Journal of Agriculture and Ecology Research International
6(2): 1-9, 2016; Article no.JAERI.22872
ISSN: 2394-1073

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Impact of Mariculture on the Macrobenthic Invertebrate Abundance and Distribution in Lagos Lagoon Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JAERI/2016/22872
Editor(s):
(1) Ki-Hyun Kim, Atmospheric Environment & Air Quality Management Lab, Department of Civil & Environmental Engineering, Hanyang University, South Korea.
Reviewers:
(1) Mauricio Laterca Martins, Federal University of Santa Catarina, Brazil.
(2) Eugene A. Silow, Irkutsk State University, Russia.
(3) Anonymous, Centro de Investigaciones Biologicas del Noroeste, Mexico.
(4) Paola Lombardo, University of L'Aquila, Italy.
Complete Peer review History: http://sciencedomain.org/review-history/13009

Original Research Article

Received 2nd November 2015
Accepted 6th January 2016
Published 18th January 2016

ABSTRACT

This study investigated the effect of a mariculture fish cage culture on the abundance, composition and distribution of macrobenthic invertebrates of Lagos lagoon from February 2011 through July 2011. A record of three animal Phyla – Mollusca, Arthropoda and Annelida was established with a total of 1469 macrobenthic taxa. The dominant species throughout the study were of the class Bivalvia - *Aloidis trigona* while the rarest species was the Polychaeta - *Nereis succinea*. - There was significant difference in the genera diversity (ANOVA test; $p < 0.05$). Generally, the diversity of macrobenthic invertebrate at the cageless site of the study area may have been influenced by the absence of fish cage because the highest fauna abundance was observed while the least diversity was at the cage downstream of the cageless site. Comparison of particle size showed a significant correlation between the three stations ($p < 0.01$), at 99% mutual relationship between the three stations. Studies on the use of macrobenthic invertebrates to investigate the environmental impacts of anthropogenic activities such as fish cage culture system on the lagoon should include ecological impact to identify possible alteration in environmental conditions of benthic macro-invertebrates.

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Keywords: Mariculture; macrobenthic invertebrates; anthropogenic activities; particle size.

1. INTRODUCTION

Globally, fish represents about 16.6 percent of animal protein supply and 6.5 percent of all protein for human consumption [1]. Fish is usually low in saturated fats, carbohydrates, and cholesterol and provides not only high-value protein but also a wide range of essential micronutrients, including various vitamins, minerals, and polyunsaturated omega-3 fatty acids [1]. According to [2] it has been predicted that fish consumption in developing countries will increase by 57 percent, from 62.7 million metric tonnes in 1997 to 98.6 million in 2020.

The importance of aquaculture has grown substantially in most countries; accounting for more than one-quarter of the total fish consumption by humans [1].

Like most other types of aquaculture, mariculture fish cage system began in Southeast Asia [3] having cage units of different shapes and sizes to suit individual farmer's needs. It can be from readily available construction materials such as polypore, wood or steel for both fresh and marine environments. Currently, most designs used are frames of plastic pipes with a synthetic fiber net suspended.

In some parts of the world, aquaculture has expanded at the expense of natural environment. It is assumed that the deposition of organic material under the cages may result in changes in abundance, dominance, and diversity of benthic species or the overlying water quality [4].

Researchers have established a pattern of relationship between benthic macro-invertebrate fauna, substrate type and organic contents of sediment. [5] studied the effects of organic enrichment on macrobenthic populations and observed a decrease in species richness and an increase in opportunistic species. Other studies using macrobenthic invertebrates as bio-indicators in an aquatic ecosystem have also shown a general decrease in invertebrate abundance, species diversity and richness [6].

Macrobenthic invertebrates are mostly non-migrant inhabitants. While this is somehow true, migrations to and from specific communities happen all the time. However, the tendency of benthic macroinvertebrates to remain in a particular habitat and at the same time be more or less intolerant of pollution, may be used as a bioindicating measure to assess the ecological status of an ecosystem [7,8].

Knowledge of the macrobenthic invertebrates of the Lagos lagoon has been limited to the biology and ecology of few species, while its diverse habitats host a wide variety of organisms [9]. However, there is no information available on the use of benthic invertebrates in examining the environmental quality where a mariculture fish cage is present. Therefore, the results illustrated in this study remain very valuable to understand and evaluate how Lagos lagoon is impacted with this activity.

2. MATERIALS AND METHODS

2.1 Study Site

The Lagos lagoon is the largest of the lagoon systems of the Gulf of Guinea located between longitude 3°10' and 3°45'E and latitude 6°15' and 6°36'N, covering an area of about 208 km^2. Its depth ranges from 3 m in most parts to between 6 m and 10 m in the deeper portions. It opens into the gulf of Guinea through the Lagos harbor [10].

2.1.1 Description of the fish cage and type of fish cultured

The mariculture fish cage was constructed using polyvinyl chloride (PVC) pipes as cage floatation material to ensure it stays afloat in water and a polyethylene netting was used for fabricating the cage (this net is used because its water repellent) through the frame to a depth of 1.5 m. A concrete slab was attached to anchor and stress the cage to give it a square shape structure and prevent indiscriminate drifting of the suspended net.

Fishes reared during the period of study were *Tilapia guineensis, Sarotherodon melanotheron* and *Clarias gariepinus* over a period of 120 days. The initial weight of fishes was about 150 g, fed with 30 – 60 g fish feed twice daily. The total biomass harvested ranged between 600 – 1200 g.

2.2 Sample Collection and Analysis

2.2.1 Sediment samples

Bottom sediments were collected monthly from February to July using a van Veen grab sampler

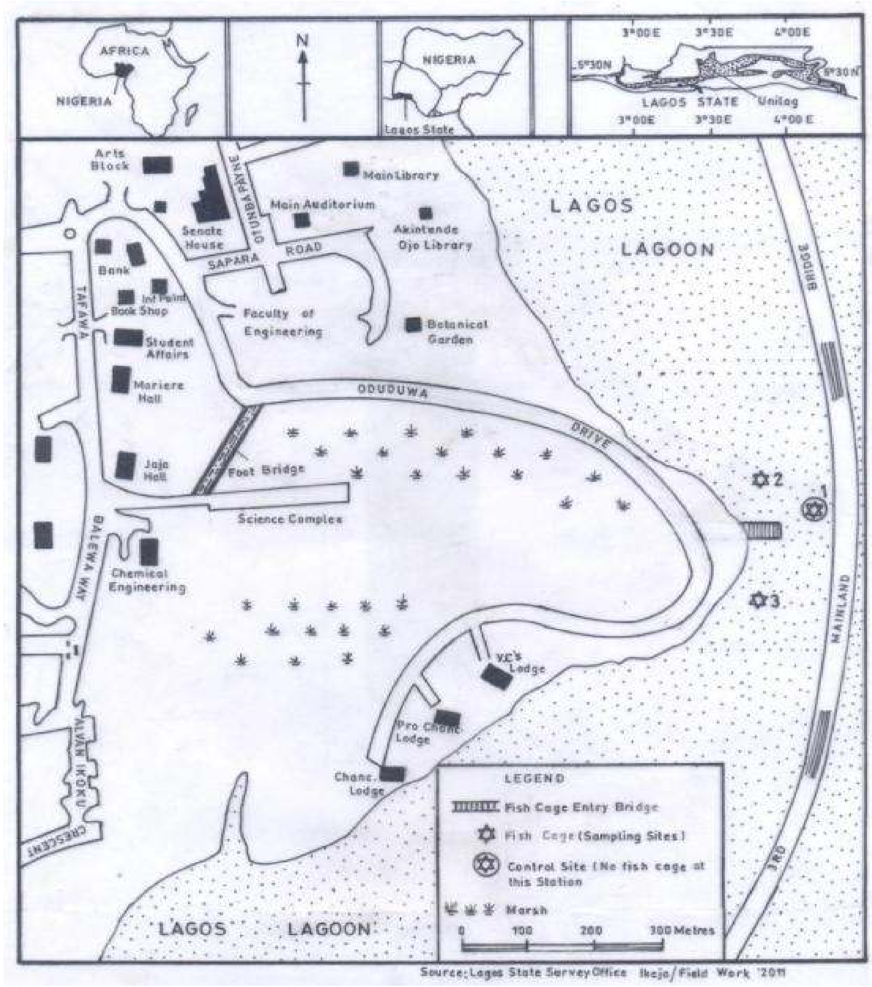

Fig. 1. Map showing the mariculture fish cage sampling sites

at each of the stations and a portion was collected into three well labeled polythene bags for further analysis [11]. The three polythene bags were labeled as (Control/ fish cage site); upstream fish cage area and downstream fish cage area.

2.2.2 Grain size analysis – (Sieve and hydrometer analysis)

Granulometric analysis was performed according to standard methods (ASTM D422-63(2007).

3. BENTHIC MACRO-INVERTEBRATES

On deck, each sample was emptied from the van Veen grab into a plastic bowl and carefully passed through a 0.5 mm mesh size sieve. The content on the sieve was transferred into a pre-labeled container and 10% formalin added for preservation before sorting in the laboratory.

In the laboratory, the fixed samples were taken into the white enamel tray at a time and carefully sorted with the aid of the magnifying glass. Sorted samples from each sampling station were then put in a transparent plastic bowls, preserved in 10% formalin. Taxonomic identification was carried out at the genus level.

3.1 Margalef's Index

This was used in computing taxa richness.

$$D^{Mg} = \frac{S - 1}{\ln N}$$

Where:

D^{Mg} = diversity index
S = number of species recorded
N = total number of individuals in the sample

3.2 Shannon Index (H)

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Where:

H = Shannon's diversity index
S = total number of species in the community (richness)
Pi = proportion of *S* made up of the *i*th species

3.3 Dominance

$$D = \frac{ni \times 100}{N}$$

Where:

N = ∑ni
ni = number of observation in group i

3.4 Analysis of Variance

Values are presented as mean ± standard deviation of the triplicate stations. One way Analysis of Variance (ANOVA) was used to test for statistical difference in the means of parameters. The results were computed statistically (SPSS software package for windows, version 15) using one way Analysis of Variance, p<0.05 was considered significant.

4. RESULTS

There is significant correlation between the three stations (p<0.01) which signifies that there is 99% mutual relationship between the three stations (Table 1). Using ANOVA also showed a significant difference between the three stations (p<0.01).

Table 1. Comparison of particle size using Pearson's correlation

Particle size	Cageless site	Upstream cage	Downstream cage
Sand%	69	75	88
Silt%	11	15	10
Clay%	14	8	1
Gravel%	6	2	1
Mean±s.d	25±29.52*$^{2\&3}$	25±33.75*$^{1\&3}$	25±42.21*$^{1\&2}$

S.D=Standard Deviation, = Significant, superscript $^{1, 2 \& 3}$ shows the correlation between the stations.*

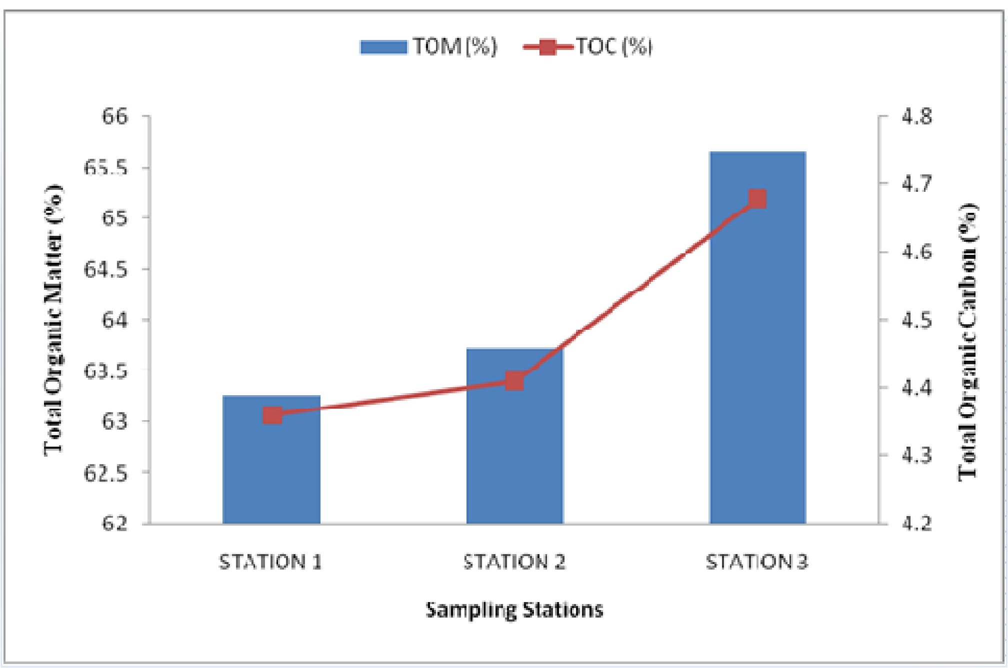

Fig. 2. Mean of TOM (%) and TOC (%) at the sampling stations Feb. – July 2011

5. COMMUNITY STRUCTURE

The overall taxa composition, distribution and abundance of macrobenthic invertebrate at the study site in Lagos lagoon is presented in Table 2. A total of 1469 macrobenthic individuals belonging to 10 genera were identified. The highest number of individuals (1026) was recorded at station 1 (cageless site) and the lowest (159) was recorded at station 3 (cage downstream). Melanidae, Potamididae, Aloididae, Neritidae and Mactridae were recorded at all sampling stations throughout the study period.

Fluctuations in the number of the major taxonomic groups' showed Bivalvia were most abundant at all stations throughout the study period while Polychaeta were the least abundant (Table 2).

5.1 Dominant and Subdominant Groups

Gastropoda were dominant at all study stations except at the cageless site while the bivalvia were dominant at all study stations except at the downstream cage site. The class polychaeta were not dominant or subdominant at any of the study stations but form the rare occurring species while the maxillopoda were sub-dominant at the upstream cage (Table 3).

Table 2. The overall taxa composition, specie distribution and number of individuals (n) of macrobenthic invertebrates at the mariculture cage site, Lagos lagoon during study period

	Cageless site (n)	Upstream cage (n)	Downstream cage(n)
Neritidae	3	83	15
Neritina glabrata			
Neritina kuramoensis			
Melanidae	43	33	41
Pachymelania aurita			
Potamididae	90	64	66
Tympanotonus fuscatus			
Tympnotonus fuscatus var. radula			
Bivalvia			
Ostreidae	21	2	
Crassostrea gasar			
Mactridae	98	21	5
Mactra glabrata			
Aloididae	760	71	12
Aloidis trigona			
Arthropoda			
Maxillopoda			
Balanidae	11	3	16
Balanus pallidus			
Annelida			
Polychaeta			
Nereidae		7	4
Nereis succinea			
Total	**1026**	**284**	**159**

Table 3. The Distribution of dominance of the major macro-invertebrate groups in Lagos lagoon study stations from February through July, 2011; the values are in percentages; > 15% Dominant, >5% to < 15% Subdominant

Class	Cageless site	Upstream cage	Downstream cage
Gastropoda	13.3*	63.4**	76.7**
Bivalvia	85.7**	30.1**	10.7*
Polychaeta	-	2.5	2.5
Maxillopoda	1.1	1.1	10.1*

*Key: ** Dominant, * Subdominant*

5.2 Genera Diversity

Both Taxa richness (d) and Shannon's diversity were highest at downstream cage and the diversity indices were lowest at the cageless site (Table 4). There was significant difference in the genera diversity (ANOVA test; $p < 0.05$) at the three stations while the overall temporal fluctuations in abundance of major taxonomic group at the study stretch are presented in Fig. 3.

Statistical evaluation using the biotic index (AMBI indices) revealed that station two (upstream cage site) is undisturbed but its presence may have effect on the cageless site and the cage downstream which ae shown to be slightly disturbed (Figs. 4 and 5).

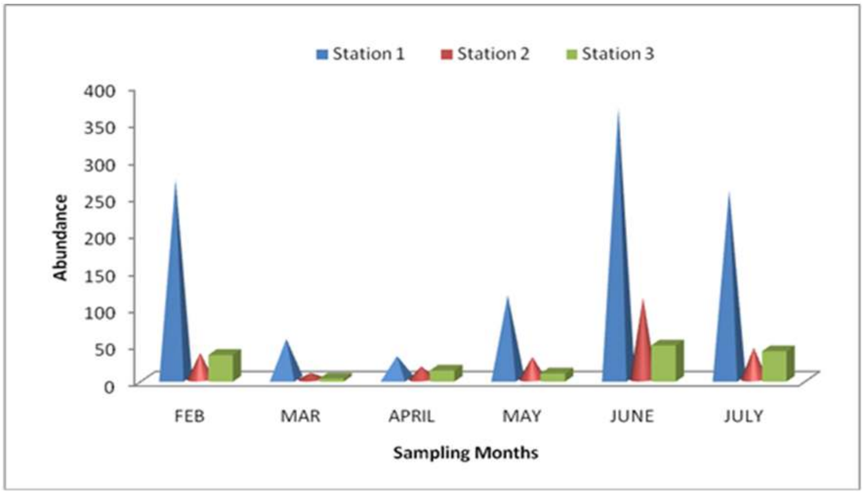

Fig. 3. Temporal fluctuation in total abundance of macrobenthic invertebrate at study stations from February through July, 2011

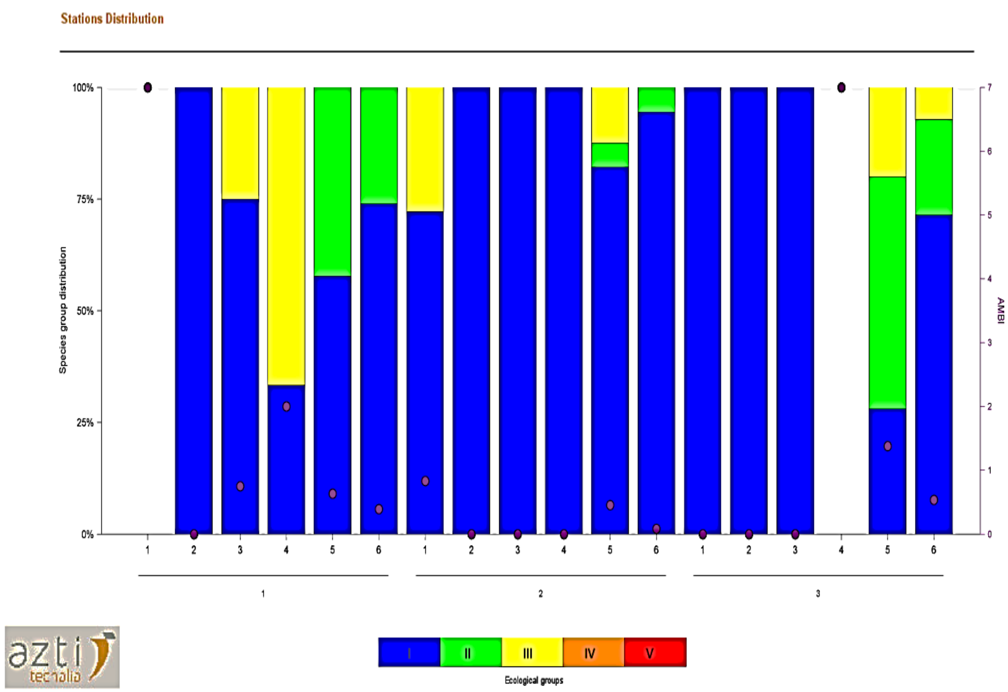

Fig. 4. Histogram of the ecological groups af the sampling stations

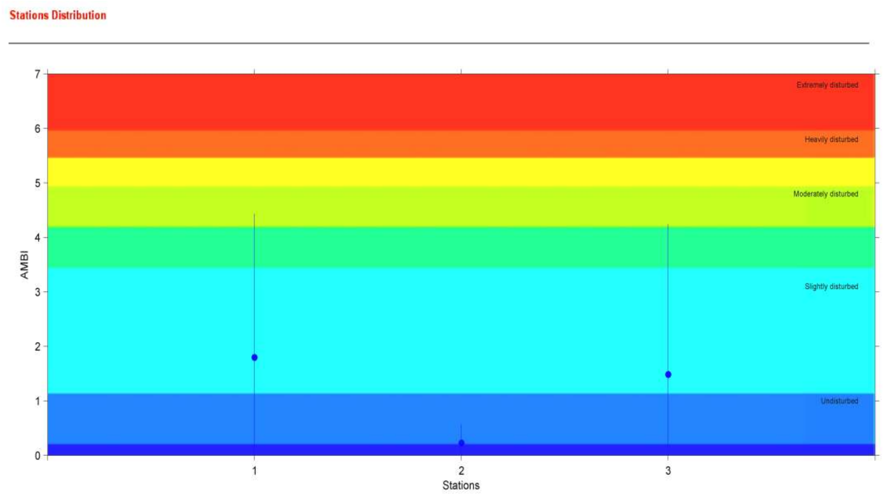

Fig. 5. The space/time distribution of the mean AMBI of the study stations

Table 4. Diversity of benthic macro-invertebrates at the study stations in Lagos lagoon from February through July, 2011

	Cageless site	Upstream cage	Downstream cage
No of samples	5	5	5
No of Taxa	8	7	8
No of individuals	1026	284	159
Taxa richness (d)	2.32	2.45	3.18
Shannon – Wiener index (H)	0.19	0.34	0.33

6. DISCUSSION

Substrate attachment, anthropogenic activities and food availability are factors which affected the macroinvertebrate abundance between the study stations. Macroinvertebrates present were mostly made up of molluscs which are endemic to West Africa found in characteristic sandy sediment type with silt – clay fraction less than 30%.

According to [9], the most abundant macrobenthic fauna in Lagos lagoon are gastropods. This observation was similar in this study where the gastropods; *Tympanotonus fuscatus* var. *radula*, *Pachymelania aurita* and bivalvia; *Aloidis trigona* occurred highest. There distribution in the Lagos lagoon is in line with past studies though a significant reduction in number of these molluscs was recorded. This could be as a result of the shorter duration of the study; fewer study stations and the activity of the fish cage culture in the study area. Other macrobenthos lying alongside *Tympanotonus fuscatus* var. *radula, Aloidis trigona* in the Lagoon include *Neritina Kuramoensis, Mactra glabrata, Nereis succinea*.

Furthermore, it has been stated by [12], that *Crassostrea gasar* is one of the dominant members of the Pachymelania community of the Lagos lagoon. These bivalves *Crassostrea gasar* and *Mactra glabrata* rarely occurred during the study while *Aloidis trigona* occurred in great number in all the study stations. The rare occurrence of *Crassostrea gasar* at the caged stations could be associated to habitat modification possibly due to organic matter deposit from mariculture cage on the bottom sediment. Additionally, this rarity may have resulted from other factors such as dredging, discharge of waste from point sources.

The nature of bottom deposits and the distribution of polychaetes in the Lagos lagoon suggest a preference for muddy over sandy sediment. It is possible that the recorded polychaetes in this study are signs of pollution in the study area because the polychaete species are indicators of an organically polluted environment [13,14].

Brooks and Mahnken [15] reported that *Capitella capitata* was observed in 69% of all samples selected from seven different salmon farms in British Columbia while [16] recorded that the principal species which were associated with organically impacted sites in Hios Island were the polychaetes – *Nereis diversicolor, Capitella capitata* and *Hyalinoecia brementi*. This is in agreement with this study as *Nereis succinea* was recorded at the caged sampling stations. This could be a possible indication that the area is becoming organically polluted which in time to come, an increase may be observed. Organic enrichment has been shown to have a significant effect on diversity and macrobenthic composition [17].

Consequently, the low diversity recorded during the study period shows that anthropogenic activities as well as fluctuations in physico-chemical conditions are possibly responsible for the observed species distribution and abundance. Furthermore, it is possible that the macrobenthic invertebrate communities have been greatly affected by environmental perturbation associated with the fish mariculture causing changes in sediment characteristics as the presence of stress indicating species suggests.

7. CONCLUSION

It has been suggested that the major causes of benthic population impoverishment are as a result of low sediment oxygen which may be responsible for the low diversity and species richness observed during this study in the area where the fish cages (upstream cage and downstream cage) were situated. Further studies in the Lagos lagoon on the use of macrobenthic invertebrates to investigate the environmental impacts of anthropogenic activities on the lagoon should include ecological impact studies to identify possible altered environmental conditions.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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