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Research Article

POTENTIAL ENVIRONMENTAL IMPACTS OF TUNA CAGE FARMING IN THE AEGEAN SEA

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ABSTRACT

The present study aimed to investigate the potential impacts of Atlantic Bluefin Tuna (*Thunnus thynnus*) farming in offshore cage systems in the Aegean Sea (Sığacık Bay-Izmir, Turkey), in respect to physico-chemical water quality parameters, nutrient loads, chlorophyll-*a*, total suspended solids, zooplankton groups, and TRIX index calculations for the potentially affected cage farm area and an unaffected reference site. Concentrations of physico-chemical variables (temperature, salinity, dissolved oxygen, pH) in the study carried out in May and August 2018, were within the acceptable limits for marine aquaculture in terms of water quality characteristics. The concentrations of PO_4-P, NH_4-N, and NO_2-N showed no temporal or spatial changes, and were recorded below 0.01 mg/L (<0.01) for PO_4-P and NH_4-N, whereas lower than 0.005 mg/L (<0.005) for NO_2-N values in both cage and reference stations in May and August 2018 periods. Results showed low levels of TSS (0.33-11.87 mg/L), both in the cage farm area and the reference site, remaining below the general quality criteria of 30 mg/L for marine environment. No eutrophication risk (TRIX index, $T<4$) was observed around the Tuna Cage Farm Site in Sığacık Bay, according to the legislations enacted for "Sensitive Areas of Enclosed Bays where fish farms are not allowed". Based on these findings, demonstrating highly interactive trophic level variability, it can be concluded that the impacts of the Tuna Cage Farm were not significant, possibly due to the consistent movement of the water in currents in the study area.

Keywords: Tuna farming, Cage aquaculture, Environmental impact, Water quality

Introduction

The traditional fish production has become a growing industry with the development of new production systems and marine technologies in fish farming facilities. As a rapid growing industry, the aquaculture sector today reached a global fish production of nearly 54.091.148 tons worldwide with about 138.537.398.000 USD economic value (FAO, 2019a) and aims to provide high quality protein for the increasing demand of the world population that is expected to reach around 9.8 billion in 2050, and 11.2 billion in 2100 (UN-WPP, 2017). However, the rapid growth in intensive culture conditions arise significant risks and pressure on the marine environment. Since water resources are limited and vital for human beings, the sustainable use of water is an important matter that needs to be considered for the future of marine resources in the world. The assessment of potential productivity without significant negative impacts on the marine environment caused by the production activities (Beveridge and Phillips, 1993; Beveridge, 1996; Kautsky et al., 1997; Pittroff and Pedersen, 2001), and the maximum sustainable nutrient input that the water body can receive without exposing any eutrophication signs (Ganguly et al., 2015), are important issues for sustainable development of the cage farming industry, which can only be achieved when the farm loads are kept below the carrying capacity limitations of the water environment. Farm impacts could be reduced or minimized via proper site selection, stock density management, optimization of feed formulations using well selected ingredients and the integration of multi-trophic aquaculture production systems such as mussels, oysters, seaweed, etc. Environmental monitoring and control of farm sites are important in terms of assuring maximum fish biomass to be maintained in a water environment without negatively influencing ecological conditions of the water body (Granada et al., 2015).

Besides the mainly produced fish species of seabream and seabass, tuna farming is a growing aquaculture industry in the Mediterranean with a production of 6.089 tons and a value of 102.308.000 USD in 2016, among which the Turkish Tuna farming covers 13% with a production of 770 tons of the total harvest with a value of 11.422.000 USD (FAO, 2019b). The difference in tuna cage farming compared to seabream or seabass is that fish caught from the wild and fattened with trash fish to larger size in one season and then harvest. The sustainable growth of the Tuna farm operations can only be ensured with environmental control of the marine sites in the Aegean and the Mediterranean. Therefore, the present study aimed to investigate potential environmental impacts of a tuna farm site in the Aegean Sea (Turkish coast) in respect to Turkish environmental legislations.

Material and Methods

Study Area and Sampling Period

The study was conducted in the potential cage farm site area No: 9 in Sığacık Bay (Seferihisar town, Izmir province, Turkey), determined and established by the Ministry of Environment and Urban Development (Figure 1, 2).

This study was conducted at 2 different sampling stations determined as "Cage and Reference" stations, with 3 different water depths of "surface (5 m), mid layer (35 m), and bottom (80 m)" in the study area of Sığacık Bay – Tuna Cage Farm Site. The "Cage Station" was designated as a sampling location next to the farm site, whereas the "Reference Station" was assigned an unaffected location of the upstream area 150 m in distance from the cage site. The study was conducted in two periods May 2018 and August 2018, which was assumed to be the highest season in terms of temperature, presence of tuna biomass and active feeding progress in the cage systems, nutritional inputs via fish feeding, and nitrogen or phosphorous loads due to excretory waste outputs, as well as plankton production in the study area.

Layout and Design of Tuna Cage Farm System

A 2x4 bay submerged grid-mooring system was used to set the Tuna cages consisting of single pipe floatation as the main upper rim, anchored to sea bottom with 16 deadweight anchors. The layout design of the Tuna cage farm operating in the study area of Sığacık Bay (Seferihisar-Izmir, Turkey) is demonstrated in Figure 3.

Analyses of Water Samples

Water Quality Analyses

In the sampling locations, seawater quality parameters such as temperature, salinity, pH, dissolved oxygen (% saturation and mg/L level) were measured *insitu* using a YSI 600QS model multi probe system. Seawater visibility was measured *insitu* using a Secchi disk.

Nutritional Element Analyses

Among the nutrients, soluble reactive phosphorus (PO_4-P), total phosphorus (TP), nitrite (NO^-_2), nitrate (NO^-_3), ammonia (NH_4) and total nitrogen (TN) were sampled from designated sampling locations and depths, and transferred to GEMAR laboratories (GEMAR, Environmental Measurements and Analyses Laboratory - Çevre Ölçüm ve Analiz Laboratuarı, Canakkale-Turkey). Consequently, spectrophotometric analyses were performed according to ISO, EPA, TS and EN standards using methods SM 4500-P E for PO_4-P and SM 4500-P B, E for TP, SM 4500-NO_2. B for NO^-_2, EPA 352.1 for NO^-_3, SM 4500-NH3 B, F for NH_4 and SM 4500-NO2 B- EPA 352.1-SM4500-Norg B for TN.

For the analyses of silicate (SiO_2) values in the samples collected from the study area in different depth were conducted spectrophotometrically according to the methods for seawater analyses described by Strickland and Parsons (1972) in the Planktonology Laboratory of Canakkale Onsekiz Mart University, Faculty of Marine Science and Technology (Canakkale, Turkey). For the silicate analyses, water samples were kept in room temperature. A water sample of 25 mL was added on a 10 mL-molybdate solution within a 50 mL flask, stirred and kept for 10 min (waiting time should not exceed 30 min). Then the flask was filled up to 50 mL with using a reducing reactive and stirred immediately, remained for 2-3 hours in order to complete the reduction, and reading was conducted spectrophotometrically at 810 nm wave length.

Total Suspended Solids (TSS) Analyses

Sampling for the determination of total suspended solids (TSS) was conducted from the water column and sea bottom using a 5-L volume Nansen bottle. The TSSs, composed by both organic and inorganic compounds and influencing light penetration an important criterion for photosynthesis, were analyzed gravimetrically according to Clesceri et al. (1998).

Chlorophyll-a Analyses

Water samples for determining the chlorophyll-*a* concentrations, an indication of primary productivity and phytoplankton density, were taken from designated depths via a 5-L Nansen bottle. Each of the 1.5 L water samples were *in situ* vacuum-filtered using a 47 mm GF/F filter paper, which were then places in glass tubes after filtration and covered by aluminum folio and kept frozen until analysis. Then, the spectrophotometric analysis after 90% acetone extraction was performed according to Greenberg et al. (1992).

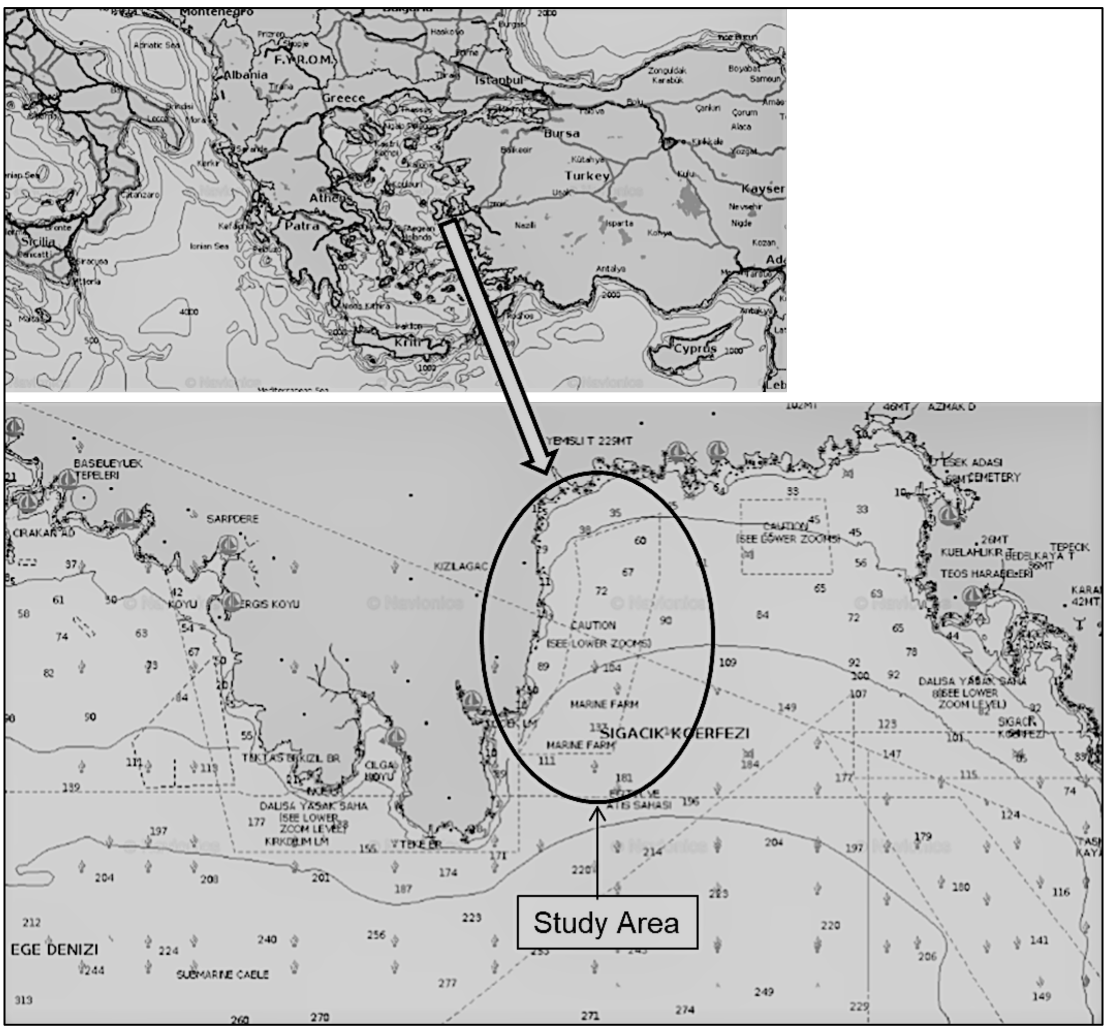

Figure 1. Location of the study area; Sığacık Bay, Izmir-Turkey (https://sailingheaven.com/nautical-map/)

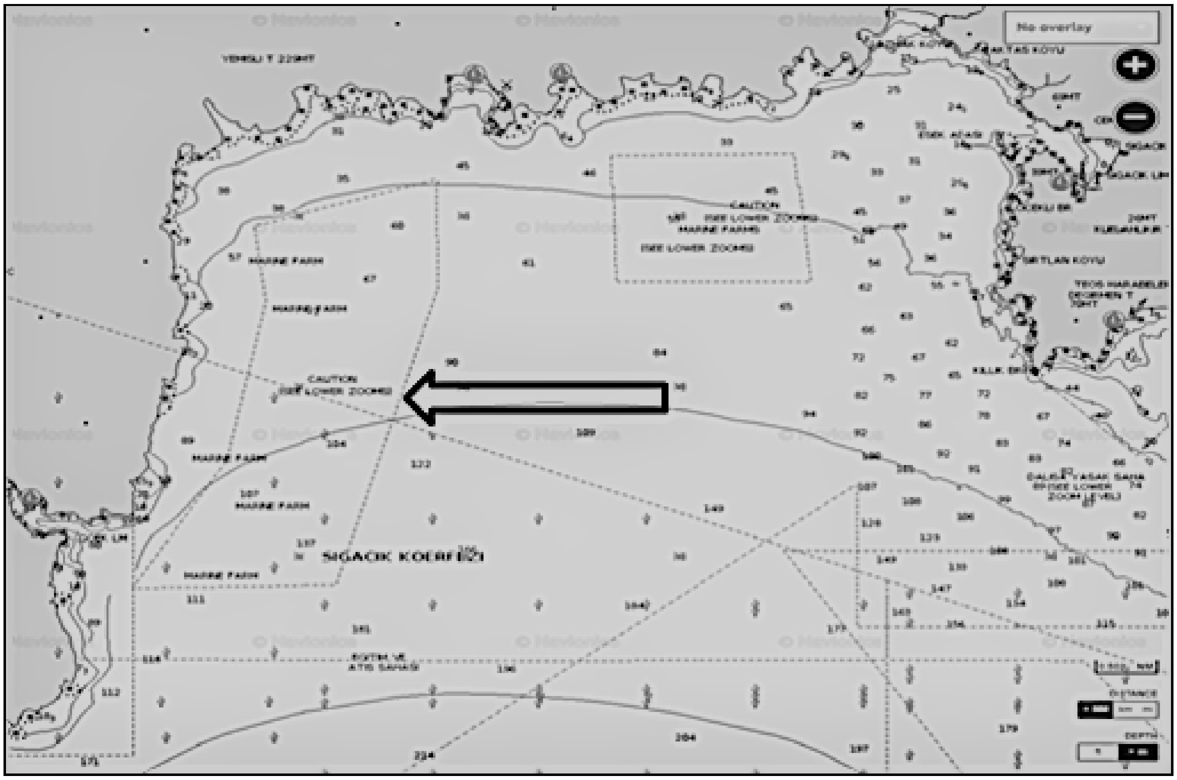

Figure 2. Sığacık Bay and site No: 9 (https://sailingheaven.com/nautical-map, July 2018)

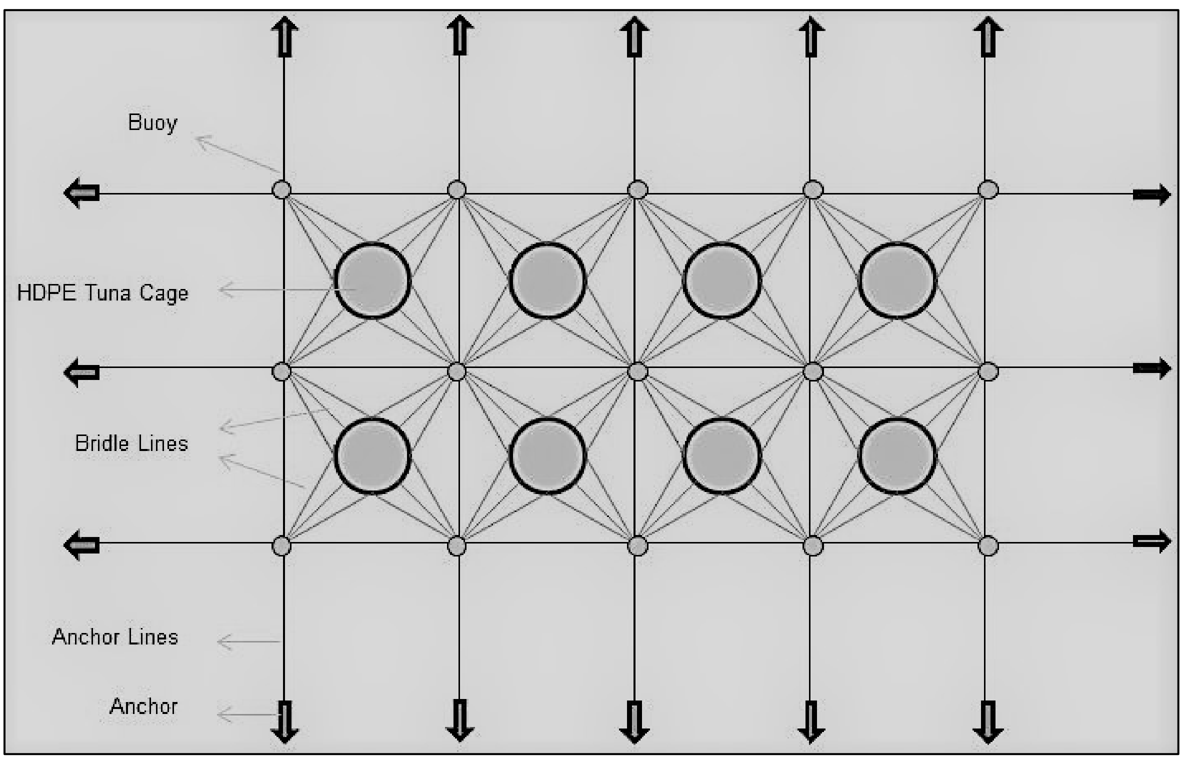

Figure 3. Layout design of the Tuna cage farm in Sığacık Bay (Seferihisar-Izmir, Turkey), HDPE: High density polyethylene

Zooplankton Analyses

In the present study, 200 µm mesh diameter standard plankton net was used for zooplankton samplings. In each of the designated sampling depths, samples were obtained through vertical towing and retained with 4% end volume buffered formaldehyde. Qualitative analyses on the zooplankton were performed in the laboratory, where the excess water was syphoned and samples transferred into smaller flasks. The distribution rate of groups and species was done using unit-sample methods (Ozel, 1998). In this point, samples were homogenous distributed on a container with a known surface area, and the sub-samples with smaller scale obtained via unit-sample method were transferred on a lamella and zooplankton analyses conducted. For the quantitative analyses, a certain volume out of the total homogeny sample was taken and the unit-sample method applied (Ozel, 1998). For the systematic classification of the species, earlier reports of Tregouboff and Rose (1957), Todd et al. (2006), and Young et al. (2006) were followed, as well as the web site of European Register of Marine Species (MarBEF, 2008) in order to check most recent additions. A trinocular stereo-zoom research microscope Olympus brand SZX7 model was used for determining the zooplankton species.

TRIX Index and Calculation

In the present study, TRIX index calculations were performed using measured values of Chlorophyll-*a*, % dissolved oxygen saturation, total dissolved inorganic nitrogen (TIN) and total phosphorous (TP) concentrations. The TRIX indexes were calculated according to the guidelines for "Sensitive Areas of Enclosed Bays where Fish Farms are not allowed" entered into force on 24.01.2017 with the law no: 26413 by of the Turkish Ministry of Environment and Forest, using following equation:

TRIX Index= (Log (Chlorophyll-*a* x $\%O_2$ x TIN x TP) + 1.5) x 0.833 (4)

where,

Chlorophyll-*a* : Chlorophyll-*a* concentration in water body (µg/L),

%O2 (The absolute percent value deviated from the saturated oxygen rate) = |%DO – 100|,

TIN (Total dissolved inorganic nitrogen, µg/L) = N - ($NO_3 + NO_2 + NH_4$),

TP : Total phosphorous (µg/L)

Results and Discussion

In the present study, seawater temperatures in different depths of the designated study area were recorded between 17.70-21.22 °C in May 2018, and between 18.69-24.85 °C in August 2018. Salinity was recorded as 38 ppt in May 2018, while it was around 31 ppt in August 2018. The percent dissolved oxygen (% DO) saturation and DO level were measured as 98-107.8 % and 7.20-7.74 mg/L in May, whereas these values were recorded as 97.50-99 % and 6.29-8.20 mg/L in August 2018, respectively. The pH values varied between 7.78-8.38 and 8.07-8.22 for the May and August 2018 terms, respectively. The values for seawater temperature, salinity, DO concentration, and pH were within the acceptable limits for marine aquaculture in terms of water quality characteristics (Table 1).

The chlorophyll-*a* value as an indication of primary productivity and phytoplankton density in the present study was measured between 0.20-0.32 µg/L and the TSS, composed by both organic and inorganic compounds and influencing light penetration that is important for photosynthesis, was measured between 8.00-11.30 mg/L during the May 2018 study period. In the sampling period of August 2018 however, chlorophyll-*a* values were recorded between 0.04–0.41 µg/L, and the TSS varied between 0.33-11.87. The TSS measured from different sampling locations and water depths in both periods were below the general quality criteria of 30 mg/L for seawater, based on the WPCL (2004) (Table 2). The Secchi disk values for the May 2018 study period were recorded as 11.60 m in the Cage Station, while 16.00 m in the Reference Station. In the August 2018 sampling period, the Secchi disk values varied between 10.25-13.50 m (Table 3).

Silicate values in all sampling depths throughout the study period remained between 30-40 µg/L, which was far below the level supporting continuous growth of diatoms (Kocatas, 1993). As known, the silicate cycle in the aquatic systems is limited, and the silicate into the marine ecosystems transported from mainly rivers, rain falls, and winds in the area (Kocatas, 1993; Goldman and Horne, 1994). The "total inorganic dissolved nitrogen" to "phosphorous" ratio (TIN:P) obtained in the study period of May 2018 remained below the Redfield ratio of "16:1", suggesting a limitation of nitrogen forms such as nitrite + nitrate and ammonium on phytoplankton development. Besides, considering that the TIN:P ratio recorded in the August 2018 period being above the 16:1 ratio in some stations might be an indication of a potential limiting effect of phosphorous on phytoplankton growth. In some sampling stations, the TIN:Si ratios were reasonably higher than the Redfield ratio of 1:1, which is deterministic for diatoms. Therefore, this can be an indication that silicate might have a potential limiting effect on the diatom growth (Kocum, 2005). Considering these measurements, it was found that nutrient concentrations in both study periods of May and August 2018 were between acceptable ranges of water quality characteristics and within the limits suitable for marine aquaculture activities. Besides, our findings in terms of nutrients in this study were similar to those of previously conducted studies in the same study area (Palta, 2010; CSB, 2018).

Table 1. Sığacık Bay Tuna Cage Farm Site; temperature, salinity, dissolved oxygen (%), dissolved oxygen (mg/L), and pH values in sampling locations and variations with depth (May – August 2018)

	MAY - 2018		AUGUST – 2018	
Sampling Station	**Cage**	**Reference**	**Cage**	**Reference**
Temperature (°C)				
Surface	21.22	20.80	23.71	24.28
Mid Layer	20.00	20.00	21.88	22.75
Bottom	18.28	17.70	18.69	18.94
Salinity (ppt)				
Surface	38	38	31.25	31.41
Mid Layer	38	38	31.16	31.31
Bottom	38	38	31.11	31.21
Dissolved Oxygen (%)				
Surface	107.8	105.0	98.0	98.2
Mid Layer	102.0	102.0	97.0	99.0
Bottom	98.0	102.0	97.0	99.0
Dissolved Oxygen (mg/L)				
Surface	7.74	7.60	7.20	6.96
Mid Layer	7.50	7.60	7.60	6.96
Bottom	7.20	7.20	8.20	7.29
pH				
Surface	8.38	8.42	8.21	8.22
Mid Layer	8.20	8.20	8.21	8.21
Bottom	7.78	8.20	8.21	8.18

Table 2. Variations of chlorophyll-*a* and TSS values according to sampling stations and depth in Sığacık Bay – Tuna Cage Farm locations (May – August 2018). (---): not enough water samples available

	MAY - 2018		AUGUST - 2018	
Sampling Station	**Cage**	**Reference**	**Cage**	**Reference**
Chlorophyll-*a* (µg/L)				
Surface	0.25	0.28	0.04	0.05
Mid Layer	0.25	---	0.15	0.12
Bottom	0.20	0.32	0.22	0.15
TSS (mg/L)				
Surface	8.70	8.00	7.23	11.87
Mid Layer	10.20	---	7.28	4.29
Bottom	11.30	8.50	8.60	0.33

Table 3. Secchi disk values in Sığacık Bay–Tuna Cage Farm sampling stations (May – August 2018)

	Secchi Disk (m)	
Sampling Station	**MAY - 2018**	**AUGUST - 2018**
Cage	11.60	10.25
Reference	16.00	11.40

During the study period of May 2018, NO_3-N, NO_2-N, NH_4-N, and PO_4-P did not exceed 0.03 mg/L, 0.006 mg/L, 0.01 mg/L, and 0.01 mg/L, respectively, in the selected sampling stations and depths. The TN values were recorded between 0.3-0.8 m/L. The TP values were found to be below 0.029 mg/L, and SiO_2 values varied between 0.03-0.09 mg/L. In the sampling period of August 2018, NO_3-N, NH_4-N and TN were recorded as 0.08-0.18 mg/L, 0.01-0.03 mg/L, and 0.35-2.91 m/L, respectively, while the NO2-N values did not exceed 0.005 mg/L. The PO_4-P values were below 0.01 mg/L, and TP values were obtained between 0.01-0.12 mg/L. In the study period, the SiO_2 values were found as 0.03-1.15 mg/L in the selected sampling stations and depths (Table 4).

Nitrogen and phosphorous loads in the surrounding water environment occur due to the feed losses, fecal and other metabolic wastes (Yildirim and Korkut, 2004), and as results of domestic and industrial pollution. When comparing offshore systems with no coastal influences and coastal zone areas under coastal influence, the impact of phytoplanktonic production on TSS in the offshore marine systems is higher (Besiktepe et al., 1994). Therefore, considering chlorophyll-*a* concentrations and TSS values, it can be concluded that the TSS was controlled by coastal effluents and/or feeding activities in the study locations during the sampling periods.

The TRIX indexes obtained in the present study via calculation of measured values of chlorophyll-*a*, % DO saturation, TIN, TP concentrations for the study periods from May to August 2018 are given in Table 5.

According to the results obtained from sampling stations in Sığacık Bay – Tuna Cage Farm Site in the highest season from May to August, when potentially high impacts could be expected, Sığacık Bay – Tuna Cage Farm Site did not show any Eutrophication Risk, being below the Eutrophication Risk Scala of less than "4" ($T<4$), based on the legislations enacted for "Sensitive Areas of Enclosed Bays where Fish Farms are not allowed". Our results obtained here during the tuna production period from May to August 2018, are in close agreement with an earlier report on environmental impacts of a large-size tuna farm with a capacity of 1840 ton/year and operating in a water surface area of 30.000 m^2 in May and August 2015 (Kocak, 2018).

The abundance and distribution of zooplanktonic organisms in the study area and sampling locations are given in Table 6. Members of *Oithona* species among copepods and *Oikopleura dioica* species among appendicularians were dominant during the May 2018 study period. With the increase of the water temperature in August 2018, the abundance of *Cladocera* was found to be higher compared to the other groups. Especially, the abundance of *Penilia avirostris*, feeding on smaller-sized particles, was the highest in the study period compared to other species.

The *Penilia avirostris*, mainly distributed in temperate enclosed bays (DellaCroce and Venugopal, 1972; Aker and Ozel, 2006) are capable to feed and utilize on a variety of trophic sources (Turner et al., 1988), and can propagate easily in temperate areas with suitable trophic conditions. The *Evadne spinifera* is a warm-water species, appearing in oceanic or coastal waters (Aker and Ozel, 2006). Due to its ecological characteristics, it may show distribution during the spring and summer period, whereas disappearing during the autumn or winter periods. The copepods are selective feeders. Calanoid copepods prefer feeding on micro-plankton and larger particles such as ciliates (>20 µm) (Paffenhöfer and Knowles, 1980; Kleppel, 1993; Fessenden and Cowles, 1994; Sommer et al., 2000; Stibor et al., 2004). The *Centropages typicus* show both carnivorous and omnivorous characteristics, and can feed on phytoplankton, ciliates appendicularians, copepod eggs and nauplii, and even on fish larvae with yolk sack (Carlotti and Harris, 2007). With their specific characteristics, these species can live and distribute in large numbers in temperate climate, neritic coastal zones, especially in bays and shallow marine areas with high salinities, and can reach significant abundance during the spring season in the Northern Mediterranean. *Oithona* species have a wide range of trophic preference and may show aggressive feeding behavior, therefore phytoplankton, ciliates, detritus, naupliu and fecal pellets are within their feed-range (Nakamura and Turner, 1997; Atienza et al., 2006). Hence, in oligotrophic waters with low chlorophyll-a levels they can easily increase their numbers (Castellani et al., 2015). Appendicularians (*Oikopleura* species) however, are filter-feeders (Siokou-frangou et al, 1998; Stibor et al., 2004). They are one of the most important parts of the secondary production, due to their ability of capturing nano-pico particles, and shorter generation-cycle compared to copepods (Uye and Ichino, 1995; Spinelli et al., 2013), being among the feed sources of high-trophic ctenophores and several fish species (Uye and Ichino, 1995; Spinelli et al., 2013). *Sagitta* sp. is generally feeding on adult copepods. Further, *Oithona* and *Oikopleura* species as well as their own younger individuals are among their feed sources (Steele, 1970; Giesecke and Gonzalez, 2008).

Table 4. Sığacık Bay – Tuna Cage Farm sampling stations; NO_3-N, NO_2-N, NH_4-N, PO_4-P, SiO_2, TN and TP values and TIN*:P, TIN:Si ratios (May – August 2018)

	MAY – 2018						AUGUST - 2018						
Sampling Station	Cage			Reference			Cage			Reference			MMR
	Surface	MidL	Bottom	Surface	MidL	Bottom	Surface	MidL	Bottom	Surface	MidL	Bottom	
TP (mg/L)	0.023	0.01	0.01	0.029	0.011	btd	btd	btd	btd	0.06	0.12	0.12	0.01-6
PO_4-P (mg/L)	btd	btd	btd	btd	btd	btd	btd	btd	btd	btd	btd	btd	0.01-6
TN (mg/L)	0.3	0.7	0.7	0.7	0.8	0.8	0.66	0.74	0.37	0.35	0.75	2.91	-
NH_4-N (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.005-0.6
NO_2-N (mg/L)	btd	btd	btd	0.006	btd	bdt	btd	btd	btd	btd	btd	btd	0.005-1
NO_3-N (mg/L)	0.021	0.01	0.01	0.03	0.02	0.02	0.13	0.12	0.09	0.13	0.11	0.08	0.1-2
SiO_2 (mg/L)	0.03	0.05	0.05	0.7	0.7	0.9	0.09	0.07	0.05	0.03	0.04	0.04	-
TIN:P	3.60	2.50	2.50	4.60	3.50	3.50	14.50	13.50	10.50	14.50	12.50	9.50	
TIN:Si	1.20	0.50	0.50	0.07	0.05	0.04	1.61	1.93	2.10	4.83	3.13	2.38	

*TIN: Total inorganic dissolved nitrogen, N-(NO_3+NO_2+NH_4); MidL: Mid Layer; MMR: Method Measured Range; btd: below detection limits (<0.01 for TP and PO_4-P and <0.005 for NO_2-N)

Table 5. Trix index values in Sığacık Bay – Tuna Cage Farm sampling stations, May – August 2018

	TRIX Index	
Sampling Station	**MAY - 2018**	**AUGUST – 2018**
Cage Location		
Surface	3.92	2.97
Mid Layer	3.00	3.57
Bottom	2.92	3.57
Reference Location		
Surface	3.97	3.66
Mid Layer	---	3.97
Bottom	3.21	3.94

TRIX index calculated according to the guidelines for "Sensitive Areas of Enclosed Bays where fish farms are not allowed" entered into force on 24.01.2017 with the law no: 26413 by of the Turkish Ministry of Environment and Forest.

Table 6. Main zooplankton species in the study area of Sığacık Bay – Tuna Cage Farm Site, May – August 2018

	MAY – 2018		AUGUST - 2018	
Sampling Stations	**Cage**	**Reference**	**Cage**	**Reference**
Zooplankton Species (individuals / m^3)				
Bivalvia veliger l.	*Nd*	2	18	5
Calanoida	*Nd*	*Nd*	125	75
Centropages typicus	62	33	*Nd*	*Nd*
Corycaeus sp.	*Nd*	3	18	23
Copepoda naupliu	5	9	53	35
Euterpina acutifrons	*Nd*	*Nd*	5	13
Evadne spinifera	*Nd*	*Nd*	118	129
Fritillaria sp.	*Nd*	2	*Nd*	*Nd*
Oithona similis	38	7	18	10
Oithona nana	6	4	*Nd*	*Nd*
Oithona plumifera	3	4	25	10
Oithona sp.	*Nd*	3	24	35
Oncaea sp.	*Nd*	2	*Nd*	*Nd*
Oikopleura dioica	42	*Nd*	*Nd*	*Nd*
Oikopleura longicauda	13	*Nd*	12	35
Oikopleura fusiformis	*Nd*	5	*Nd*	*Nd*
Penilia avirostris	*Nd*	*Nd*	231	385
Pleopsis polyphemoides	*Nd*	*Nd*	17	38
Sagitta sp.	2	3	15	15
Others*	19	3	8	5

* Gastropoda, Bivalvia, Polychaeta, Echinodermata, Siphonophora, Thaliacea, fish larvae and fish eggs; *Nd*: Not detected

Conclusion

As a conclusion of the present study in terms of water quality parameters, nutrient load, TIN:P ratio, TRIX index eutrophication risk, and zooplanktonic data evaluation, it can be concluded that highly interactive trophic level variability was observed in the study area of Sığacık Bay, during the sampling period. The Eutrophication Risks Scala of less than "4" ($T<4$) recorded in this study might indicate that there is no eutrophication risk in the Tuna Cage Farm Site of Sığacık Bay, according to the environmental legislations enacted for "Sensitive Areas of Enclosed Bays where Fish Farms are not allowed". Further investigations are encouraged in terms of continuous monitoring of cage farm sites in order to control water quality and potential farm effects for the sustainable growth of tuna aquaculture in the Mediterranean.

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: No Ethical committee approval is required for this study, since no experimental living organisms were used.

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