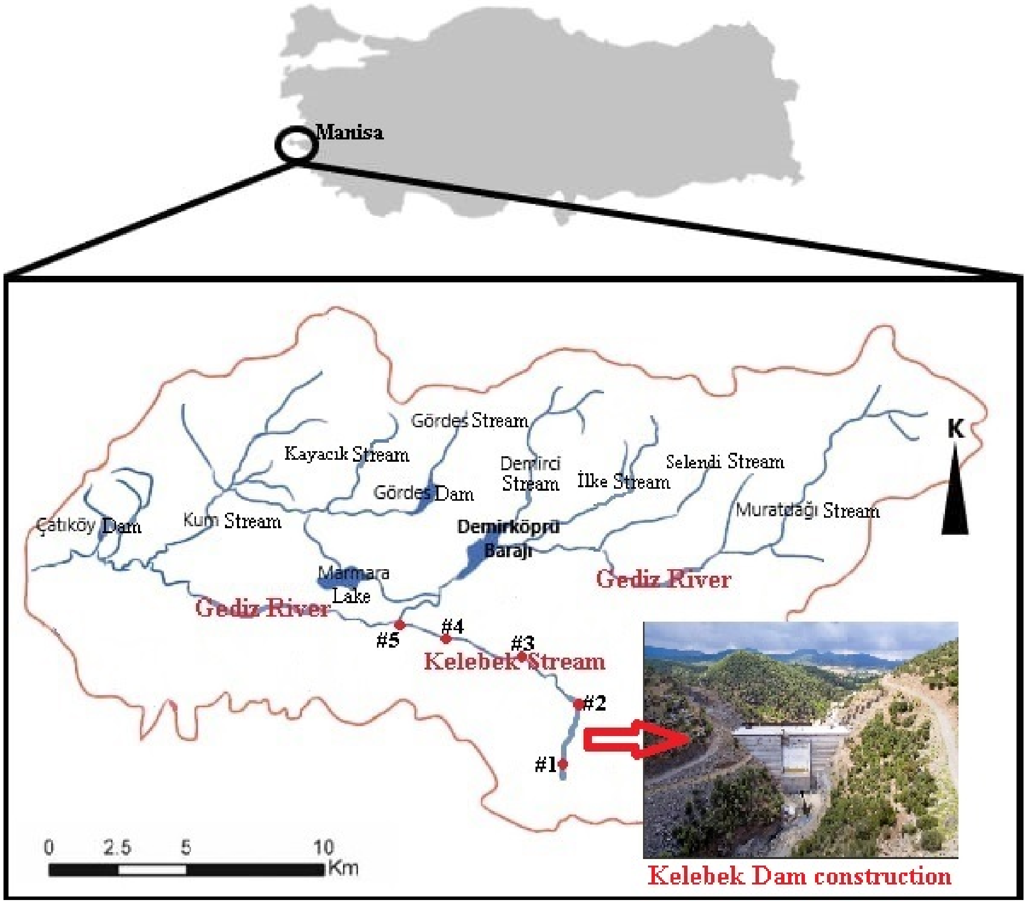

Figure 1. Map of the sampling stations in Kelebek Stream.

Table 1. Key characteristics of sampling stations in Kelebek Stream.

Sampling Station		Coordinates (N-E)	Habitat	Stream morphology	Riparian vegetation
#1	The source point of the stream.	38º 39' N 27º 90' E	Large rocks (> 50 cm) mixed with stone and wood debris	Flow velocity >12 m/sec No Macrophyte were present	Well developed in both side.
#2	Kelebek Stream in village Horzum. Agricultural areas and domestic settlements around the stream. The construction of Kelebek Dam is ongoing.	38º 41' N 27º 92' E	Large stones, gravels and wood debris.	Flow velocity >8 m/sec No Macrophyte were present	Well developed in both side.
#3	Kelebek Stream in village Dereköy. Agricultural areas and domestic settlements are intense around the stream.	38º 47' N 27º 93' E	Rubbles, gravel, silt and cobbles	Construction waste present. Low water flow. Flow velocity <5 m/sec No Macrophyte were present	It's not well developed.
#4	Kelebek Stream in Ahmetli district. Domestic settlements are intense around the stream.	38º 52' N 27º 94' E	Sand, rubbles, silt and cobbles	Domestic wastes runoff. Flow velocity <3 m/sec. No Macrophyte were present	It's not well developed.
#5	The point where the Kelebek Stream drain into the Gediz River.	38º 55' N 27º 95' E	Cobbles, gravels, sand	Flow velocity 4 m/sec. No Macrophyte were present	Well developed in both sides.

Physicochemical Parameters

To determine the water quality classes, 12 physicochemical parameters were monitored over a year period. Water temperature (T°C), pH, Electrical conductivity (EC), Turbidity (TU), Oxygen saturation (Sat. O_2) and dissolved oxygen (DO) of each water sample were measured at the sampling points by oxygen meter and multiparameter.

The Biochemical oxygen demand (BOI_5) parameter was assessed by using a spectrophotometer on the base of Winkler azide method with Merck BOD Cell Test Kits. The orthophosphate (PO_4-P), ammoniacal nitrogen (NH_4-N), nitrate (NO_2-N), nitrite (NO_3-N), and chloride (Cl^-) were analysed by using appropriate Merck kits according to manufacturer's instructions (Merck Phosphate, Ammonium, Nitrite, Nitrate and Chloride Test Kits). For each analysis, two containers (1.0 L) were taken from the water samples in duplicate. All water samples were stored in insulated cooler containing ice and taken on the same day to laboratory and stored at 4ºC until processing and analysis (APHA 2005).

Belong to all mathematical and statistical analyses on the physicochemical data sets were made using Excel 2019 (Microsoft Office^R) and SPSS version 20.0.

Biotic Indices

The benthic macroinvertebrates were analyzed to determine the biological quality score by using ASTERICS 4.04 software program (AQEM Consortium, 2002). With this purpose, the BBI, FBI, SI, ASPT, BMWP (Original), BMWP (Spanish) and BMWP (Greek) indices were used to determine the water quality of Kelebek Stream. The values obtained are evaluated in five classes by presenting common color code according to European Union (EU) Directive 2000/60/EC 2004–2006 (2005).

SWDI, SDI and MDI were used to determine the species richness of the stations in the stream by using the ASTERICS 4.04 software program. The faunal similarities based on benthic macroinvertebrates between the sampling stations were assessed by using Bray- Curtis similarity index (Sommerfield, 2008; Yoshioka, 2008). Pearson's based correlation analysis and multiple regression analysis were applied by using from SPSS version 20.0. In this study, the relationships between physicochemical and biotic parameters were determined by using CCA based on multivariate statistical analysis (Ter Braak, 1995).

Results and Discussion

Physicochemical Variables

The results of the analyzed physicochemical variables of water in five sampling stations along the stream are presented in Table 2. According to the One-Way Anova test, the all physicochemical parameters varied significantly with respect to the stations *($P <0.05$)*.

TºC is a very important parameter for aquatic life. It is known that the metabolism of organisms, especially fish, varies with temperature. For example, carp is euriterm but begins feeding (8-10°C) and breeding (15°C) only after certain temperatures (Nikolsky, 1963). The most suitable water temperature for trouts is 8-16°C (Wetzel, 2001). The mean value of TºC varied from 9.92ºC in station #1 in the source area, up to 15.9ºC in station #5 of the stream.

pH, which is an indicator of the acidity of water, is one of the important factors affecting the life. In lake waters that are not contaminated in any way, the pH value varies between 6.0 and 9.0. While many fish species show good growth in waters with a pH of 6.5-8.5 (Arrignon, 1976, Dauba, 1981), waters with a pH higher than 10.8 and less than 5.0 have a lethal effect for the Cyprinidae (especially carp) (Svobodá et al. 1993). Generally, alkaline waters are more suitable for trout production (Wetzel, 2001). For cyprinid health, the mandatory pH range in waters is expected to be 6.00 – 9.00 (EC 2006). According to the pH data determined in the region, there is no risk for cyprinid species. The pH has shown small alteration, with minimum value 6.94 in station #5 and maksimum value 7.60 in station #1, meaning that in all stations the stream water is neutral.

The increase in EC in drinking water indicates that the water is contaminated or sea water is mixed into the water. The highest mean value of EC in this study were measured in station #4 (440.5 mS/m) in the downstream area. It is known that EC values increase as the pollution increases in freshwaters (Verep et al. 2005).

TU is seen in waters containing suspended solids, which prevent the passage of light. It is recommended not to exceed 1 NTU (turbidity unit) by EPA and world health organization (WHO). The strength of the sewer and commercial waste is expressed with turbidity (Tanyolaç, 2004). Therefore, the degree of turbidity of surface water is measured as the degree of pollution. The mean value of TU concentration varied from 3.09 ppt (station #1) to 73.5 ppt (station #5).

Oxygen is a vital variable for a healthy aquatic life. It is desired that the fish grown waters are saturated with oxygen (Bremond and Vuichard, 1973). Bremond and Vuichard (1973) stated that the minimum amount of DO required for the cyprinid to survive should be 5.0 mg/L. For trouts, the oxygen of the water should be at least 7.0 mg/L (Wetzel, 2001). BOI_5 is the amount of dissolved molecular oxygen used by microorganisms during the 5-day incubation period to oxidize the structure of organic substances in water at 20°C (Bytyçi et al., 2019; Etemi et al., 2020). The mean value of DO concentration varied from 12.0 mg/L (station #1) to 7.75 mg/L (station #5). The mean values of BOI_5 in sampling stations ranged from 1.29 mg/L in station #1 to 8.76 mg/L in station #4. The mean values of Sat. O_2 in sampling stations ranged from 118.2% in station #1 to 81.7% in station #5.

Elements that limit efficiency in aquatic environments are mostly PO_4-P, NH_4-N, NO_2-N, NO_3-N (Moss, 1987). The NO_3-N in groundwater and surface waters results from the oxidation of ammonia, which occurs as a result of the decomposition of proteins contained in vegetable and animal wastes, and nitrate fertilizers used in agricultural areas. NO_3-N is the most common form of nitrogen in freshwaters, and it is very rare in uncontaminated waters (Wetzel, 2001). The NO_3-N range was from 1.10 mg/L in station #1 to 6.12 mg/L in station #4. It is also below the limit value reported as 50 mg/L in World Health Organization, where the NO_3-N values determined at all stations examined in the stream are below the recommended 10 mg/L limit value in healthy waters reported by EPA. (WHO, 2011). The increase of NO_3- in station #4 and #5 showed the rich of these two stations with nutrients caused by discharges of domestic wastes in the vicinity of Kelebek Stream.

Table 2. Summarize statistics of water quality parameters at the stations in Kelebek Stream.

Parameters		Station 1	Station 2	Station 3	Station 4	Station 5
T	R	9.2-10.4	9.8-11.0	13.8-16.6	13.9-17.1	14.0-17.6
(°C)	M±Sd.	9.92±0.55	10.4±0.58	15.2±1.47	15.6±1.63	15.9±1.75
pH	R	7.51-7.73	7.44-7.65	7.00-7.12	7.00-7.02	6.87-7.00
	M±Sd.	7.60±0,10	7.53±0.09	7.04±0.05	7.00±0.009	6.94±0.06
EC	R	151-173	196-276	228-301	401-487	283-369
(mS/m)	M±Sd.	165.5±9.88	245.7±35.7	278.7±34.3	440.5±35.9	316.7±36.8
TU	R	2.01-3.84	2.91-5.37	33.7-58.1	55.7-81.6	60.1-84.3
(ppt)	M±Sd.	3.09±0.76	4.09±1.18	46.7±12.3	69.2±13.6	73.5±11.8
DO	R	10.4-13.8	9.95-13.1	9.18-9.77	7.34-9.12	6.90-8.79
(mg/l)	M±Sd.	12.0±1.67	11.5±1.70	9.52±0.26	8.35±0.87	7.75±0.90
Sat. O_2	R	104-135	96-117	88-104	77-100	68-94
(%)	M±Sd.	118.2±13.6	106.5±9.67	95.5±7.32	88±11.6	81.7±13.1
BOI_5	R	1.11-1.39	1.23-1.44	4.38-4.64	7.19-9.78	6.05-6.64
(mg/l)	M±Sd.	1.29±0.12	1.36±0.09	4.52±0.10	8.76±1.11	6.32±0.25
NH_4-N	R	0.04-0.07	0.09-0.36	4.37-9.76	11.2-14.9	9.46-11.3
(mg/L)	M±Sd.	0.05±0,01	0,21±0.12	7.11±2.60	13.4±1.57	10.4±0.86
NO_2-N	R	0.05-0.10	0.09-0.12	3.05-3.85	4.76-5.94	2.12-3.56
(mg/L)	M±Sd.	0.08±0.02	0.10±0.01	3.29±0.37	5.31±0.50	3.14±0.68
NO_3-N	R	1.07-1.13	1.10-1.18	2.18-2.37	5.13-6.89	3.81-4.78
(mg/L)	M±Sd.	1.10±0.02	1.14±0.03	2.25±0.08	6.12±0.73	4.30±0.40
Cl^-	R	2.75-3.11	3.02-4.14	3.78-6.37	27.4-36.5	19.2-25.4
(mg/L)	M±Sd	2.99±0.16	3.78±0.51	5.41±1.12	33.1±4.16	23.0±2.68
PO_4	R	0.03-0.05	0.04-0.06	4.26-5.11	5.87-9.57	3.27-6.71
(mg N/L)	M±Sd	0.04±0.008	0.047±0.009	4.89±0.42	8.12±1.58	5.10±1.41

R: Range; M: Mean; Sd: Standard deviation

PO_4-P in ground and surface waters depends on population density, agricultural fertilization methods and fertilization frequency, and vegetation and soil structure are also significantly influenced by PO_4-P accumulation in waters. In addition, it has been reported that detergents used in cleaning and reaching the receiving water environment with wastewater are factors affecting PO_4-P concentration (Wetzel, 2001). According to the classification reported by Uslu and Türkman (1987) based on phosphate concentrations in waters; waters with phosphate concentrations up to 0.02 mg/L is Class I, waters up to 0.16 mg/L Class II, waters up to 0.65 mg/L Class III, water higher than 0.65 mg/L has class IV water quality (Wetzel, 2001). The minimum mean value of PO_4-P was 0.04 mg/L, registered in stations #1, and the maximum was 8.12 mg/L in station #4.

According to the drinking water standards reported by the WHO, it is expected that the NO_2-N value in the waters will not exceed the 0.2 mg/L limit (WHO, 2011). According to the EC directive reported by the European Commission, the NO_2-N concentration in waters is expected not to exceed the 0.03 mg/L limit in terms of cyprinid health (EC, 2006). The minimum mean value of NO_2-N was 0.08 mg/L in station #1, and the maximum was 5.31 mg/L in station #4. Accordingly, NO_2-N concentrations detected downstream stations in Kelebek Stream almost pose a risk to cyprinid health. As it is known, the most important sources of NO_2-N in waters are; organic substances, nitrogenous fertilizers and some minerals (Wetzel 2001). The very high nitrite values detected in the waters of the region show that the wastes of the settlements are discharged into the system without any or sufficient purification and that agricultural fertilizers used in the basin are an ecologically important source of stress.

Ammonium content increases as a result of the deterioration of organic materials, especially organic fertilizer and chemical fertilization from inorganic ammonium, discharge of domestic and industrial wastewater (Egemen and Sunlu, 1996). Tanyolaç (2004) states that ammonium nitrogen is generally below 1.0 mg/L in clean waters. The minimum mean value of NH_4-N was 0.05 mg/L in station #1, and the maximum was 13.4 mg/L in station #4.

Cl^- values are very important in terms of both drinking, industrial and irrigation water quality (Ünlü et al. 2008). The high Cl^- values indicate that the electrical conductivity is also high. The amount of chloride in many drinking water does not exceed 30 mg/L (Egemen and Sunlu, 1996). The mean value of Cl (mg/L) varied from 2.99 mg/L in station #1 in the source area, up to 33.1 mg/L in station #4 of the stream.

These values showed that upstream stations of the stream indicates the “good” water quality class according to Klee (1991), but the water quality decreases in the downstream stations of the stream.

Benthic Macroinvertebrate Data

In this study, a total of 4.130 benthic macroinvertebrate samples were collected; all the specimens collected belong to nine groups: Oligochaeta, Mollusca, Crustacea, Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, Diptera. The maximum numbers of individual were collected at station #5 (928 individuals), while the minimum numbers of individual were collected at station #1 (711 individuals). The lowest number of individuals were determined in autumn while the highest number of individuals were determined in spring with the collection of all benthic invertebrate samples (Figure 2).

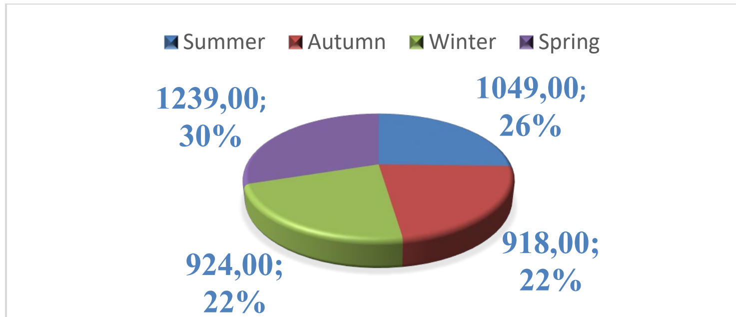

Figure 2. The total percent of benthic macroinvertebrates according to season.

As a result of this count, the most dominant group in all benthic macroinvertebrate groups was Insecta in the stream (Figure 3).

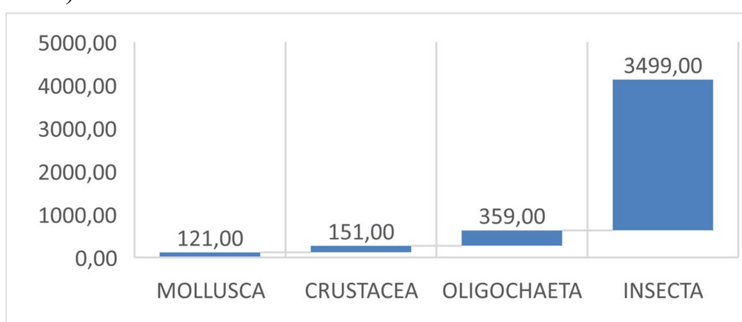

Figure 3. Benthic invertebrate groups in Kelebek Stream.

Considering all taxonomic groups in the stream, Ephemeroptera is the most dominant group in station #1, #2 and #5 (44%, 34% and 27% respectively). Diptera is the most dominant group in station #3 and #4 (43%) (Figure 4).

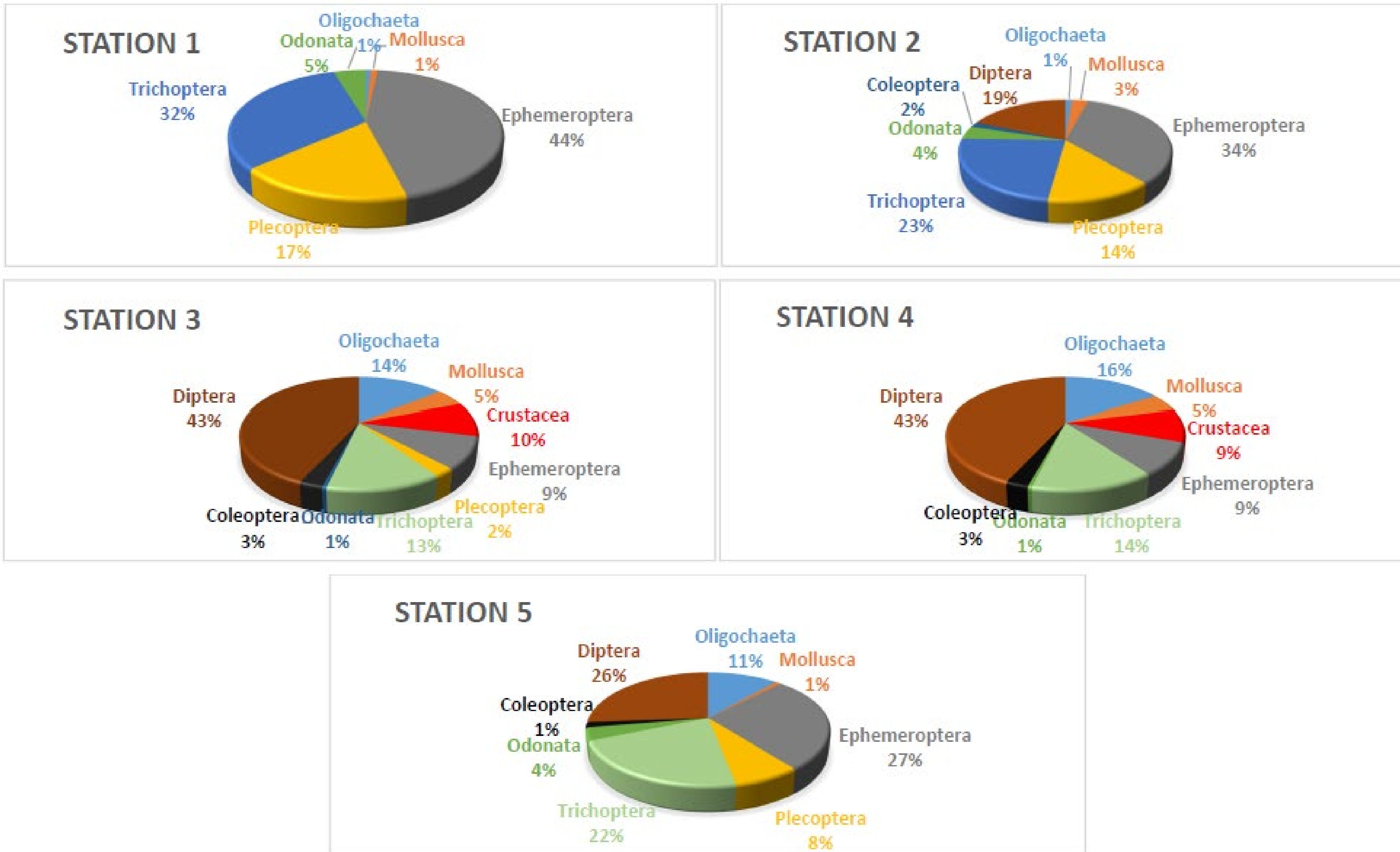

Figure 4. Dominancy (%) of benthic macroinvertebrate orders at the stations.

Distributions and relative percentage of occurrence (%), along with a list of the recorded macroinvertebrates with color codes, were showed in Table 3. The relative percentages of occurrence (%) of the determined species were differed from each other. For instance, *Baetis* sp. was the most dominant species (7.454%, 5.698%) at the station #1 and #2, respectively; *Gammarus* sp. (9.961%, 9.591%) at the station #3 and #4, respectively; *Simulium* sp. (5.585 %) at the station #5. *Gammarus* sp., which belongs to the group of Amphipoda is found in low polluted river sections (Meyer, 1987). *Limnodrilus* species, *Chironomus* sp. and *Chironomus tentans* (Fabricius, 1805) were dominant species at the station #3, #4 and #5. These species are an indicator for polysaprobic (heavy polluted) aquatic systems (Kalyoncu and Zeybek 2011; Arslan et al. 2016; Zeybek, 2017). According to Moisan and Pelletier (2008), these organisms tolerant range are high. They can find low or high DO (mg/l) concentration, Sat O_2 (%) and T (°C). Existent abundant of the organic matter are favorable for benthic macroinvertebrates such as Diptera and Oligochaeta (Rashid and Pandit, 2014). Kalyoncu and Zeybek (2009) determined that the 6th station, which is the downstream point of the stream, has low organism diversity. On the other hand, the most dominant group was Diptera followed by Oligochaeta (*Tubifex tubifex*). *Chironomus thummi* from Diptera, and *Simulium* sp. were the most dominant taxa in Isparta Stream.

Table 3. Distributions and relative occurrence (%) of macrobenthic invertebrates at the stations.

	#1	#2	#3	#4	#5
OLIGOCHAETA					
Haplotaxida					
(1) *Tubifex tubifex* (Muller, 1774)	-	0.223	2.883	3.324	2.738
(2) *Tubifex nerthus* (Michaelsen, 1908)	-	0.111	2.359	2.941	1.971
Naididae					
(3) *Limnodrilus hoffmeisteri* (Claparede, 1862)	-	-	2.491	2.685	2.519
(4) *Limnodrilus udekemianus* (Claparede, 1862)	-	-	2.228	2.685	2.081
(5) *Limnodrilus claparedianus* (Ratzel, 1869)	-	-	2.621	1.918	1.533
(6) *Psammoryctides albicola* (Michaelsen, 1901)	0.141	0.111	1.048	0.895	0.657
Enchytraeidae					
(7) *Cognettia glandulosa* (Michaelsen, 1888)	-	0.558	0.786	0.767	-
(8) *Henlea perpusilla* (Friend, 1911)	0.562	0.223	-	1.151	-
MOLLUSCA					
Physidae					
(9) *Physella acuta* (Draparnaud, 1805)	-	0.782	1.572	1.662	-
Planorbidae					
(10) *Gyraulus albus* (Muller, 1774)	-	0.558	1.179	1.406	-
Lymnaeidae					
(11) *Radix labiata* (Müller, 1774)	-	0.671	0.917	0.383	-
Valvatidae					
(12) *Valvata piscinalis* (Müller, 1774)	0.562	0.558	0.917	0.639	0.547
Melanopsidae					
(13) *Melanopsis* sp.	0.421	0.446	0.524	1.023	0.328
CRUSTACEA					
Gammaridae					
(14) *Gammarus* sp.	-	-	9.961	9.591	-

INSECTA					
Ephemeroptera					
Baetidae					
(15) *Baetis* sp.	7.454	5.698	2.752	2.685	3.504
(16) *Baetis alpinus* (Pictet, 1843)	4.781	3.687	1.834	1.662	2.957
(17) *Baetis muticus* (Linnaeus, 1758)	4.501	3.687	1.441	1.406	2.628
(18) *Baetis rhodani* (Pictet, 1843)	7.454	5.811	1.965	1.791	3.943
Ephemeridae					
(19) *Ephemera* sp.	4.219	3.016	0.262	0.383	2.628
(20) *Ephemera danica* (Müller, 1764)	3.797	2.793	0.131	0.255	2.519
Heptageniidae					
(21) *Heptagenia* sp.	4.078	3.798	0.655	0.639	3.395
(22) *Heptagenia sulphurea* (O.F. Müller, 1776)	4.219	3.575	0.262	0.383	3.066
(23) *Rhithrogena* sp.	3.797	3.128	0.131	0.127	3.066
Plecoptera					
Perlidae					
(24) *Perla sp.*	5.485	4.022	0.655	-	1.971
(25) *Perla bipunctata* (Pictet, 1833)	5.485	4.134	0.786	-	1.861
Nemouridae					
(26) *Nemoura marginata* (Pictet, 1836)	3.375	2.793	0.524	-	1.861
(27) *Nemoura* sp.	3.094	2.905	0.524	-	1.971
Trichoptera					
Glossosomatidae					
(28) *Glossosoma* sp.	3.375	2.905	2.359	2.557	3.395
(29) *Glossosoma boltoni* (Curtis 1834)	2.390	1.787	1.703	1.791	2.301
(30) *Glossossoma conformis* (Neboiss, 1963)	2.109	1.675	1.048	1.151	2.409
Hydropsychidae					
(31) *Hydropsyche* sp.	4.501	3.351	2.096	2.046	2.738
(32) *Hydropsyche fulvipes* (Curtis, 1834)	3.516	2.569	1.179	1.662	2.519
(33) *Hydropsyche instabilis* (Curtis, 1834)	2.672	1.899	0.655	0.767	0.657
Limnephilidae					
(34) *Limnephilus* sp.	2.251	2.011	1.048	1.023	1.752
(35) *Limnephilus lunatus* (Curtis, 1834)	2.251	1.899	-	-	1.204
Rhyacophilidae					
(36) *Rhyacophila* sp.	3.094	2.458	1.834	1.662	1.861
(37) *Rhyacophila isparta* (Sipahiler, 1996)	2.251	1.341	1.048	1.151	1.861
(38) *Rhyacophila balcanica* (Radovanovic 1953)	3.516	1.899	0.524	0.511	1.314
Odonata					
Aeshnidae					
(39) *Aeshna viridis* (Eversmann, 1836)	0.984	1.005	-	-	0.766

(40) *Anax imperator* (Leach 1815)	0.984	0.782	-	-	0.985
Calopterygidae					
(41) *Calopteryx virgo* (Linnaeus, 1758)	0.421	0.446	-	-	0.328
Coenagrionidae					
(42) *Coenagrion ornatum* (Selys, 1850)	0.562	0.335	-	-	0.328
Gomphidae					
(43) *Onychogomphus* sp.	0.984	1.117	0.524	0.511	1.095
(44) *Gomphus* sp.	0.703	0.671	-	-	0.219
Coleoptera					
Dytiscidae					
(45) *Agabus bipustulatus* (Linnaeus, 1767)	-	0.893	1.179	1.151	0.766
(46) *Scarodytes halensis* (Fabricius, 1787)	-	0.446	0.917	0.895	0.766
(47) *Hydroporus angustatus* (Sturm, 1835)	-	0.335	0.655	0.639	-
Diptera					
Simulidae					
(48) *Simulium* sp.	-	3.911	7.339	7.672	5.585
(49) *Simulium ornatum* (Meigen, 1818)	-	3.351	5.111	4.475	2.519
Chironomidae					
(50) *Chironomus* sp.	-	0.558	6.291	7.289	3.066
(51) *Chironomus tentans* (Fabricius, 1805)	-	-	5.242	5.626	2.519
(52) *Chironomus pallidivittatus* (Edwards, 1929)	-	0.335	4.062	4.731	2.519
(53) *Synendotendipes lepidus* (Meigen, 1830)	-	1.452	2.752	2.301	1.861
(54) *Polypedilum convictum* (Walker, 1856)	-	1.452	2.096	1.791	1.423
(55) *Polypedilum laetum* (Meigen, 1818)	-	1.341	2.491	2.173	1.204
(56) *Procladius* sp.	-	2.346	3.801	3.324	2.519
Tipulidae					
(57) *Tipula* sp.	-	2.122	2.621	2.685	1.752
Tabanidae					
(58) *Tabanus* sp.	-	2.122	2.359	1.791	1.642

In terms of diversity, the richest was sampling station #2 with 26 families each, 9 of them belonging to Ephemeroptera-Plecoptera-Trichoptera (EPT) group that are classified as sensitive organisms to the oxygen concentration in the water. The high percentage of EPT taxa indicates high water quality (Lenat, 1993). In station #2 the most dominant within EPT were Trichoptera, with 4 families. The dominance of the orders Ephemeroptera, Plecoptera and Trichoptera which are considered to be sensitive to environmental stress signifies relatively clean conditions (Merritt, 1978). Four Diptera and Odonata, five Mollusca, three Oligochaeta an one Coleoptera families composed the rest of the macroinvertebrates in station #2. The station #2 is in the upstream of the Kelebek Stream. According to Meyer (1987), *Baetis* sp. and *Baetis rhodani* located in the organically less polluted stream section and included in water quality "class I-II". Zeybek et al. (2014) determined most dominant taxon was Ephemeroptera (a pollution sensitive species) in upstream sampling stations in Değirmendere Stream. In the downstream stations except station #5, the number of EPT families decreased, comparing to station #1 and station #2.

EPT-Taxa [%] was one of the metrics given the best response to the physicochemical variables of water. This metrics are indicated that EPT taxa are sensitive to anthropogenic effects while Oligochaeta taxa are tolerant to anthropogenic effects in aquatic ecosystems (Ode et al. 2005). In this study, the highest EPT-Taxa [%] values are obtained at the station #1 and #2. These stations are the upstream part of the stream and they are less affected by domestic wastes. On the contrary, the station #3 and #4 are downstream part of the stream. These stations are mostly affected the domestic wastes. The cause of low EPT-Taxa [%] values at the downstream stations in stream is of the pollution that accumulates in the stream as a result of the anthropogenic activities. Other factors depend of the physical properties of the stream such as high temperature, low stream incline and reduction of stream flow.

In sampling station #4 due to heavy pollution with dam construction and domestic waste waters, diversity of macroinvertebrates decreased and was dominated by semi tolerant and tolerant families to pollution, such as Baetidae, Chironomidae, Tubificidae, Haplotaxida, Naididae, Enchytraeidae, Tipulidae, Tabanidae and Dytiscidae. According to Hynes (1994), presence of numerous families of highly tolerant organisms usually indicates poor water quality. Due to the pollution of river water, the number of sensitive species is reduced and gradually the environmental conditions change in favor of semi tolerant and tolerant species (Zimmerman, 1993). Going downstream, in sampling station #3, #4 and #5 macroinvertebrate samples consisted from Oligochaeta worms and Diptera, presented in high abundance. Oligochaeta is very common in streams and rivers. They are known as tolerant of bad or poor water quality and can tolerate heavy to extreme pollution. According to Brinkhurst and Kennedy (1965), many species of Oligochaeta are tolerant of low oxygen concentration and can live in anoxic conditions (Brinkhurst and Kennedy, 1965). Due to high tolerance to organic pollution, they are used as a good indicator species of organic pollution (Barbour, 1996).

The increased number of species in station #2 and #5 occured as the result of increased water level and flow velocity in this station. Due to this improvement in environmental conditions, in the station #5, the number of taxa further increased. In total 22 families were present, 9 belonging to the sensitive and semi-sensitive EPT group, and the rest consisted of semi tolerant-tolerant organisms (Dytiscidae, Physidae, Planorbidae, Valvatidae, Melanopsidae, Lymnaeidae).

Biotic Index Correlations and Statistical Data Analysis

The ecological conditions of Kelebek Stream indicate that the stream is disturbed by anthropogenic activities. The water classification in quality classes (QCs) with biotic and diversity indices is shown in Table 4. The distribution of the biotic index results according to seasons are shown by using multiple regression analysis ($R^2>0.5$) in Figure 5.

All diversity indices have shown the highest values in station #2, whereas the lowest values are registered in station #4. High species diversity at the upstream stations indicates unpolluted conditions whereas low species diversity in station #3 and #4 indicates environmental stress. The sampling station #3 and #4 are heavily disturbed due to dam construction and many domestic wastes discharged in this part of the stream. In these two stations, the BOI_5 value is the highest, which indicates the presence of organic pollution in the water and oxygen consumption for the decomposition of organic matter. The oxygen depletion at these stations is manifested with low species diversity. Regarding the usefulness of diversity indices in the assessment of water bodies, they have been proven to be useful tools for describing the structure of the communities, but they do not indicate the pollution level of aquatic bodies. They are good for assessing organic pollution and eutrophication but poor for assessing toxicity and physical changes.

The all versions of BMWP index values were highest in station #1 and #5. Based on the ecological quality ratio (EQR), in these two stations, the water is classified in II quality class. The stream water quality is decreasing drastically and becomes of moderate quality (station #2, #3 and #4). According to SI, the station #1 is *Oligosaprob/ Betamesosaprob*- Class I-II quality class while the rest of the stations are *Betamesosaprob*- Class II. This index scores in Table 4 indicates that upstream of the stream, due to the distance with inhabited areas and lack of waste discharge, the water has a minimum human impact and is of high quality. Going downstream, in urban and rural areas, human activities become more intensive and impact physical and chemical parameters of the water that is manifested with moderate water quality.

Our results show that there are differences in water quality classification with different indices analyzing similar research in water quality assessment with biotic and diversity indices in other countries, we can see that some of the macroinvertebrate based indices are more sensitive and some are less sensitive to the environmental changes and it is difficult to choose which index is more reliable to be applied in stream and river quality assessment in a country (Kalyoncu and Zeybek, 2011). In our research BMWP (Original), BMWP (Spanish) and BMWP (Greek) seem to be more reliable and reflect better the environmental situation since they both are based on the presence of sensitive species to environmental variables.

In this study, the random sample cases (*10% select case*) was made on the biotic indices and physicochemical parameters to verify data sets and to determine that the data was transferred without errors in the SPSS version 20.0. Table 5 indicates the correlations of biotic and diversity indices.

As a result of the correlation analysis, the highest positive significant correlation was found between the BMWP (Original), BMWP (Spanish) and BMWP (Greek). The SI is the negatively significant correlated with ASPT, BMWP (Original), BMWP (Spanish) and BMWP (Greek). BMWP (Greek) is the positively significant correlated with ASPT *(r-value 0.952, p<0.05)*; BMWP (Greek) is the negatively significant correlated with FBI *(r-value 0.952, p<0.05)*. ASPT is the negatively significant correlated with FBI *(r-value -0.970, p<0.01)*. However, the increase in index values of BMWP (Original), BMWP (Spanish) and BMWP (Greek) shows good ecological quality.

Table 4. Average score values and water quality classes of all indices in the stream.

Metric	Station 1	Station 2	Station 3	Station 4	Station 5
SI	1.751	1.863	1.883	1.874	1.784
Water quality class	**I-II**	**II**	**II**	**II**	**II**
QCs defined by WFD	**High**	**Good**	**Good**	**Good**	**Good**
BMWP (Original)	113	87	88	73	103
Water quality class	**II**	**III**	**III**	**III**	**II**
QCs defined by WFD	**Good**	**Moderate**	**Moderate**	**Moderate**	**Good**
BMWP (Spanish)	124	95	98	83	112
Water quality class	**II**	**III**	**III**	**III**	**II**
QCs defined by WFD	**Good**	**Moderate**	**Moderate**	**Moderate**	**Good**
BMWP (Greek)	1174	921	912	767	1076
Water quality class	**II**	**III**	**III**	**III**	**II**
QCs defined by WFD	**Good**	**Moderate**	**Moderate**	**Moderate**	**Good**
ASPT	6.946	5.722	5.026	4.812	6.161
Water quality class	**I**	**II**	**II**	**III**	**I**
QCs defined by WFD	**High**	**Good**	**Good**	**Moderate**	**High**
BBI	10	10	9	8	10
Water quality class	**I**	**I**	**I**	**II**	**I**
QCs defined by WFD	**High**	**High**	**High**	**Good**	**High**
FBI	3.25	4.08	4.91	5.20	4.21
Water quality class	**I**	**II**	**II**	**II-III**	**I-II**
QCs defined by WFD	**High**	**Good**	**Good**	**Moderate**	**High**
Diversity Indices					
SDI	0.962	0.976	0.964	0.959	0.972
SWDI	3.528	3.681	3.574	3.293	3.684
MDI	7.036	7.627	7.507	5.025	7.317

Table 5. Pearson's based correlation assesment between biotic and diversity indices in the stream.

	SI	BMWP (Original)	BMWP (Spanish)	BMWP (Greek)	ASPT	FBI	BBI	SDI	SWDI	MDI
SI	1	-,916*	-,919*	-,920*	-,939*	0,833	-0,648	0,004	0,325	0,748
BMWP (Original)		1	,998**	,999**	,941*	-0,878	0,801	0,033	-0,288	-0,653
BMWP (Spanish)			1	,994**	,933*	-0,866	0,76	-0,029	-0,342	-0,692
BMWP (Greek)				1	,952*	-,892*	0,821	0,059	-0,27	-0,644
ASPT					1	-,970**	0,823	0,033	-0,33	-0,715
FBI						1	-0,848	0,01	0,375	0,69
BBI							1	0,463	0,13	-0,227
SDI								1	,930*	0,65
SWDI									1	0,868
MDI										1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

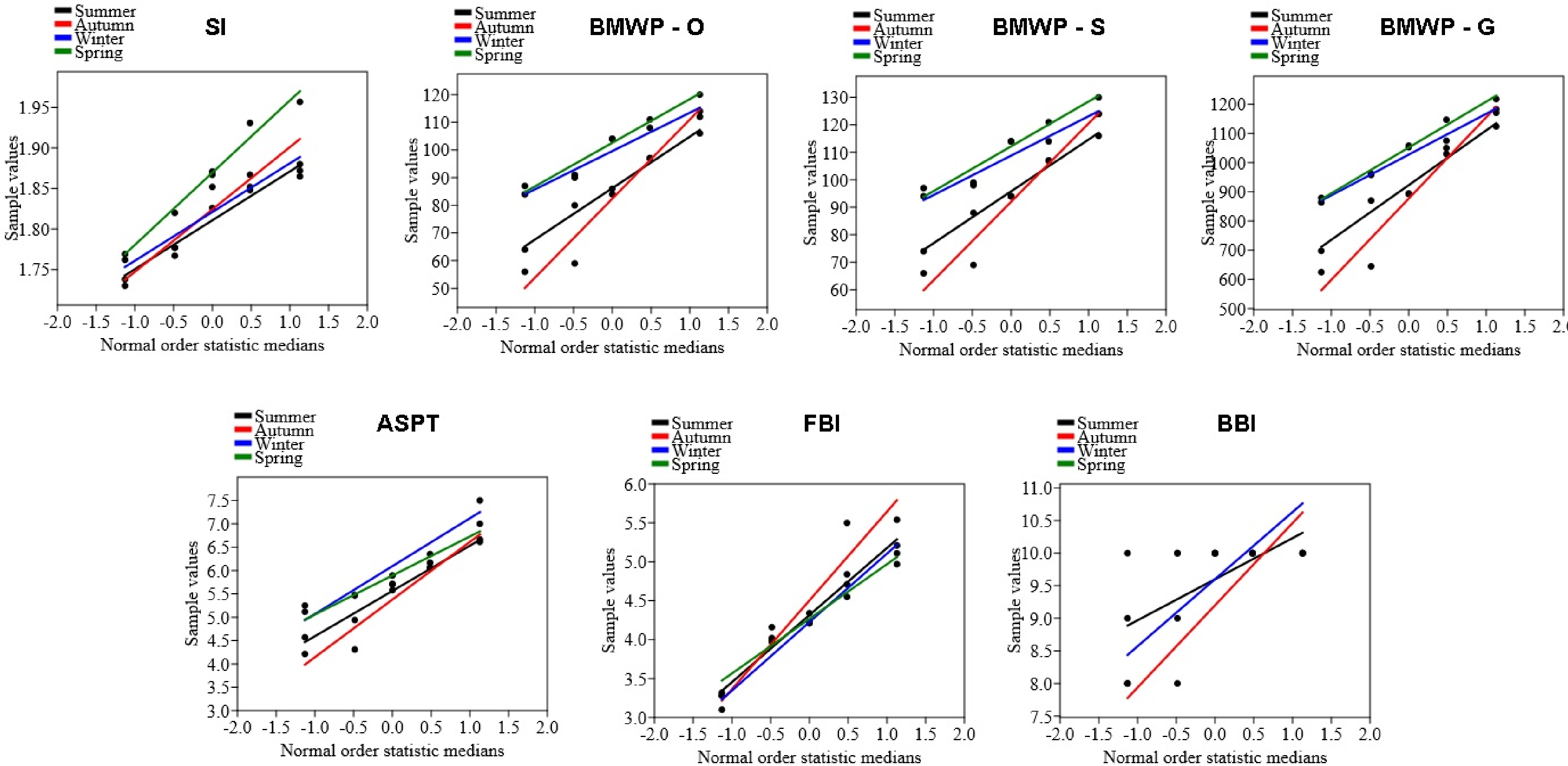

Figure 5. The distribution of the biotic index scores according to seasons in Kelebek Stream.

In this research, CA was applied on lake parameters, to determine spatial similarity and dissimilarity for classifying of stations. The resulted dendogram (Figure 6), grouped all the five sampling stations into two statistically significant clusters, as station (station #1- #2) and (station #3- #4). On the other hand, the highest similarity was identified in the 3rd and 4th station while the second highest similarity was identified in the 1st and 2nd station.

Biotic parameters and 22 environmental variables were only used in CCA analysis according to the Kaiser-Meyer-Olkin (KMO) Sample Proficiency Test (Figure 7). The obtained results of the KMO Sample Proficiency Test were calculated as 0.793 and show that the sample size is quite good and sufficient. The CCA analysis led to the explanation total of 88% variance according to benthic macroinvertebrate orders. The distributions of EPT/OL [%] and EPT- Taxa [%] are positively correlated to DO, Sat. O_2 and pH. The distributions of Oligochaeta is positively correlated to EC, Cl, Turbidity, BOI_5, PO_4-P, NH_4-N, NO_2-N and NO_3-N (Figure 7a). The CCA analysis led to the explanation total of 86.2% variance according to benthic macroinvertebrate species. The distributions of *Simulium* sp., *Chironomus* sp., *Chironomus tentans*, *Tubifex tubifex* and Limnodrilus species are positively correlated to EC, Cl, Turbidity, BOI_5, PO_4-P, NH_4-N, NO_2-N and NO_3-N while they are negatively correlated to DO, Sat. O_2 and pH (Figure 7b). The CCA analysis led to the explanation total of 88.1% variance according to biotic indices. The distributions of BMWP (Original), BMWP (Spanish), BMWP (Greek), ASPT and BBI are positively correlated to DO, Sat. O2 and pH (Figure 7c).

Kazancı and Dügel (2000) recorded that the BBI was in compliance with the physicochemical parameters in Yuvarlak Stream. Kantzaris et al. (2002) recorded that the BMWP, ASPT and Land Quality Indicators (LQI) were insufficient in evaluating water quality while BBI and IBE were proper. Öz and Şengörür (2004) reported that BBI was in accordance with the other indices. Kalyoncu et al. (2008) stated that the BBI and physicochemical data were more proper to evaluate the water quality. Kazancı et al. (2010) mentioned that the BMWP and ASPT were sufficient to evaluate water quality in Aksu Stream. Ogleni and Topal (2011) mentioned that the BMWP and ASPT were sufficient to evaluate water quality. Kalyoncu and Zeybek (2011) found that SWDI and BBI seem to be the most reliable to determine the water quality. Yorulmaz et al. (2015) applied five biotic indices and noted that the FBI was insufficient in evaluating water quality while ASPT, BMWP, SI, and BBI were appropriate. Zeybek et al. (2014) found deviations between BMWP versions. Zeybek (2017) found that the most appropriate indices for the physical and chemical indices were BMWP (original version) and ASPT (original and Czech versions).

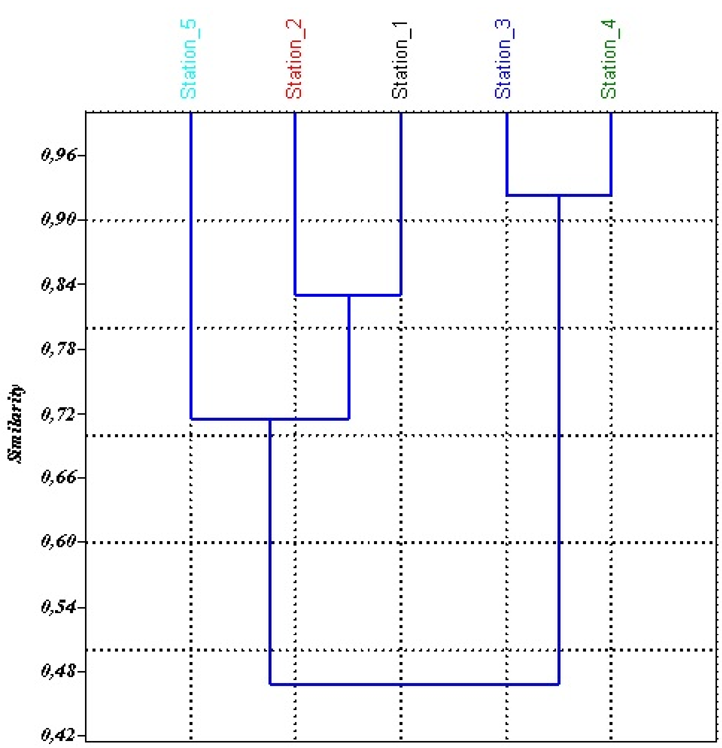

Figure 6. Classification of stations based on similarities of in Kelebek Stream.

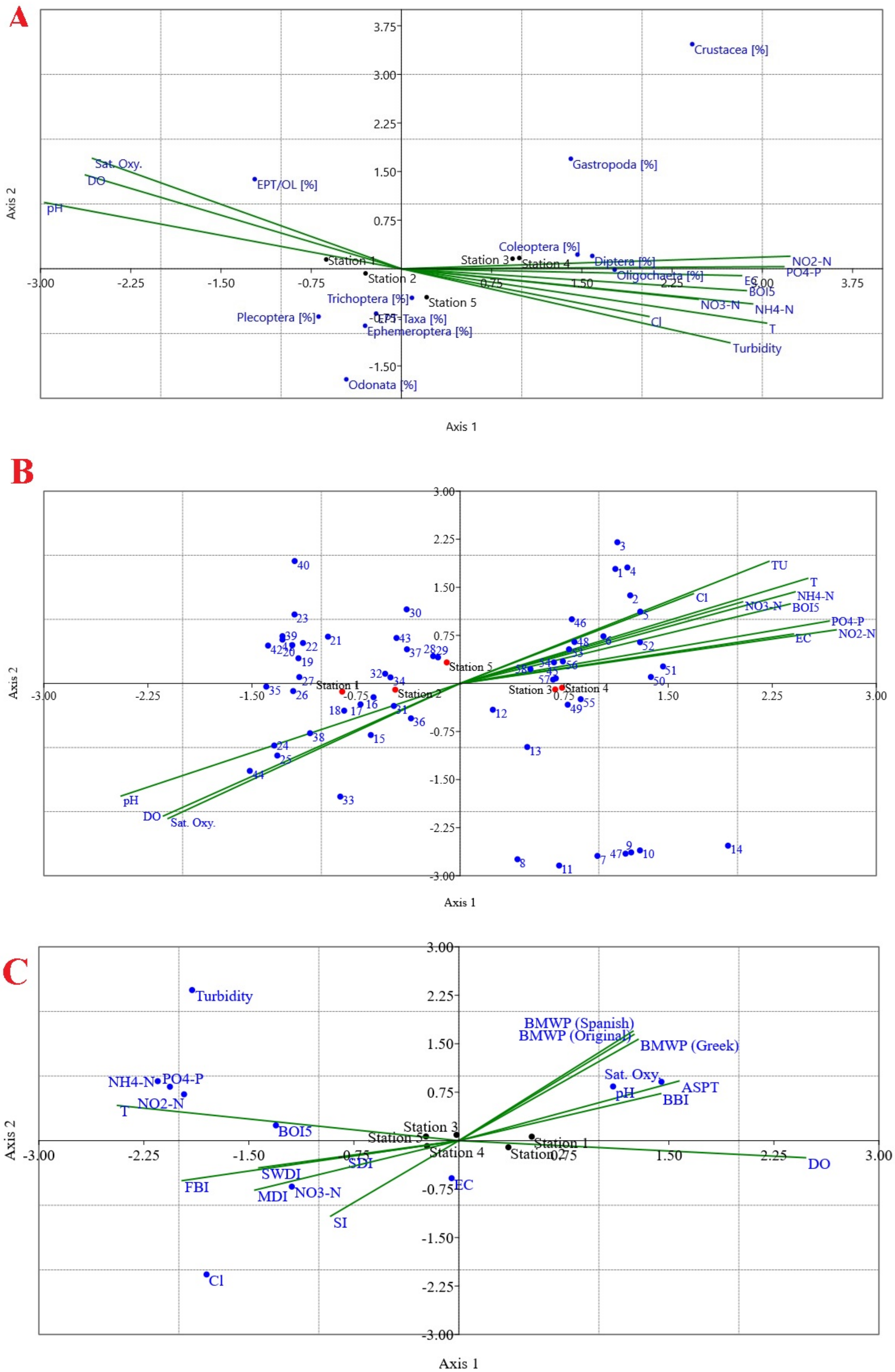

Figure 7. CCA plot of reference-, test-, and the most disturbed sites distributions with environmental variables.

Conclusion

From our results, we can conclude that Kelebek Stream is disturbed by many anthropogenic activities. The main pollution sources remain the untreated wastewaters that are directly discharged into the stream, as well as industrial discharges, agricultural runoff and land use. The upstream stations of the stream are less polluted due to the distance with populated areas and farming activities, whereas in urban areas the stream is heavily polluted and this is reflected in macroinvertebrate assemblage and distribution. The increased pollution in station #3 and #4 caused the disappearance of sensitive species from this part of the stream and appearance of more pollution tolerant species, adapted to specific habitats. Our results have shown that the ecological status of the Kelebek Stream is moderate quality and urgent measures for the protection of Gediz River Basin and other water resources in Turkey must be implemented through professional management plans for river basins.

To improve the quality of Kelebek Stream, one of the most important branch of the Gediz River, to reduce stress and pressure on aquatic organisms and to protect the health of the local people;

- Prevention of uncontrolled discharge of debris removed during the dam construction into the stream,
- Industrial establishments located in the basin should be inspected frequently and prevented from giving their wastes to the system without treatment,
- In addition, the water quality of the stream should be monitored continuously, both physically, chemically and biologically, and should be able to intervene quickly if necessary.

We believe that this study will constitute a vital perspective to the monitoring of freshwaters in terms of data.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

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Ordu ili iç sularında *Carassius auratus* (Linnaeus, 1758) türünün ilk kaydı ve türün Ulugöl Yaylası Göleti popülasyonuyla ilgili bazı veriler

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ÖZ

Akvaryum balığı ticareti dünyada git gide popülaritesini arttıran global sanayi alanlarından biridir. Bu sektör tüm dünyada olduğu gibi Türkiye'de de istilacı türlerin en önemli yayılma nedenlerinden biridir. Günümüzde Türkiye iç sularında da yerli olmayan akvaryum balığı türlerinin varlığını bilinmektedir. Bu çalışmada, *Carassius auratus* türü Orta Karadeniz Bölgesi Ordu ili iç sularında ilk kez kaydedilmiştir. *C. auratus* türünün balıklandırma amacıyla Ordu-Mesudiye'de bulunan Ulugöl Yaylası Göleti'ne bırakıldığı tahmin edilmekle birlikte, bu habitata uyum sağladığı da görülmektedir.

Anahtar Kelimeler: *Carassius auratus*, İstilacı tür, Akvaryum balığı, Karadeniz, Türkiye

ABSTRACT

First record of the *Carassius auratus* (Linnaeus, 1758) in inland waters of Ordu province and some data on the Ulugöl plateau pond population of the species

Aquarium fish trade is one of the global industrial areas that is gradually increasing in popularity throughout the world. The sectors all over the world as well as in Turkey is one of the major causes of the spread of invasive species. The non-native aquarium fish species is known for the existence of Turkish inland waters these days. In this study, *Carassius auratus* were recorded for the first time in the inland waters of Ordu province of the middle Black Sea Region. *C. auratus* was stocked in the Ulugöl Plateau Pond in Ordu-Mesudiye for fisheries purposes and adapted to this habitat.

Keywords: *Carassius auratus*, Invasive species, Aquarium fish, Black Sea, Turkey

Giriş

Akvaryum sektörü dünyada en önemli sektörlerden biri olmaya aday olan bir ticaret dalı olarak görülmektedir. Ancak bu alanda Almanya, Amerika, Hollanda, İngiltere ve Japonya gibi birkaç gelişmiş ülke hariç diğer ülkelerde akvaryum sektörüyle alakalı bilgiler oldukça sınırlı sayıdadır (Çelik vd., 2014). Bu sektörde en büyük ithalatçı devlet olarak Amerika yer alırken onu sırasıyla İngiltere ve Almanya izlemektedir (FAO, 2011). En büyük ihracat yapan ülke ise İspanya olup onu sırasıyla Singapur ve Japonya izlemektedir (FAO, 2011). Türkiye'de ise bu sektör oldukça kısıtlı olup son yıllarda git gide artış göstermektedir (Hekimoğlu, 2006; Çelik vd., 2014).

Ülkemizde her ne kadar akvaryum balığı yetiştiriciliği yapılıyor olsa da bu sektördeki ürünlerin büyük çoğunluğu ithalat yoluyla temin edilmektedir (Büyüktaş ve Kızak, 2018). Örneğin TUİK 2013 verilerindeki Türkiye'de gerçekleştirilen ithalat ve ihracat değerleri incelendiğinde de bu sektörün ithalat değerinin ihracat değerinden oldukça fazla olduğu gözlemlenmiştir. Türkiye'de bu sektörde ithalatta en büyük payı *Carassius auratus* türü almaktadır. Bu yüzden akvaryum piyasasında en bilinen ve akvaristler tarafından en fazla tercih edilen balıklar arasındadır (Yanar ve Tekelioğlu, 1999).

C. auratus türü Cyprinidae familyasında *Carassius* cinsi içerisinde yer alan beş türden biridir (Froese ve Pauly, 2020). Bu türün doğal yayılım alanı Çin ve Japonya suları olup doğal formları gümüş veya grimsi renklerdedir. Ancak günümüzde bu türün kültür formları da bulunmakta olup bunlar beyaz, kırmızı, turuncu ve karışık gibi farklı renklerde olabilmektedir (Froese ve Pauly, 2020). IUCN kırmızı listesine göre düşük seviyede (LC) tehdit altında olarak sınıflandırılan bu tür (Huckstorf ve Freyhof, 2013) Türkiye iç sularında istilacı bir balık türü konumundadır. Ayrıca bu türün Türkiye iç sularında farklı bölgelerde varlığı rapor edilmiştir (İnnal, 2011). Bu türün ülkemiz sularına akvaristler tarafından yanlışlıkla veya bilinçli olarak bırakılmasıyla ya da balıkların üretim çiftliklerinden kaçması sonucunda yayıldığı tahmin edilmektedir. Bu çalışma ile Orta Karadeniz Bölgesi'nde Ordu ili iç sularında *C. auratus* türü ilk defa rapor edilmekte olup, bu türün Ulugöl Yaylası Göleti popülasyonundaki bireyler için bazı metrik ve meristik karakterleri de bildirilmiştir.

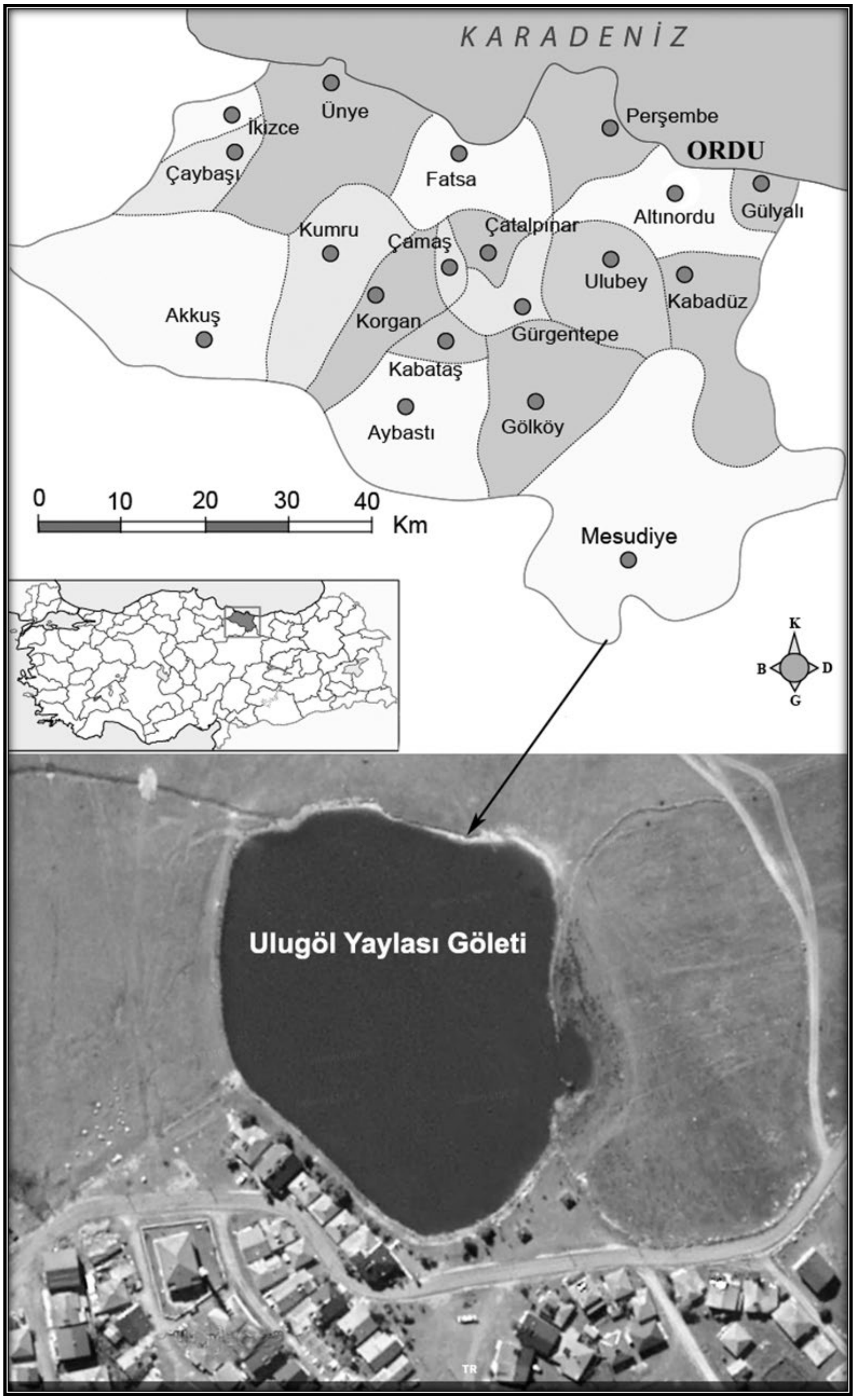
Materyal ve Metot

Arazi çalışmaları Ordu ilinin iç kesimlerinde yer alan Mesudiye ilçesindeki Ulugöl Yaylası Göleti'nde gerçekleştirilmiştir (40°23'57.1"N - 37°50'00.2"E) (Şekil 1). Balık örnekleri göletin derinliği az olan kıyı kesimleri boyunca Samus marka elektroşoker yardımıyla yakalanmıştır. Yakalan balık örnekleri Ordu Üniversitesi Hidrobiyoloji laboratuvarına getirilmiş ve tür tayinleri balık katalogları (Kottelat ve Freyhof, 2007) ve Fishbase veri tabanı (Froese ve Pauly, 2020) kullanılarak yapılmıştır. Balık örneklerinin ağırlıkları 0,1 g hassasiyetle alınmış olup total boy, çatal boy ve standart boy ölçümleri ise 0,1 mm hassasiyetle ölçülmüştür. Morfometrik ölçümlerin tanımlayıcı istatistik değerleri belirlenmiştir. Daha sonra yanal çizgideki pul sayısı, dorsal, anal, pektoral ve ventral yüzgeçlerinde bulunan diken ve yumuşak ışınlar sayıları belirlenmiştir. Balık örnekleri karın bölgesinden kesilerek gonad durumuna göre cinsiyetleri saptanmıştır.

Bulgular ve Tartışma

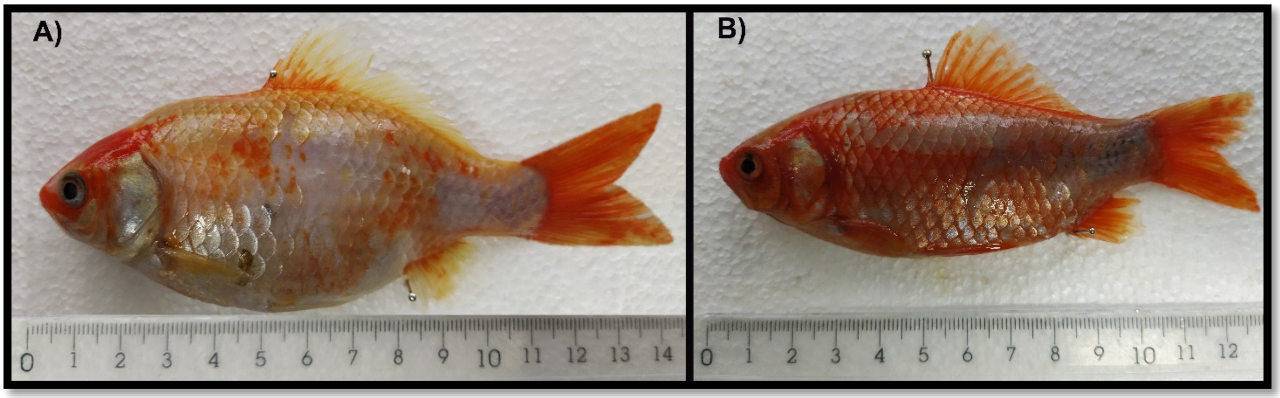
Ordu ili sınırları içerisinde bulunan Ulugöl Yaylası Göleti'nde yapılan çalışmalarda ilgili habitatta çok sayıda *Carassius auratus* bireyi gözlemlenmiştir. Bu habitattan yakalan örneklerin önce gerekli metrik ve meristik ölçümleri yapılmış ve daha sonra örneklerin cinsiyet tayinleri yapılmıştır. Ulugöl Yaylası Göleti'nden örneklenen *Carassius auratus* türünün dişi ve erkek bireyleri Şekil 2'de sunulmuştur.

Yakalanan balık örneklerinin vücutları oval, gözleri iri ve ağızları terminal konumlu olup bıyık bulunmamaktadır. Çalışmada örneklenen bireylerin vücutlarının turuncu, beyaz, kırmızımsı veya karışık renklerde oldukları gözlemlenmiştir (Şekil 2). Örneklenen erkek *C. auratus* bireylerinin total boy, çatal boy ve standart boy ölçümlerinin minimum, maksimum ve ortalama standart hata değerleri sırasıyla 10,8-14,7 cm (12.6 ±0.8), 9.5-12.8 cm (11.3 ±0.7) ve 7.4-10.0 cm (9.3 ±0.6) olduğu, dişi bireylerde ise bu değerlerin yine sırasıyla 11,5-15.2 cm (13.9 ±0.4), 10.9-13.3 cm (12.3 ±0.3) ve 9.4-11.3 cm (10.5 ±0.3) olduğu belirlenmiştir. Dişi ve erkek bireylerin minimum, maksimum ve ortalama vücut ağırlıkları ise sırasıyla dişiler için 26.2-49.2 g (37.1 ±2.5) olarak erkekler için ise 11.4-29.4 g (23.7 ±4.2) olarak belirlenmiştir. Çalışmamızda örneklenen *C. auratus* bireylerinde tespit edilen bazı metrik ve meristik özellikler Tablo 1'de gösterilmiştir.



Şekil 1. Örnekleme alanı, Ulugöl Yaylası Göleti, Mesudiye, Ordu (Saygılı, 2015; Google Earth, 2020)

Figure 1. Sampling area, Ulugöl Plateau Pond, Mesudiye, Ordu (Saygılı, 2015; Google Earth, 2020)



Şekil 2. Ulugöl Yaylası Göleti'nden örneklenen dişi(A) ve erkek(B) *Carassius auratus* bireyleri

Figure 2. Female (A) and male (B) *Carassius auratus* individuals sampled from Ulugöl Plateau Pond

Tablo 1. Dişi ve erkek *Carassius auratus* bireylerinin bazı metrik ve meristik özellikleri

Table 1. Some metric and meristic characteristics of male and female *Carassius auratus*.

	Dişi	Erkek
Ağırlık (g)	26,2-49,2 (37,1±2,5)	11,4-29,4 (23,7±4,2)
Total Boy (cm)	11,5-15,2 (13,9±0,4)	10,8-14,7 (12,6±0,8)
Çatal Boy (cm)	10,9-13,3 (12,3±0,3)	9,5-12,8 (11,3±0,7)
Standart Boy (cm)	9,4-11,3 (10,5±0,3)	7,4-10,0 (9,3±0,6)
Linea Lateraldeki Pul Sayısı (L.lat.)	28-30	
Dorsal Yüzgeç Işınları (D)	III-IV / 16-20	
Ventral Yüzgeç Işınları (V)	II / 7-8	
Anal Yüzgeç Yüzgeç Işınları (A)	II-III / 5-6	
Pektoral Yüzgeç Yüzgeç Işınları (P)	I / 15-18	

Ordu orta Karadeniz'in kıyı şehirlerinden biri olup çok sayıda göl, akarsu ve nehir gibi farklı iç su kaynaklarında yaşayan birçok balık türüne sahiptir. Bunun için Ordu ili iç sularında balık faunasının belirlenmesi üzerine birçok çalışma yapılmıştır (Turan vd., 2008; Dönel, 2012; Bostancı vd., 2015; Bostancı vd., 2016a; Yılmaz, 2016; Bostancı vd., 2016b; Bostancı vd., 2020). Ordu ili Mesudiye ilçesi Ulugöl Yaylası Göleti'nde yaptığımız arazi çalışmaları sonucunda Ordu ili iç su balık faunasında daha önce varlığı rapor edilmemiş olan *Carassius auratus* türünün varlığı ilk kez rapor edilmiştir. Ayrıca türün Ulugöl Yaylası Göleti popülasyonuna ait bazı metrik ve meristik veriler ilk kez sunulmuştur.

Çalışmamız sonucunda elde edilen veriler türün literatürdeki diğer verileriyle karşılaştırıldığında genel anlamıyla uyumlu oluğu görülmüştür (Uğurlu ve Polat 2007; Froese ve Pauly, 2020). Ancak metrik ve meristik veriler farklı habitatlarda yayılış gösteren *C. auratus* türü için bazı farklılıklar da gösterebilir. Çünkü çevresel faktörler balık türlerinin sadece büyümelerini değil aynı zamanda onların biyometrilerini de etkileyebilir (Saylar vd., 2018) ve bu etkilerde aynı balık türünün metrik ve meristik ölçümlerinde bazı farklılıklara neden olabilmektedir. Örneğin, Taylor ve Mahon (1977) Laurentian Büyük Gölleri'nde, Nam vd. (1989) Kore'nin Yongnam Bölgesi'nden, İlhan vd. (2005) Tunca Nehri, Bulanık Dere, Marmara Gölü, Işıklı Gölü, Karın Gölü ve Eğrigöl'den, Uğurlu ve Polat (2007) Samsun ili iç sularından ve Yıldırım vd. (2015) Keban Baraj Gölü'nden örnekledikleri *C. auratus* bireylerinin meristik özellikleri incelendiğinde genel anlamda benzerlik göstermelerine rağmen bazı farklılıkları da barındırdıkları belirlenmiştir (Tablo 2). Bu farklılıklar örnekleme bölgelerinin fizikokimyasal özelliklerinden ve ilgili habitatlarda yaşayan bireylerin genetik farklılıklarından kaynaklandığı düşünülmektedir.

Yapılan literatür incelemelerinde Türkiye sularına yayılmış olan altı akvaryum balığı türü olduğu görülmektedir. İzmir-Çeşme-Ildır'daki Azmağı'nda *Poecilia reticulata* (Türkmen, 2019), Asi Nehri'nde *Pterygoplichthys disjunctivus* (Özdilek, 2007) türünün, Eskişehir'deki Pınarbaşı Deresi'nde *Pterygoplichthys pardalis* (Emiroğlu vd., 2016) türünün, Sakarya Nehri'nde *Pygocentrus nattereri* (Tarkan, 2006) ve *Pangasius sanitwongsei* (Yoğurtçuoğlu ve Ekmekçi, 2018) türlerinin, Eğirdir Gölü'nde (İzci, 2001), Kızılırmak'ta (Aydın, 2001), Keban Baraj Gölü'nde (Duman ve Şen, 2002) ve Samsun ili iç sularında (Uğurlu, 2006; Uğurlu ve Polat, 2007) ise *C. auratus* türünün bulunduğu rapor edilmiştir. Türkiye'nin iklim koşullarının bu türlerin popülasyon oluşturmasında önemli rol oynadığı ve bu altı tür arasından *P. pardalis, P. disjunctivus* ve *C. auratus* türlerinin doğal popülasyonlarında süreklilik sağladıkları rapor edilmiştir (Yoğurtçuoğlu ve Ekmekçi, 2018; Türkmen, 2019).

Tablo 2. *Carassius auratus* türünün farklı araştırmacılar tarafından rapor edilen meristik ölçümleri

Table 2. Meristic measurements of *Carassius auratus* were reported by different researchers

	Taylor ve Mahon 1977	Nam vd., 1989	İlhan vd., 2005	Uğurlu ve Polat 2007	Yıldırım vd., 2015	Bu çalışma
L.lat.	28-31	27-32	26-31	28-32	26-30	28-30
D	II-III / 15-18	IV-VI / 14-18	III/ 16-20	III-IV / 17-21	III / 17-20	III-IV / 16-20
V	I / 7-9	-	-	II / 7-9	I / 7-8	II / 7-8
A	II-III / 5-6	III-IV / 5-6	II-III / 5-7	II-III / 5-6	II-III / 6-7	II-III / 5-6
P	I / 13-15	-	-	I / 14-18	I / 10	I / 15-18

*L.lat.:Linea Lateraldeki Pul Sayısı; D:Dorsal Yüzgeç Işınları; V:Ventral Yüzgeç Işınları; A: Anal Yüzgeç Yüzgeç Işınları; P: Pektoral Yüzgeç Yüzgeç Işınları

Sonuç

Ordu ili sınırları içerisinde bulunan Ulugöl Yaylası Göleti deniz seviyesinden 1614 m yüksekte olup göletin çevresi 450 m, yüzey alanı ise yaklaşık 14100 m^2'dir. Bu gölette hiçbir akarsu ya da dere girdisi olmayıp, genel olarak yağmur ve eriyen kar suları ile beslenmektedir. Ordu ilinde yaylalar turizm açısından oldukça önemli bir yer tutmaktadır. Bu yüzden yaylara gelen turist sayısı yerel halk tarafından oldukça önemlidir. *C. auratus* türünün kültür formları görsel olarak oldukça renkli olduğu için yöre halkı tarafından göletin dikkat çekmesini sağlayarak yaylalara gelen turist sayısının artırılması amacıyla bırakılmış olduğu tahmin edilmektedir. Ulugöl Yaylası Göleti'nin çevresinde bu balıkların kaçabileceği bir balık çiftliğinin bulunmaması ve *C. auratus* türünün Ordu ili iç sularında sadece bu gölette gözlemlenmiş olması bu türün buraya bırakıldığı düşüncesini kuvvetlendirmektedir. Ulugöl Yaylası Göleti'nde *C. auratus* türüne ait farklı boy gruplarından dişi ve erkek bireylerin yakalanmış olması *C. auratus* türünün bu alana oldukça iyi bir şekilde uyum sağladığını, üreyebildiğini ve bu sayede de bu habitatta devamlılık arz eden bir popülasyon oluşturduklarını göstermektedir. Çalışmamızda elde edilen sonuçlar *C. auratus* türünün Ulugöl Yaylası Göleti popülasyonu için ilk verileri oluşturmaktadır.

Gerek doğal gerekse insan kaynaklı olarak ülkemiz iç sularında girmiş ve bu alanlarda devamlılık arz eden popülasyon oluşturan egzotik balık türlerinin bu habitatlardaki yerel türler ve özelliklede endemik türler üzerindeki etkileri mutlaka araştırılmalı ve egzotik türlerin insan kaynaklı yayılımını engellemek için akvaristlerin ve balıkçıların bu konuda farkındalıkları arttırılmalıdır (Türkmen, 2019).

Etik Standart ile Uyumluluk

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Etik kurul izni: Bu çalışma için etik kurul iznine gerek yoktur.

Finansal destek: -

Teşekkür: -

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Fluoksetin hidroklorid'in kılıçkuyruk balıklarında (*Xiphophorus hellerii*) oluşturduğu oksidatif hasarın belirlenmesi

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ÖZ

Bu çalışma ile dünyada gittikçe artış gösteren sağlık sorunlarından biri olan depresyonun tedavisinde yaygın olarak kullanılan ve kardiyovasküler olarak güvenilir kabul edilen SSRI (Özgül Serotonin Geri Alım Engelleyicileri) grubu antidepresanlardan Prozac®'ın etken maddesi olan Fluoksetin Hidroklorür'ün, sucul bir organizma olan kılıçkuyruk balığı (*Xiphophorus hellerii* Heckel, 1848) dokularında oluşturduğu oksidatif stresin belirlenmesi amaçlanmıştır. Fluoksetin-HCl, doğada yüzey sularında 0.012 µg/L, atık sularda 0.54- 0.929 µg/L doz aralığında bulunmuştur. Bu bilgiler doğrultusunda kılıçkuyruk balıklarına 0.1 µg/L ve 1 µg/L Fluoksetin-HCl uygulaması yapılmıştır. 96 saat sonunda balıklardan kalp ve karaciğer dokuları antiseptik şartlarda disekte edilip homojenize edilmiştir. Daha sonra malondialdehit (MDA), total glutatyon (GSH) miktarları, katalaz (CAT) enzim aktivitesi, süperoksit dismutaz (SOD) enzim aktivitesi ve total protein miktarı spektrofotometrik yöntemlerle belirlenmiştir. Sonuç olarak, kalp dokuda CAT enzim aktivitesi ve MDA seviyesi azalırken, SOD enzim aktivitesi ve GSH seviyesi artmıştır. Karaciğer dokuda ise, CAT enzim aktivitesi ve GSH miktarı artarken, SOD enzim aktivitesi ve MDA seviyesi azalmıştır. Sonuç olarak bu çalışmada kontrol grubu ile yapılan karşılaştırmalar sonucu Fluoksetin-HCl'nin kılıçkuyruk balıklarında stres yolaklarını etkileyerek, stres cevabının düzenlenmesinde etkili olduğu belirlenmiştir.

Anahtar Kelimeler: Fluoksetin-HCl, Oksidatif stres, Kılıçkuyruk balığı, *Xiphophorus hellerii*, Kalp, Karaciğer

ABSTRACT

The determination of oxidative damage caused by fluoxetine hydrocloride in swordtail fish (*Xiphophorus hellerii*)

In this study, it was aimed to determine the oxidative stress in the tissues of the swordtail fish (*Xiphophorus hellerii* Heckel, 1848) after exposed to the active ingredient of Prozac® and one of the SSRI (Selective Serotonine Reuptake Inhibitor) group antidepressants, Fluoxetine Hydrochloride, which is considered to be safe cardiovascular. It is widely used in the treatment of depression, which is one of the increasing health problems in the World. Fluoxetine-HCl has been found 0.012 µg/L in surface waters and in the dose range of 0.54-0.929 µg/L in wastewater (Sehonova et al., 2018). In line with this information, 0.1 µg / L and 1 µg / L Fluoxetine-HCl was administered to swordtails. At the end of 96 hours, heart and liver tissues of the fish were dissected under antiseptic conditions and homogenized. Later, malondialdehyde (MDA), total glutathione (GSH), catalase (CAT) enzyme activity, superoxide dismutase (SOD) enzyme activity and total protein amount were determined by spectrophotometric methods. As a result, while CAT enzyme activity and MDA level decreased in heart tissue, SOD enzyme activity and GSH level increased. In liver tissue, while CAT enzyme activity and GSH amount increased, SOD enzyme activity and MDA level decreased. As a result of the comparisons with the control group, it was determined that Fluoxetine-HCl is effective in regulating the stress response by affecting the stress pathways in swordtails.

Keywords: Fluoxetine-HCl, Oxidative stress, Swordtail fish, *Xiphophorus hellerii*, Heart, Liver

Giriş

Stres, günümüzde sık karşılaşılan sorunlardan birisidir. Toplumun %12-17'sinde stresle ilişkili olarak depresyon görülmektedir. Depresyonun en etkili şekilde tedavisi için çeşitli antidepresan ilaçlar kullanılmaktadır. Son zamanlarda bu amaçla Özgül Serotonin Geri Alım Engelleyicileri (ÖSGE, SSRI=Selective Serotonine Reuptake Inhibitor) kullanılmaya başlanmıştır. İlk SSRI grubu antidepresanlardan biri olan Fluoksetin-HCl, 1987 yılında piyasaya sürülmüştür ve 2001 yılında etken madde olarak genel kullanıma açılmıştır (Panlilio ve diğ., 2016; McCallum ve diğ., 2017; Zindler ve diğ., 2020).

Akılcı bir tasarım ile hedeflenerek sentezlenen Fluoksetin-HCl, *in vitro* koşullarda %94.5 oranında albümin ve insan serum proteinlerine bağlanır. Aktif metaboliti olan Norfluoksetin ve tanımlanmamış diğer metabolitlerine karaciğerde yoğun olarak metabolize edilerek dönüşür. İnaktif metabolitleri idrarla atılır. Yarılanma süresi uzundur. Antidepresan etkisinin yanı sıra obsesif-kompülsif bozukluk, bulimiya nervoza ve premenstrual disforik bozukluğun tedavisinde de kullanılır (Yang ve diğ., 2014; Yan ve diğ., 2020).

Farmasötiklerin sucul ortamlardaki davranışları, akibetleri ve onların metabolitleri henüz tam olarak tanımlanmamıştır. Farmasötikler çevreye verildiğinde hayvanlarda benzer veya aynı hedef organlar, dokular, hücreler veya biyomolekülleri etkileyebilir (Balcı ve diğ., 2010). Farmasötik bileşiklerin çevresel değerlendirmeleri yapılırken, beklenen çevresel giriş konsantrasyonu (EIC) 1 µg/L' yi aşarsa türlerin bu bileşiğe verdiği tepkiler göz önüne alınır (FDA-CDER, 1998). Son yıllarda akarsu, göl ve deniz gibi sucul ortamlarda yüzey sularında 0.012 µg/L, atık sularda 0.54-0.929 µg/L doz aralığında Fluoksetin-HCl bulunmuştur (Sehonova ve diğ., 2018). Fluoksetin ve onun metaboliti Norfluoksetinin, balık dokularında 10 µg/kg konsantrasyonda bulunması, bu bileşiklerin biyolojik olarak birikme kapasitesine sahip olduğunu düşündürmektedir (Orem ve Dolph, 2002; Yan ve diğ., 2020).

Balıklar da dahil olmak üzere suda yaşayan organizmalar, doğal olarak kirleticilerin bir karışımına maruz kalır. Balıklardaki antioksidatif enzim aktivitelerinin ölçümleri, sucul ekosistemlerdeki kimyasalların neden olduğu oksidatif hasarı gösterebilir (Jin ve diğ., 2010). İlaçlara maruz kalma, DNA, lipidler ve proteinlere zarar verebilen süperoksit anyon (O_2^-), hidrojen peroksit (H_2O_2) ve hidroksil radikali (HO) gibi reaktif oksijen türlerinin (ROT) gelişimini uyarabilir (Halliwell ve Gutteridge, 2015).

Farmasötiklerin çoğu uzun yarılanma ömürlerinden dolayı ekosistemde besin zinciri yolu ile sucul ortamlarda taşınırlar. Fluoksetin; hormon seviyelerini düşürmek, beslenme davranışlarını ve yüzmeyi azaltmak, fizyolojik ve üreme gelişimini geciktirme gibi 5-HT yolu üzerindeki etkisinden dolayı maruz kalan sucul faunanın fizyolojik süreçleri üzerindeki önemli yıkıcı etkileri nedeniyle hedef olmayan sucul organizmalar için toksik ilaçlardan biri olarak kabul edilmiştir (Mennigen ve diğ., 2017; Weinberger ve Klaper, 2014; Vera-Chang ve diğ., 2019). Kılıçkuyruk balığı küçük olması ve yetiştirme kolaylığı, kısa nesil süresi ve farklı cinsel özellikler gibi büyük avantajları nedeniyle genellikle davranış ekolojisi, genetik, biyoloji (Kayım ve diğ., 1999) ve biyocoğrafya (Gutierrez-Rodriguez ve diğ., 2007) çalışmalarında sıklıkla kullanılır ve toksikolojik çalışmalar için ideal bir tür olarak kabul edilir (Kwak ve diğ., 2001). Bu özelliklerinden dolayı seçilen kılıçkuyruk balıklarının farklı dokularında Fluoksetin-HCl'nin oksidatif stres oluşturma potansiyelinin belirlenmesi bu çalışmanın amacını oluşturmaktadır. Bu çalışma, Fluoksetin-HCl'nin sucul canlılar üzerinde meydana getirebileceği olası zararlı etkilerinin değerlendirilmesi açısından önemlidir.

Materyal ve Metot

Yöntem

Bu çalışmada kullanılan kılıçkuyruk balıkları ticari akvaryumculardan satın alınmıştır. Laboratuvar ortamına getirilen balıklar için akvaryumlardaki su sıcaklığı 26-28°C, pH 7 ve aydınlık: karanlık (14:10) olacak şekilde ayarlanmıştır. Akvaryumlara bir hava motoru yardımı ile yeterli düzeyde (9-12 mg/L) sürekli hava verilmiştir. Denemede balıkların beslenmesi için granül balık yemi kullanılmıştır. Balıkların yeni şartlara adaptasyonu için iki hafta beklenmiştir. Uygulama için balıklar biri kontrol olmak üzere üç gruba ayrılmıştır (n=10). Fluoksetinin uygulama dozları 0.1 µg/L ve 1 µg/L akvaryum sularına eklenmiş ve 96 saat boyunca maruziyet sağlanmıştır.

Uygulama sonrası balıklar, soğuk şoku ile hissizleştirilerek disekte edilmiştir. Cryo tüplere alınan dokular dismembranatör ile cam boncuklar vasıtasıyla hemen homojenize edilmiştir. Ardından 10000 rpm'de 4°C'de 20 dk. santrifüjlenerek deneylerde kullanılmak üzere süpernatant alınmıştır.

Malondialdehit (MDA) Tayini

Ledwozyw ve diğ. (1986) yöntemine göre belirlenmiştir. 250 µl doku homojenatı, 1250 µL TCA çözeltisi (1.22 M, 0.6 M HCl'deki) ile karıştırılır. 15 dk. sonra 750 µL TBA çözeltisi (0.047 M) ile 30 dk. kaynar su banyosunda inkübe edilir.

Daha sonra 2000 µL ticari n-Bütanol ilave edilen karışım 10 dk. 3000 rpm'de santrifüj edilir. Butanol fazı alınarak 532 nm'de absorbanslar kaydedilip ve nmol/g doku olarak hesaplanır.

Katalaz (CAT) Enzim Aktivitesi Tayini

Aebi (1974) yöntemi ile yapılmıştır. CAT enzimi; H_2O_2'nin, H_2O'ya dönüşüm reaksiyonunu katalizler. Bu dönüşüm 240 nm'de absorbansın azalması ile takip edilebilir. 1 dk.'da absorbanstaki azalma katalaz aktivitesi ile ilgilidir. 0.4 mL doku homojenatı üzerine kör için 0.2 mL Fosfat tamponu (50 mM, pH=7.0), numune için 0.2 mL H_2O_2 çözeltisi (30 mM) + Fosfat tamponu eklenir ve U/mg protein dk. cinsinden hesaplanır.

Süperoksit Dismutaz (SOD) Enzim Aktivitesi Tayini

Mylorie ve diğ. (1986) yöntemi ile yapılmıştır. SOD aktivitesi, riboflavin ile duyarlandırılmış o-dianisidinin foto-oksidasyon hızını arttırma yeteneği olarak ölçülür. Riboflavinin floresans ışığı etkisiyle oluşturduğu süperoksit radikali, ortamdaki SOD'un etkisiyle hidrojen peroksite dönüşür. H_2O_2 ise o-dianisidin ile reaksiyona girerek renkli ürün oluşturur. SOD aktivitesi ne kadar çok ise renkli ürün oluşumu da o kadar fazla olur. Oluşan renkli ürünün absorbansı 460 nm'de spektrofotometrik olarak U/ mg protein cinsinden değerlendirilir.

Total Glutatyon (GSH) Tayini

Beutler (1975) yöntemi kullanılacaktır. 0.2 mL homojenat üzerine 0.3 mL metafosforik asit, NaCl ve EDTA-Na içeren proteinsizleştirme çözeltisinden ilave edilir. 4000 rpm'de 10 dk. santrifüj edilen homojenattan 0.2 mL süpernatant alınır ve 0.8 mL Na_2HPO_4 çözeltisi (0.3 M) ve 0.1 mL % 40 mg DTNB (5-5' ditiyobis 1-2 nitrobenzoik asit) ile karıştırılır. 412 nm'de DTNB ile sülfidril gruplarının reaksiyonu sonucu oluşan renkli ürün spektrofotometrik olarak nmol/g protein cinsinden değerlendirilir.

Total Protein Hesaplama

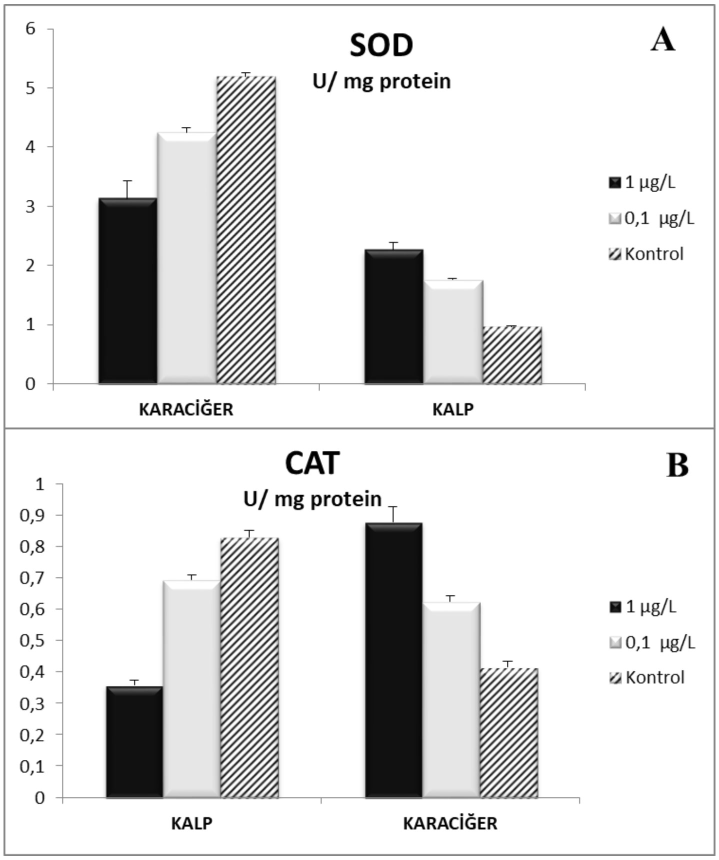
Protein tayini Bradford (1976) yöntemi ile ölçülmüştür. Stok albümin çözeltisi ile standart eğri grafiği oluşturulur. 25 µL doku homojenatı 775 µL distile su ve 200 µL ticari Bradford reaktifi ile karıştırıldıktan 15 dk. sonra 595 nm'de köre karşı absorbansları kaydedilir. Protein miktarları µg/µL cinsinden ifade edilir.

İstatistiksel Analiz

Biyokimyasal parametrelerin istatistiksel analizi IBM SPSS Statistic version 23 yazılım programı (IBM Corp., Armonk, NY, ABD) kullanılarak yapıldı. Veriler, ortalama ± standart hata olarak ifade edildi. İki grup arasındaki karşılaştırmalar parametrik Student's t-testi ve parametrik olmayan Mann-Whitney U testi ile eşit olmayan varyanslar varsayılarak yapıldı. İkiden fazla grup arasındaki karşılaştırmalar tek yönlü varyans analizi (ANOVA) ile yapıldı. ANOVA'yı takiben gruplar arasındaki önemli farkı karşılaştırmak için Tukey post-hoc testi yapıldı. $p < 0.05$ anlamlı kabul edildi.

Bulgular ve Tartışma

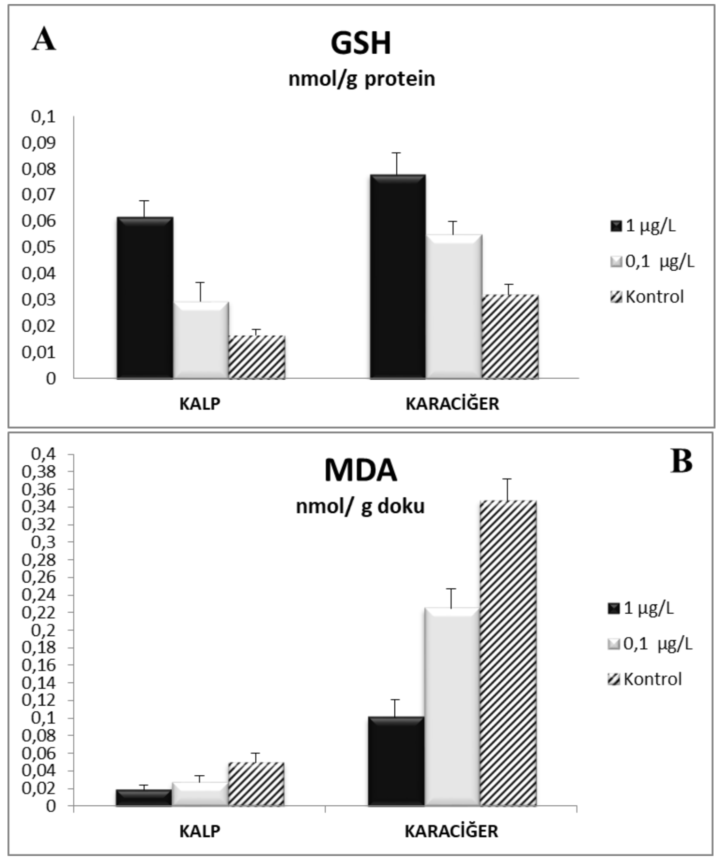
Kılıçkuyruk balıklarının kalp ve karaciğer dokularında Fluoksetin-HCl'nin etkilerinin biyokimyasal parametrelerle incelendiği bu çalışmada, doza bağlı olarak SOD enzim aktivitesi kalp dokuda artarken ($p<0.01$), karaciğerde azalmıştır ($p<0.05$) (Şekil 1A). SOD, süperoksit radikalinin oksijen ve hidrojen peroksite dönüşümünü katalizler. CAT aktivitesi ortamda bulunan hidrojen peroksitin konsantrasyonuyla doğru orantılı olarak artar. Eğer ortamda düşük konsantrasyonda bile hidrojen peroksit bulunuyorsa bu bileşiği substrat olarak kullanan katalaz devreye girerek zararlı bileşiği ortamdan uzaklaştırır (Airhart ve diğ. 2007). Ancak bu çalışmada, CAT enzim aktivitesi kalp dokuda azalırken, karaciğerde artmıştır ($p<0.01$) (Şekil 1B). Teorik bilgiler ile çelişen bu durum artan toksisiteyle enzimlerin inhibe olmasıyla açıklanabilir. Gökkuşağı alabalıklarına (*Oncorhynchus mykiss*) Propiconazole (PCZ) uygulanması ile yapılan bir çalışmada enzimatik olmayan antioksidan parametrelerinde yüksek seviyeler ile antioksidan enzimlerde inhibisyon görülmüş, uzun süreli muamelelerin ise ciddi oksidatif hasara yol açtığı bildirilmiştir (Li ve diğ., 2010). Ek olarak, fluoksetin detoksifikasyon ve antioksidan fonksiyonları bozarak organizmaların oksidatif hasarla baş edememesine neden olabilir (Cunha ve diğ., 2016). Fluoksetin hidroklorüre ve diazepama akut maruziyetin *Danio rerio*'da oluşturduğu stres cevabına etkilerinin araştırıldığı çalışmada, Fluoksetin ve diazepamın stres yolaklarını engellediğini gösterilmiştir. Bu sonuca bağlı olarak da psikotik ilaçların sucul sistemlerdeki varlığının nöroendokrin işlev yitimine sebep olabileceğini belirtmişlerdir (Abreu ve diğ., 2014).



Şekil 1. Kılıçkuyruk balıklarında kalp ve karaciğer dokularında Fluoksetin-HCL'nin; A) Süperoksit dismutaz (SOD) enzim aktivitesine, B) Katalaz (CAT) enzim aktivitesine etkileri

Figure 1. Effects of Fluoxetine-HCL in heart and liver tissues in swordtail fish; A) Superoxide dismutase (SOD) enzyme activity, B) Catalase (CAT) enzyme activity

GSH, oksijen radikali yakalayıcısı olarak oksidatif strese karşı savunmada önemli bir antioksidandır. GSH miktarı, hücresel işlevlerin korunmasında önemlidir ve detoksifikasyon ve oksidatif stres durumlarında oksidatif strese karşı koyabilmek amacıyla seviyeleri artar (Oliveira, 2016; Sehring ve diğ., 2016). Bu çalışmada da kalp ve karaciğer dokuda kontrole göre artış gözlenmiştir ($p<0.05$) (Şekil 2A). Chen ve diğerleri (2018) yaptıkları çalışmada fluoksetinin *Pseudorashbora parva* balıklarının karaciğer dokularında CAT enzim aktivitesinin ve GSH miktarının akut uygulamalarda artırdığını, kronik uygulamalarda azalttığını belirtmişlerdir. Zebra balığı larvalarına fluoksetin, β-nafthoflavon, östrojen ve 17α-etinilestradiol uygulanarak çeşitli çevresel atıkların akut toksisite mekanizması incelenmiştir. Fluoksetin ve β-nafthoflavonun tüm vücutta Na^{+} ve K^{+} değerlerini düşürdüğü gözlemlenmiştir. Sucul ortamdaki birçok atık maddenin varlığı, balıklarda iyon dengesini bozarak toksisiteye neden olabileceğini belirtmişlerdir (Alsop ve Wood., 2013).



Şekil 2. Kılıçkuyruk balıklarının kalp ve karaciğer dokularında Fluoksetin-HCL'nin; A) Total Glutatyon (GSH) miktarı, B) Malondialdehit (MDA) miktarına etkileri

Figure 2. Effects of Fluoxetine-HCL in the heart and liver tissues of swordtail fish; A) Total Glutathione (GSH) amount, B) Malondialdehyde (MDA) amount

Lipid peroksidasyonu (LPO), oksidatif stresin bir belirteci olarak yaygın olarak kullanılmaktadır ve hücre zarı lipidlerinin ayrışması olarak belirlenebilir (Sayeed ve diğ., 2003). Malondialdehit (MDA), LPO sonucu oluşan ürünlerden biridir ve oksidatif hasarı göstermede sıklıkla kullanılan bir parametredir. MDA miktarının yüksek bulunması, yüksek lipid peroksidasyonuna işarettir. LPO meydana gelmemesi veya düşük olması oksidatif enzimlerin koruyucu etkilerini gösterir. Bu çalışmanın sonucunda, kılıçkuyruk balıklarının kalp ve karaciğer dokularında Fluoksetin-HCl uygulamasının MDA miktarını azalttığı bulunmuştur ($p<0.01$) (Şekil 2B).

Ding ve diğerleri (2016) Fluoksetinin *Carassius auratus* dokularında MDA seviyesini artırdığını bildirmişlerdir. Trisiklik antidepresan olan amitriptilin'e maruz bırakılan zebra balığı embriyolarında oksidatif stres parametrelerine bakılmış ve amitriptilin'in toksik etkileri belirlenerek diğer antidepresanların sucul ortama için potansiyel risk oluşturduğunu ortaya koymuşlardır (Yang ve diğ., 2014).

Sonuç

Sonuç olarak, sucul ortamlarda bulunabilen dozlardaki Fluoksetin-HCl'nin kılıçkuyruk balıklarında oksidatif strese neden olduğu ve buna antioksidan savunma ile karşılık verilse dahi, enzimlerde inhibisyona neden olduğu bulunmuştur. Fluoksetin-HCl'nin depresyon tedavisinde en çok kullanılan antidepresan olduğu bilindiğinden, sucul canlılarda da bu etkileri ile antioksidan cevapları etkilediği düşünülmektedir. Ayrıca, bu çalışma ile sucul biyotadaki antidepresan konsantrasyonlarını tespit etmek ve ölçme için daha iyi tekniklerin geliştirmesine acil bir ihtiyaç olduğu ortaya koyulmuştur. Hatta bu ilaçların çevredeki biyolojik ve biyolojik olmayan yollardan dolayı yaşadığı kimyasal değişikliklerin daha iyi anlaşılması, antidepresan bileşikleri verimli bir şekilde bozabilmek için atık su arıtma tesislerinin yeniden tasarlanması ve güncellenmesi gerekmektedir.

Etik Standart ile Uyumluluk

Çıkar çatışması: Yazarlar herhangi bir çıkar çatışmasının olmadığını beyan eder.

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Short Communication

The confirmed occurrence of two specimens of *Remora remora* (Linnaeus, 1758) from Mersin Bay (NE Mediterranean, Turkey)

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ABSTRACT

Remoras attach to sharks, big fish, and sea turtles and continue their lives with these creatures. Kapızlı and Tekeli beaches are located near Göksu Delta and Anamur nesting areas of *Caretta caretta*. In this study, two *Remora* individuals were caught with a fishing rod in July, when the ovulation was most intense. The smaller remora individual (33 cm) was caught from the coast of Tekeli with the chicken breast at a depth of 2.5 m, and the larger one (66 cm) with bread at a depth of 1.5 m from Kapızlı beach on 24.07.2020. The two *Remora* individuals caught were probably attached to the sea turtles. However, probably due to sea turtles going to the beach to lay eggs, *Remoras* started to free-swimming, and they were caught with the fishing line since they could not be fed. The present study reported that the first occurrence of *Remora* specimens is probably attached to turtles for Turkey's northeastern Mediterranean coast. Besides, this study is provided some morphometric and meristic data on this species and discussed a probable host of these specimens.

Keywords: Echeneidae, Shark sucker, Record, Mediterranean Sea, Turkey

Introduction

The family Echeneidae is represented in the Mediterranean Sea by two genera *Echeneis* (Sucking disc with 18 to 28 laminae), *Remora* (Pelvic fins broadly attached to the abdomen; disc laminae 16 to 20), and four species of live sharksucker *Echeneis naucrates* Linnaeus, 1758, Whalesucker *Remora australis* (Bennett, 1840), Marlin sucker *Remora osteochir* (Cuvier, 1829), and Shark sucker *Remora remora* (Linneaus, 1758) (Bilecenoglu et al., 2014; Stamouli et al., 2018; Tuncer et al., 2012).

The sucking disc easily distinguishes *R. remora* on the top of the head, which represents a modification of the spinous dorsal fin. It is a globally distributed, epipelagic species found to a maximum depth of 200 m (Fricke et al., 2011) in tropical to warm temperate waters in the western and eastern Pacific, western and eastern Atlantic, including the Mediterranean (Fishbase, 2020). This species is frequently associated with sharks, large fishes, turtles, and occasionally free-swimming (Eschmeyer et al., 1983; Mundy, 2005). It feeds mainly on scraps resulting from the feeding activities of their host and sometimes feed on parasitic copepods (Muus & Nielsen, 1999).

Remora species may attach to a diverse array of host types. *Remoras* probably are benefited from this association in several ways, including transport, feeding opportunities, and protection from some predators (Alling, 1985; Fertl & Landry, 2002; O'Toole, 2002).

This study aimed to document the first confirmed record of two specimens of *R. remora* for the northeastern Mediterranean coast of Turkey. Besides, provide some morphometric and meristic data on the species and discuss a probable host of this specimen.

Material and Methods

One specimen of the *R. remora* was caught with a fishing rod at a depth of 1.5 m in the Kapızlı (36°24'11.0"N-34°04'44.4"E) (Figure 1), and other specimen was caught by a fishing rod at a depth of 2.5 m on Tekeli coast (Coordinate: 36°07'55.0"N - 33°07'39.2"E) Mersin Bay on 24 July 2020 (Figure 2). Sampling points of the species in Turkey's Eastern Mediterranean Sea coast is presented in the map (Figure 3). These specimens were immediately transported to the laboratory for a more detailed examination. Morphometric measurements of the samples were made to the nearest 0.1 mm using a digital caliper and weighed to the nearest gram (g). All measurements, counts, and morphological characters agree with those of Muus & Nielsen (1999). These specimens were preserved in 4% formaldehyde and deposited in the Museum of the Systematic, Faculty of Fisheries, Mersin University, (catalog number: MEUFC-20-11-131).

Results and Discussion

The specimens of *R. remora***,** 33.0 cm and 66.0 cm in total length and 356 and 1665 g in weight, presented the following meristic characters: dorsal fin rays 21-23, anal-fin rays 21-22, pectoral fin rays 25-26, and suction disc laminae (modified first dorsal fin), 19-22 (Table 1).

Body elongate and robust. Head depressed. Head with a sucking disc which does not extend posteriorly as far as the end of depressed pectoral fin short and round. Caudal fin emarginate and caudal peduncle thick. Scales minute and indistinct. Disc extending more or less to the distal end of the pectoral fin. Lower jaw extending beyond the upper jaw. Teeth on jaws, palatines, vomer, and tongue. Dorsal and anal fins are originating well behind the middle of standard length, low, longest ray about 6th (Paulin & Habib, 1982).

The morphometric data gave the following ratios, as a percent (%) of Standard Length (SL) or Head Length (HL): body depth 7.3-7.4, head length 70.0-69.7, predorsal length 32.9-33.0, preanal length 74.5-74.9, caudal peduncle length 3.3-3.4, all in SL; eye diameter 8.8-9.6, preorbital distance 42.6-43.7, postorbital distance 39.7-40.8, all in HL. The morphometric measurements and meristic counts of *R. remora* were indicated in Table 1 and compared to previous reports from New Zeland (Paulin & Habib, 1982) from Irish waters (Quickley et al., 1994). Morphological data of *R. remora* are consistent with measurements and counts reported by other authors describing this species (Muus & Nielsen 1999; Paulin & Habib, 1982; Quickley et al., 1994), with minor differences.

The color of fresh specimens was the body brown, and the sucker disk contained light brown and dark brown stripes. The edge lower sides of the body were colored light grey-blue strips.

Remoras select a wide variety of large fishes, reptiles, cetaceans, and some species as hosts or attach themselves to floating objects. This species shows considerable host specificity (Strasburg, 1964; Lachner, 1966). According to Nelson (1976), the *Remora* specimens have pressed the disc against its intended host and adheres by the partial vacuum created by operating the disc ridges like slats in a Venetian blind.

Table 1. Morphometric (mm) and meristic characteristic of the *R. remora* specimens from the Northeastern Mediterranean (Mersin Bay, Turkey) compared with and compared with previous record (Paulin & Habib, 1982 and Quickley et al., 1994)

Measurements	Values (cm)		
	This Study (n=2)	**Paulin & Habib (1982) (n= 36)**	**Quickley et al. (1994) (n=1)**
Total length	33.0-66.0	-	36.5
Standart length	26.7-53.5	6.0-26.5	29.5
Head length	6.8-13.5	2.6-3.0	7.5
Body depth	1.9-3.9	1.3-1.6	-
Disc length	4.8-9.6	3.2-3.9	9.5
Disc width	2.5-4.9	1.4-2.0	4.3
Eye diameter	0.6-1.3	0.3-0.5	-
Preorbital distance	2.9-5.9	-	-
Postorbital distance	2.7-5.5	-	-
Dorsal fin length	4.0-8.0	2.6-3.2	-
Predorsal length	8.8-17.7	6.2-7.0	-
Preanal length	20.0-40.0	-	-
Caudal peduncle length	0.9-1.8	0.5-.0.7	-
Dorsal fin rays	21-23	20-24	21
Anal fin rays	21-22	-	21
Pectoral fin rays	25-26	-	25
Disc laminae	19-22	16-18	17

Figure 1. A specimen of *Remora remora* 66 cm TL, in Kapızlı, Mersin Bay

Figure 2. A specimen of *Remora remora* 33 cm TL, in Tekeli, Mersin Bay

Remora remora lives more active as parasite pickers (Smith, 1997) and can reach up to 86.4 cm (Claro, 1994) and commonly occur 40 cm in total length, TL (Sanches, 1991). Froese & Pauly (2020) suggested that its maximum published weight was 1100 g (IGFA, 2001) for this species.

According to O'Toole (2002), *Remoras* (Echeneidae) are known to attach to several types of marine vertebrates, including fishes (large teleost fish and sharks), turtles, and mammals. However, they sometimes can be free swimming. Lachner (1966) is reported that several genera and species of sharks and large teleost's as hosts for this species, and he stated that in his study, the hosts to which *Remora* specimens collected by the purse-seiner were attached to could not be recorded because when the *Remoras* are taken out of the water, they detach themselves from the host. Besides, a few researchers (Kaspiris & Ondrias, 1984; O'Toole, 2002) reported samples of *R. remora* found with attached on a turtle in the southeast Aegean Sea.

Kapızlı and Tekeli coasts are located near Anamur and Göksu Delta, the significant nesting areas of Mersin, which allows *Caretta careatta* turtles to go out on the beaches and lay their eggs (Türkozan & Kaska, 2010). In this study, two *Remora* individuals caught were probably be attached to the sea turtles. It is assumed that *R. remora* samples caught by fishing rod probably free swimming when caught. Similarly, Phillipps (1964) are reported the recording of *R. remora* individuals is associated with the marlins, *Caretta caretta* turtle, and the blue shark in New Zealand waters.

Fretey (1978, 1979) had observed specimens of *R. remora* in the French Guiana coast accompanying a female leatherback turtle onto the beach during the nesting season. Result of this study, he had informed that although some of the *Remoras* died from dehydration, others actually survived and again returned to the sea still attached to their hosts. Similarly, Quickley et al. (1994) reported six *R. remora* specimens had been recorded in association with leatherback turtles *Dermochelys coriacea* in Irish waters 1980's. Also, Quickley et al. (1994) declared that about the occurrence of both species with together along the south Irish coast and even in northern European waters by several researchers (Angel, 1922; Bouxin et al., 1933; Brongersma, 1967, 1972; Wheeler, 1969, 1978; Whitehead et al., 1986) in previous years.

Conclusion

In the present study, two *Remora* individuals captured are probably associated with the *Caretta caretta* turtles. However, we think that because the turtles go to the beach for nesting, the *Remoras* may tend to free swimming, and due to they cannot be fed, they probably are caught by fishing rods.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: Approved by institutional, regional and national animal ethical statements.

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Disclosure: -

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Short Communication

New record of *Caenis nigropuctatula* Malzacher, 2015 (Ephemeroptera: Caenidae) from Southern India

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ABSTRACT

Caenis nigropuctatula Malzacher, 2015, a new mayfly record of the fauna of Indian Ephemeroptera, is recorded from the Vaigai River, Tamil Nadu, India. It is known before from Thailand, Java, and Sumatra. The distribution map of *C. nigropuctatula* is given.

Keywords: *Caenis nigropuctatula*, India, Mayfly, New record

Introduction

The following are the described species of *Caenis* known from India: *C. picea* Kimmins, 1947; *C. incurva* Malzacher, 2015; *C. piscina* Kimmins, 1947; *C. srinagari* Traver, 1939; *C. maratha* Malzacher, 2015; *C. kimminsis* Ali, 1967 and *C. americani* Srinivasan, Sivaruban, Barathy, Malzacher & Isack, 2021. Of the seven species, three are known from Southern India (*C. maratha*, *C. kimminsis*, and *C. americani*); however, the current status of *C. kimminsis* is vague as Ali (1967) described this species as a superficial one which lacks informative drawings (Staniczek *et al.,* 2020). We determine a new record of *Caenis nigropunctatula* Malzacher, 2015 based on comparing the samples that we have collected with the existing collections. Differential diagnosis of *C. nigropunctatula* is confirmed based on the literature of Malzacher, 2015. From this new record, the species number of *Caenis* in India has expanded to eight. With poor available data of *Caenis* species, the Biomonitoring status remains insufficient, so more work to be carried out on family Caenidae in India and other Oriental regions.

Material and Methods

The specimens were collected from the Vaigai River, Madurai, Tamil Nadu, India (Figure 1). 7 larvae were collected using a D net and all of them were subsequently reared into imago in the laboratory and were collected and preserved in 80% ethanol. The imagos of *C. nigropunctatula* were easily reared from mature nymphs having dark wing pads and they can become imagos within a week in the rearing tank at 32°C without any aeration and food. Adult characteristics of *C. nigropunctatula* were studied using Magnus MSZ binocular stereo microscope and photographs were acquired using Canon EOS 1500D. Specimens studied under Scanning electron microscope were first dehydrated using ethanol and dried by critical point drying and examined with an EVO-18 scanning electron microscope at 10 k. Digital SEM photographs were made and edited with Adobe Photoshop 7.0. Terminologies were followed based on Malzacher (1991) for male genital sclerites and Kluge (1994) for thoracic structures. The distributional map of *Caenis nigropuctatula* was done with the help of the software SimpleMappr (Shorthouse 2010). The collected specimens are deposited in the American College Museum (AMC), Madurai, and Tamil Nadu.

Figure 1. Habitat of *Caenis nigropunctatula* Malzacher, 2015

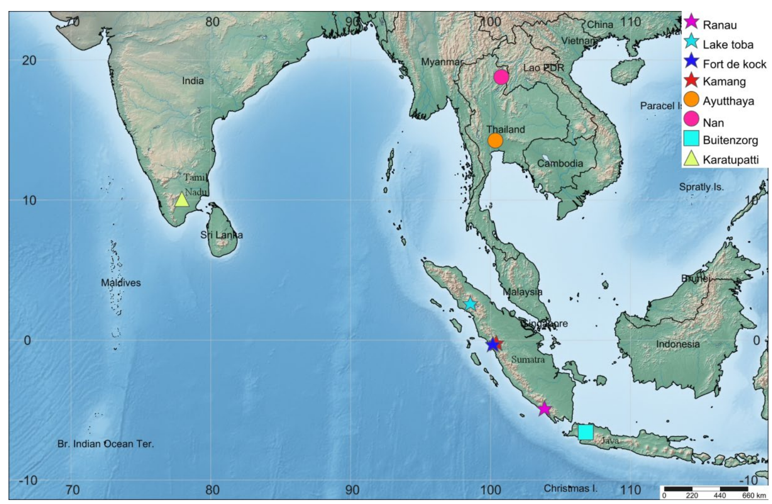

Figure 2. Distributional map of *Caenis nigropunctatula* Malzacher, 2015

Results and Discussion

Caenis nigropuctatula **Malzacher, 2015** (Figure 3)

Caenis nigropuctatula Malzacher, 2015: 28, Figures 1a–l, 2a–e, 4l, 8–15.

Non-Type Material Examined

2 male imagos (AMC/ZN/199), 3 female imagos (AMC/ZN/200), South India, Tamil Nadu, Madurai, Vaigai River, 10°08324'N & 77°93220'E; 192 m; 3/X/2020, Pandiarajan Srinivasan & Rajasekaran Isack.

Description

Caenis nigropunctatula is known earlier from Thailand, Java and Sumatra (Malzacher, 2015). This is the first record that it is known from India and the extension of this species goes over 1000 kilometers (Figure 2). *C. nigropunctatula* also shows a wide range of intraspecific variations in leg ratios, however, the genitalia remains similar in all individuals of various populations (Malzacher, 2015). The Indian population of *C. nigropunctatula* shows the comparative kind of attributes of Thailand population as the apical dilation of tarsomere remains small. The characters of the Indian population are as follows: size of male imago- 3.5 mm (Figure 3A); size of female imago- 4.3 mm (Figure 3B); wing length- 2.1mm; cerci length- 5.4 mm; length of foreleg- 2.1 mm; head length ratios: c:a- 2.34; a:b- 1.07; ratio of forefemur: foretibia- 0.58; ratio of foretibia: foretarsus- 1.27; ratio of foreleg: hindleg- 1.47; ratio of segments of fore tarsus 1st : 2nd : 3rd : 4th : 5th = 1: 4: 2.2: 2.1: 1.3; ratio of body length : length of cercus : length of terminal filament = 1 : 2.8 : 3.8.

Caenis nigropunctatula can be distinguished from all other *Caenis* species in male imago (Malzacher, 2015) by strong prosternal ridges and forms an isosceles triangle (Figure 3C); tarsomeres 2-4 of fore tarsus apically broadened; broadenings with small strong spines, not tongue-shaped (Figures 3E & 3F); proportion of forefemur : foretibia = more than 0.46; proportion of foreleg : hindleg = less than 1.90; Penis broad, with rounded lobes of moderate length (Figure 3G); forceps marginally narrowed to the tip, with a short spine pretty much bent medially (Figure 3H).

The lone contrast of character we noted from the Indian population is the fore margin between lateral and frontal ocelli slightly bowed in the head of the adult imagos (Figure 3D) but in other populations, it looks straight (Malzacher, 2015). Therefore, further analysis is needed in other parts of India and the rest of the Oriental region to know the exact status of *Caenis nigropunctatula* and its disparities among various populations.

Of the eight known species of *Caenis* from India, *C. piscina*, *C. srinagari*, and *C. kimminsis* lacks important diagnostic characters, as both *C. piscina* and *C. srinagari* are distinguished based on their color pattern only whereas *C. kimminsis* lacks the novel diagnostic features of larvae. So, these three species should be redescribed soon based on the fresh material from their particular localities. The key to male for *C. picea*, *C. incurva*, *C. maratha*, and *C. nigropunctatula* was given by Malzacher (2015), Malzacher & Sangpradub (2020). So, based on modern diagnostic characters about half of the species of *Caenis* described from India needs quick redescription soon to sort out problems in the taxonomy of Caenidae in India.

Distribution

Thailand, India (new record), Indonesia (Sumatra and Java).

Conclusion

The present study confirms the presence of *Caenis nigropunctatula* in Tamil Nadu, Southern India. The distribution range of *C. nigropunctatula* remains unknown as the earlier findings in Thailand and Indonesia lack ecological characteristics of *C. nigropunctatula,* so it is unable to predict the distribution range of *C. nigropunctatula* at the present scenario. The findings of the present study reveal the taxonomy and morphology of this particular species and help to know more about the phylogenetic relationship of mayflies in India.

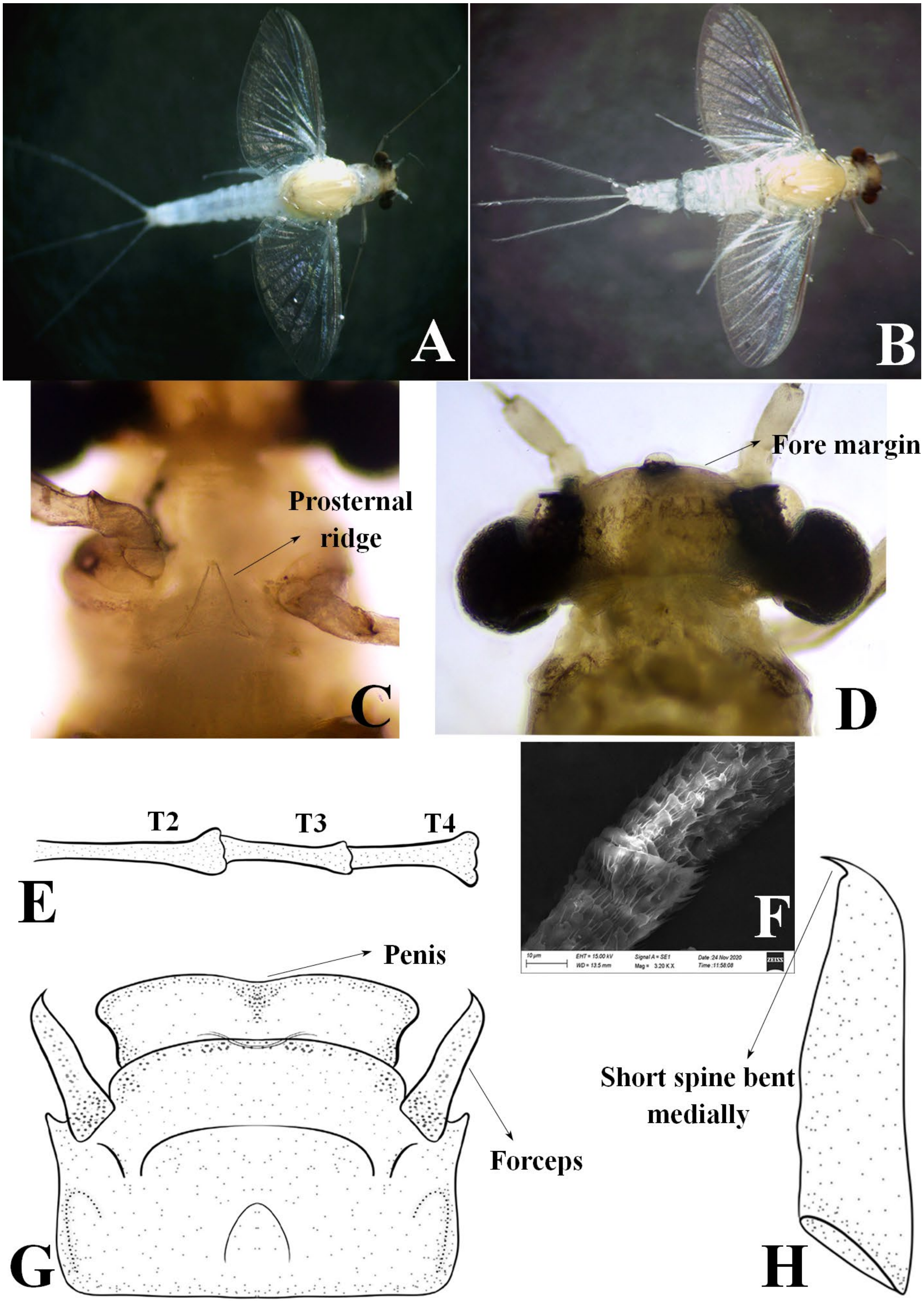

Figure 3. *Caenis nigropunctatula* Malzacher, 2015 (A-H). A- male imago; B- female imago; C- prosternal ridge; D- head of male imago; E- structure of fore tarsomere; F- SEM view of tarsomere 3; G- male genitalia; H- forceps

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: All authors declare that this study does not include any experiments with human or animal subjects.

Funding disclosure: -

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Disclosure: -

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....(Crockatt, 1995).

Direct quote from the text

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