

## DIATOMS AND DINOFLAGELLATES DISTRIBUTION DURING DRY SEASON IN MACROTIDAL TANINTHARYI RIVER ESTUARY, MYANMAR

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### ABSTRACT

The present study was conducted to analyze the spatio-temporal distribution of diatoms and dinoflagellates in the macrotidal Tanintharyi River estuary during dry season. Water samples were collected by plankton net from surface water during the neap-spring tidal cycle from 28 February to 7 March 2019 from the downstream to the upstream through the estuary. Further, the environmental parameters were measured using CTD probe. The distribution and abundance of species was analyzed using compound microscope. The salinity was increased from neap to spring tide and it varied spatially from the downstream (26-30.7) to the upstream (2-7.3). Turbidity was increased from neap tide and reached highest value in spring tide at mid upper estuary. A total of 82 phytoplankton species consisting of 59 diatoms and 23 dinoflagellates were observed. The cell density of diatoms and dinoflagellates were ranged from  $7.0 \times 10^3$ - $2.3 \times 10^5$  cells L<sup>-1</sup> and  $1.3 \times 10^2$ - $6.1 \times 10^4$  cells L<sup>-1</sup>. The abundance of diatoms and dinoflagellates were higher in neap tide than that in spring tide. Diatoms were increased from neap to intermediate tides and it depleted in spring tide. Dinoflagellates were decreased from neap to spring tides. Additionally, diatoms and dinoflagellates abundances were increased from downstream to mid lower-estuary and decreased in the upstream. Salinity and turbidity led to increase from neap to spring tide while the diatoms and dinoflagellates distribution decreased oppositely. The present study indicated that salinity, turbidity and mixing driven by the neap-spring tidal cycle were the influencing factors for the phytoplankton distribution in a tide-dominated estuary.

*Keywords:* Diatoms, dinoflagellates, phytoplankton distribution, neap-spring tidal cycle

### 1. INTRODUCTION

Estuaries are among the most dynamic and complex environments on earth, which form a transition zone between marine and terrestrial environments. They are the important regions for both human beings and wildlife because of their unique geographical location and abundance of natural resources (Azhikodan and Yokoyama, 2016). Estuaries serve as nursery ground and major spawning site for many species of fish and wildlife (Courrat et al., 2009). Therefore, estuaries are highly productive areas for coastal environments. The productivity of estuarine ecosystems are highly influenced by the phytoplankton production as the primary producer (Canini et al., 2013).

Phytoplankton is a unicellular and microscopic organisms found in both marine and freshwater environments, which has a rapid growth rate and short life span. Approximately 40% of planet's total annual photosynthetic production come from phytoplankton production (Araña, 2007). According to the coastal and estuarine food web, most of organisms such as zooplankton (secondary producer), shellfish, finfish and other organisms (tertiary producer and so on) depend on the phytoplankton directly or indirectly for their food (Ananthan et al.,

2008). Because, phytoplankton has a vital role in the carbon, nutrient and oxygen cycling in estuarine and coastal waters (Paerl and Justic, 2011). Additionally, the rapid increase in phytoplankton can lead to eutrophication and affect the health of the ecosystem. Therefore, the composition and distribution of phytoplankton in estuaries are important factors affecting the population of other organisms in estuarine food web (Lehman, 2007). Hence, detailed knowledge of phytoplankton distribution is essential to understand the estuarine production and manage a healthy environment.

Phytoplankton composition and distribution in estuaries are affected by the freshwater input, tidal forcing, and grazing rates of zooplankton. However, the tidal forcing has the strong impact on the distribution and abundance of phytoplankton since the spring-neap transition can control the environmental factors such as light, salinity, turbidity, and nutrients in estuaries (Azhikodan and Yokoyama, 2016; Domingues et al., 2010; Gao and Song, 2005; Paerl and Justic, 2011). Further, phytoplankton response varies spatio-temporally with in an estuary as well as regionally (Monbet, 1992). Many studies focused on the composition, distribution, and influencing factors of phytoplankton in estuaries worldwide (Azhikodan and Yokoyama, 2016; Domingues et al., 2010; Gao and Song 2005; Monbet, 1992; Pednekar et al., 2014; Wan Maznah et al., 2016). Azhikodan and Yokoyama (2016) focused on the variation of phytoplankton related with salinity, suspended sediment concentration and light intensity in the macrotidal Chikugo River estuary, Japan during a spring-neap-spring tidal cycle. They mentioned that the light availability driven by the mixing and formation of estuarine turbidity maximum (ETM) zone are the main factor that control the phytoplankton dynamics in tide dominated estuaries. Domingues et al., (2010) studied the variation of phytoplankton in the mesotidal Guadiana estuary and reported that the tidal variability was the important factor that influence the phytoplankton behavior. Further, Gao and Song (2005) reported that the sufficient light and high nutrient availabilities led to phytoplankton bloom in the macrotidal Changjiang estuary, China. Monbet (1992) studied the controlling factors on phytoplankton biomass in 40 microtidal and macrotidal estuaries around the world. He observed that the tidal range, tidal mixing, current velocity, light penetration, and sediment resuspension influenced the phytoplankton biomass in estuaries. Pednekar et al., (2014) carried out the research focusing on spatio-temporal distribution of phytoplankton at the macrotidal Mandovi estuary, India and they discussed salinity was the main factor for phytoplankton distribution in estuaries. The effects of tidal cycle on the phytoplankton composition and distribution in Merbok River estuary, Malaysia was conducted by Wan Maznah et al., (2016) and the authors reported that water parameters varied by tide and these variation affected the composition and distribution of phytoplankton.

Although these studies helped to get a better understanding of the phytoplankton dynamics in relation with environmental factors in estuaries, they were inadequate to truly demonstrate the distribution of individual species of phytoplankton especially in tide dominated estuaries. Further, there are no systematic studies conducted on phytoplankton distribution in the estuaries of Myanmar. Therefore, the present study aims to investigate the spatio-temporal distribution of phytoplankton species in the macrotidal Tanintharyi River estuary (TRE), Myanmar during a neap-spring tidal cycle in the dry season. The TRE is an important region by the presence of many diverse commercial small-scale fishery, which has a strong impact on the economy of Myanmar.

## **2. MATERIALS AND METHODS**

### **2.1 Study area**

The macrotidal Tanintharyi River estuary (Fig. 1) is a highly productive estuary in Myeik and local fishermen are exploited fishery resources from it. Strong tidal range of Andaman Sea and freshwater flow from the Tanintharyi River influences the estuary. Tanintharyi River is a major river of southeastern Myanmar and the largest river running through the Tanintharyi Region. The river is formed from the gathering of the rivers Kamaungthwe and Ban, near Myitta. It is 300 km long and flows into southern part of the Andaman Sea throughout the estuary. It has a tropical monsoon climate with dry season (November to April) and wet season (May to October). The average annual rainfall is about 3900 mm and 90% of total rainfall occurred during wet season (Dept. of Meteorology and Hydrology, Myanmar). The estuary experiences semidiurnal tidal amplitude of 6 m at spring tide and 2 m at neap tide. Kyauk Phyar River estuary and Thamoke River estuary are the main branches of Tanintharyi river estuary in Myeik water. Although the present study was emphasized on the 50 km long Kyauk Phyar River estuary, the name of the study site in the present paper was referred as Tanintharyi river estuary.

### **2.2 Field measurement and sampling**

Field measurements and sampling were conducted in the macrotidal Tanintharyi River estuary at four stations from downstream (0 km) to upstream (45.59 km) during the dry season from 28 February to 7 March 2019. The four stations are K010 (lower estuary), K080 (mid lower estuary), K110 (mid upper estuary) and K170 (upper estuary) (Fig.1). Water samples were collected by plankton net (20  $\mu$ m mesh size, 20 cm in diameter, 60 cm in length) from the surface layer during the daytime for analyzing phytoplankton. The collected water samples

were immediately preserved with 2% formaldehyde solution. Further, the vertical profiles of salinity and turbidity were measured by using CTD (conductivity, temperature, depth) probe (AAQ 175, JFE Advantech, Japan) at all the stations. The water level data were collected by using ONSET HOBO-U20L-02 in 10 min interval at 8 m depth that is located in the river mouth of estuary. All the surveys were conducted at the high tide during a neap-spring tidal cycle.

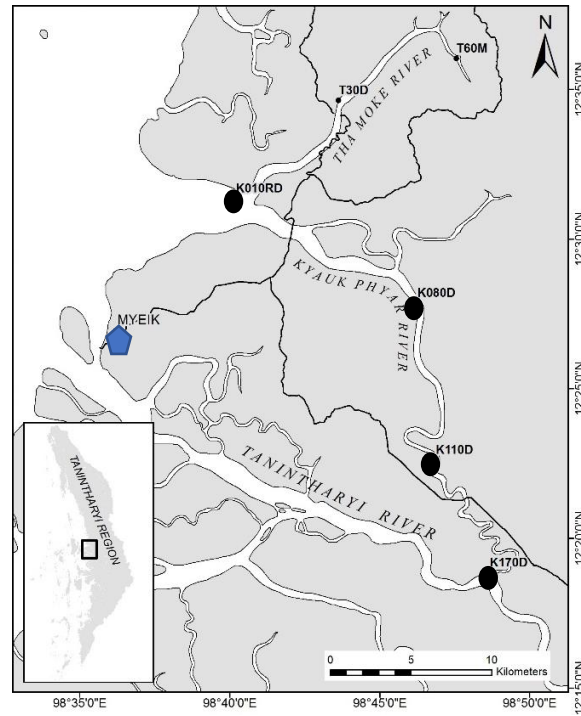


Figure 1. Map showing the study area

### 2.3 Laboratory analysis

Quantitative analysis of phytoplankton were conducted using a light microscope (NIKON: E100 LED) from the laboratory. Phytoplankton were identified into species level by the following references: Al-Kandari et al., (2009); Tomas (1997). Phytoplankton was grouped as diatoms (Bacillariophyta) and dinoflagellates (Dinophyta). Diatoms and dinoflagellates are the most abundant and widespread phytoplankton groups in estuarine waters. Number of each phytoplankton species were counted in 1 ml – 5 ml subsamples after 24 hours sedimentation time by using counting slide to calculate the abundance of phytoplankton.

### 2.4 Data analysis

The abundance of phytoplankton was estimated by counting the number of species. For analyzing diatoms and dinoflagellates species, firstly the filtered volume of water entering the phytoplankton net was calculated by the formula:

$$V = \pi r^2 L \quad (1)$$

where, V is the volume of filtered water, r is the radius of the hoop of the front of the net, L is the distance through which the net is hauled.

To calculate the cell density of the phytoplankton, the concentration factor of water samples was needed in order to use the counting slide. The concentration factor of water samples is calculated as:

$$CF = A/B \quad (2)$$

where, CF is the concentration factor, A is the original volume of sampled water and B is the final volume of sampled water.

Phytoplankton cell in the concentrated water sample was counted with counting slides (10 x 10 x 1 mm<sup>3</sup>) following the guidelines by LeGresley and McDermott (2010). The resulting number of cells were estimated by:

$$Cell\ density = n \times 10^3\ cell/ml \quad (3)$$

where, n is the number of cells.

To obtain the cell density of the phytoplankton from the original water sample, the total cell numbers was divided by CF.

### 3. RESULTS

#### 3.1 Physical parameters

The environmental factors (surface salinity, surface turbidity and water level) measured during the study period are given in figure 2. It is clear from figure 2a that the study period was a neap-spring tidal cycle with tidal amplitude varied between 1.2 m at neap tide and 4.9 m at spring tide.

The surface salinity was increased from neap tide to spring tide and the range of surface salinity in the estuary was 2 – 30.7 throughout the study period (Fig. 2b). The surface salinity in the lower estuary was 27 during neap tide and 30.7 during spring tide. On the other hand, the surface salinity in the upper estuary was 4 at neap tide and 5 at spring tide. Further, surface salinity in middle estuary was 16 and 24 during neap tide and spring tide respectively. This shows that the surface salinity was higher in the lower and middle estuary compared to the upper estuary.

Surface turbidity in the estuary was less than 8 FTU during neap and one day after neap tide (Fig. 2c). Turbidity gradually increased during the intermediated tide (7 – 42 FTU) and became maximum (155 FTU) during spring tide. During spring tide, turbidity was 41 FTU in the lower estuary, 56 FTU in the mid lower estuary, 155 FTU in the mid upper estuary and 79 FTU in the upper estuary respectively. Therefore, turbidity was high during spring tide especially in the mid upper estuary and upper estuary. When turbidity was maximum (155 FTU), the salinity value was 21 in mid upper estuary.

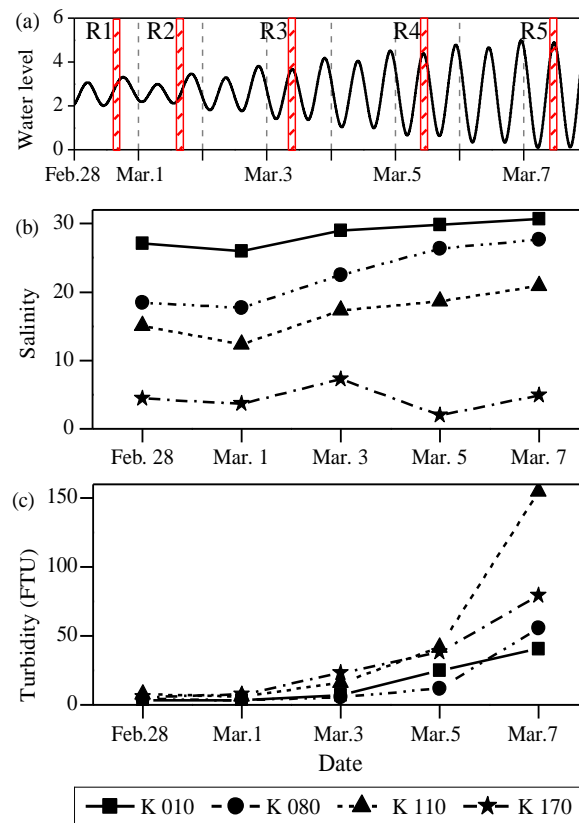


Figure 2. Variation of physical parameter a) tide, b) surface salinity and c) surface turbidity

#### 3.2 Phytoplankton abundance and distribution

A total of 82 phytoplankton species belonging to 30 families were identified in the present study. Among them, 59 species (belonging to 22 families) were diatoms and 23 species (belonging to 8 families) were dinoflagellates. Thalassionemataceae was the most dominant family together with Thalassiosiraceae, Coscinodiscaceae, Bacillariaceae in diatoms whereas Protoperidiniaceae was the common in dinoflagellates. The total abundances of phytoplankton recorded during neap to spring tide are shown in figure 3. The maximum abundance was found during intermediate tide with  $2.4 \times 10^5$  cells  $L^{-1}$  in the mid lower estuary due to the abundance of chain form species (*Thalassiosira eccentrica*, *Thalassionema* spp and *Pseudonitzschia seriata*, etc). However, the abundance reduced from intermediate tide to spring tide.

Additionally, the abundance of diatoms and dinoflagellates are shown in figure 4. The ranges of diatoms and dinoflagellates cell density were  $7 \times 10^3$  to  $2.3 \times 10^5$  cells  $L^{-1}$  and  $1 \times 10^2$  to  $6 \times 10^4$  cells  $L^{-1}$  respectively. The diatoms was increased from neap tide until three days after neap tide (intermediate tide), and then decreased towards the spring tide (Fig. 4). *Thalassionema nitzschioides* ( $535 - 73,864$  cells  $L^{-1}$ ) and *Thalassionema frauenfeldii* ( $668 - 47,293$  cells  $L^{-1}$ ) were the most common species and the following were *Melosira miniliformis*, *Pseudonitzschia seriata*, *Thalassiosira eccentrica* and *Skeletonema costatum* (Fig. 5). Although the diatoms was abundant throughout the estuary, the highest was found at the mid lower estuary and lowest in the upstream.

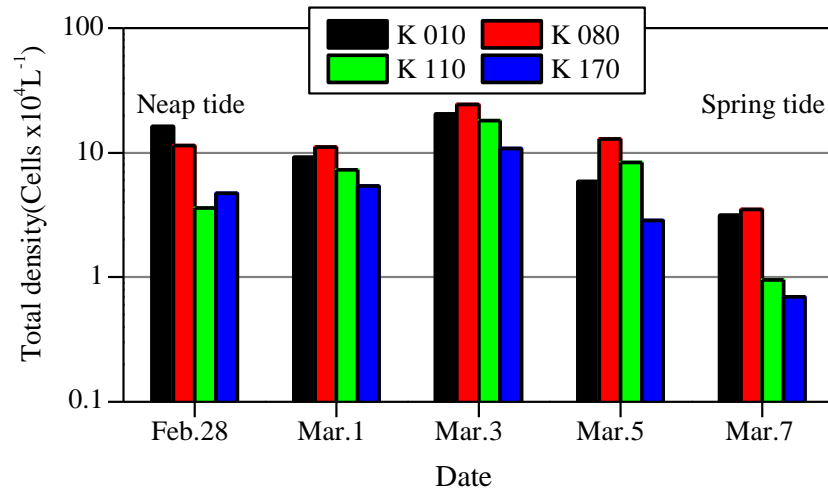


Figure 3. Total abundance of phytoplankton during 28 February – 7 March, 2019

Higher dinoflagellates abundance occurred during the neap tide and depleted during the intermediate tide and almost disappeared when the spring tide arrives. The minimum distribution was found at the upper stations of estuary (K110 and K170) due to low salinity while the maximum was observed at downstream (Fig. 4). *Protoperidinium depressum* was the dominant species throughout the study period and maximum abundance was  $21,725$  cells  $L^{-1}$  in neap tide. (Fig. 5).

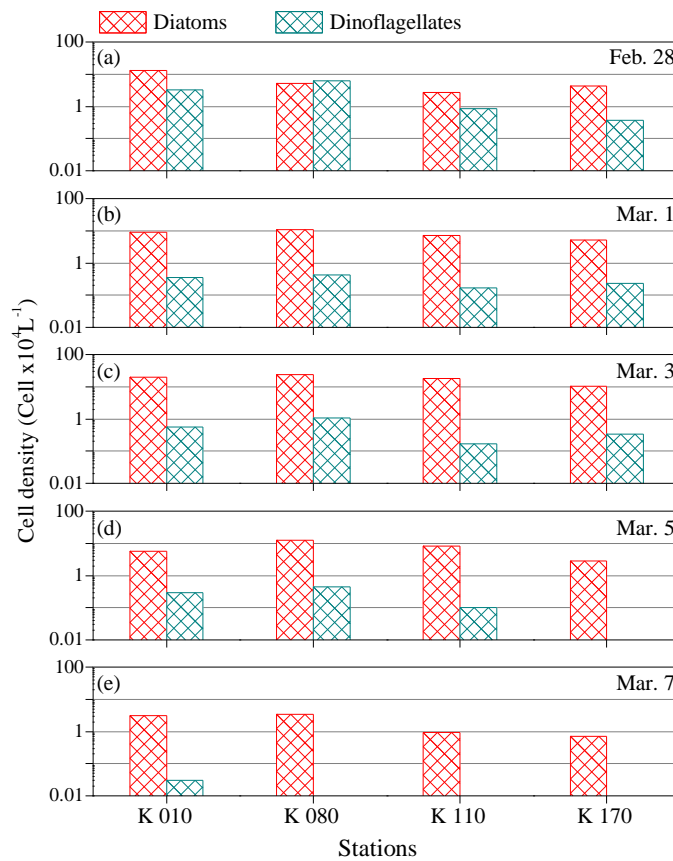


Figure 4. Variation of cell density of diatoms and dinoflagellates during neap-spring tidal cycle

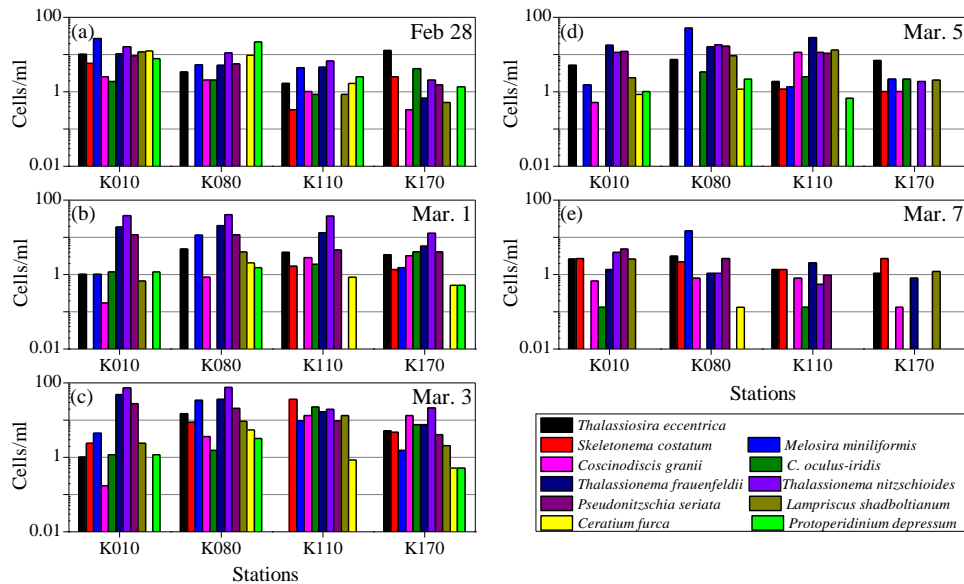


Figure 5. Dominant phytoplankton species found in neap-spring tidal cycle

## 4. DISCUSSION

### 4.1 Diatoms and dinoflagellates distribution

In the present study, 82 phytoplankton species (which includes 59 diatoms and 23 dinoflagellates species) were identified in the Tanintharyi River estuary during a neap-spring tidal cycle. Among these, diatoms were found as the major group over dinoflagellates throughout the estuary (Fig. 4). The earlier studies conducted in other estuarine areas also found similar results. Gao and Song (2005) observed 87 phytoplankton which include 54 species of diatoms in Changjiang estuary, China. Pednekar et al., (2014) found 209 phytoplankton species in the Mandovi estuary, India in which diatoms was the main group. Further, diatoms was the main group in Kyun-Su jetty area of Myeik water, Myanmar (Si Thu Hein and Lett Wai Nwe, 2014).

*Thalassionema nitzschioides* and *Thalassionema frauenfeldii* were the most dominant diatoms species in the Tanintharyi River estuary during the study period (Fig. 5). The other common diatoms species found in the estuary during the study period were *Pseudonitzschia seriata*, *Melosira miniliformis*, *Skeletonema costatum*, *Thalassiosira eccentrica* and *Coscinodiscus oculus-iridis*. Most of the dominant diatoms species found in the Tanintharyi River estuary are chain-forming species except *Coscinodiscus oculus-iridis* which is a single cell species. Further, they are characterized by large surface area, which make them slow sinking (Suthers and Rissik, 2009) and tolerant to tidal mixing than single cell species. Among the dinoflagellates, *Ceratium furca* and *Protoperidinium depressum* were the dominant species in Tanintharyi River estuary throughout the tidal cycle except spring tide. During spring tide, dinoflagellates were almost disappeared in the estuary. All the dominant species of diatoms and dinoflagellates in present study can be found in both marine and brackish waters (Al-Kandari et al., 2009; Tomas, 1997). Similar researches in different estuaries were observed *Skeletonema costatum* as the most dominant species since they are euryhaline (Gao and Song, 2005; Wan Maznah et al., 2016). The other dominant species found in estuaries and coastal regions were *Thalassionema frauenfeldii* (Canini et al., 2013; Pednekar et al., 2014), *Bacillaria paxillifera* and *Melosira miniliformis* (Si Thu Hein and Lett Wai Nwe, 2014), *C. granii* and *Pseudonitzschia seriata* (Vajravelu et al., 2018) and *Ceratium furca* (Canini et al., 2013).

### 4.2 Influence of physical parameters on diatoms and dinoflagellates distribution

In order to understand the effect of salinity and turbidity on the diatoms and dinoflagellates distribution in Tanintharyi River estuary, temporal and spatial variation of diatoms and dinoflagellates along with surface values of salinity and turbidity were shown in figure 6. During the neap-spring tidal cycle, the diatoms abundance in Tanintharyi River estuary was highest at intermediate tide and lowest at spring tide (Fig. 6a, Fig. 4). This shows that the diatoms starts to grow during the neap tide due to the favorable conditions of weak mixing and high light availability (low turbid water) and reaches its maximum growth two to three days after neap tide (intermediate tide). Then the diatoms depleted during the intermediate tide to spring tide because of the strong mixing and high turbidity. On the other hand, dinoflagellates abundance was maximum ( $6 \times 10^4$  cells  $L^{-1}$ ) during neap tide and it gradually depleted after neap tide and almost disappeared ( $1 \times 10^2$  cells  $L^{-1}$ ) when spring tide arrives (Fig. 6b, Fig. 4). Dinoflagellates have a fast growth rate that can proliferate in explosive ways within a day (Paerl and Justic, 2011). This can be attributed to the abundance of dinoflagellates during neap tide due to the weak mixing and low turbidity. However, dinoflagellates depleted soon after neap tide due to its short



lifespan. Therefore, the abundance of diatoms and dinoflagellates in the present study varied during the neap-spring tidal cycle due to the large difference in tidal range between neap tide (1.2 m) and spring tide (4.9 m). Phytoplankton abundance in the mesotidal Guadiana Estuary, southwestern Iberia had no significant correlation with tidal cycle because of its weak mixing and low tidal range compared with a macrotidal estuary (Domingues et al., 2010).

On a spatial perspective, the composition and abundance of both diatoms and dinoflagellates were maximum in the lower estuary (K010) and mid lower estuary (K080) whereas they decreased towards upstream (K170). This may be due to the high salinity and low turbidity in the lower part of estuary compared with the low salinity and high turbidity in the upper part of estuary. When the turbidity value reached maximum in mid upper and upper estuary, the diatoms abundance was decreased and dinoflagellates was disappeared. Turbidity concentration had a negative correlation with the variation of diatoms and dinoflagellates distribution in the Tanintharyi River estuary during the study period. This is because high turbidity can restrict the light intensity that need for the phytoplankton growth in estuaries (Azhikodan and Yokoyama, 2016). Pednekar et al., (2014) reported that diatoms was positively correlated with salinity while dinoflagellates was negatively correlated with salinity in the Mandovi estuary, India. Further, Bacillariophyta (diatoms) has high salinity tolerance and can observe similar number in both freshwater and marine environments while Dinophyta (dinoflagellates) was dominant only in river mouth near to the sea with high salinity in the Merbok river estuary, Malaysia (Wan Maznah, et al., 2016). Therefore, diatoms and dinoflagellates distribution in the tide dominated estuaries were influenced not only by salinity but also by the factors such as mixing and turbidity driven by the neap-spring tidal cycle.

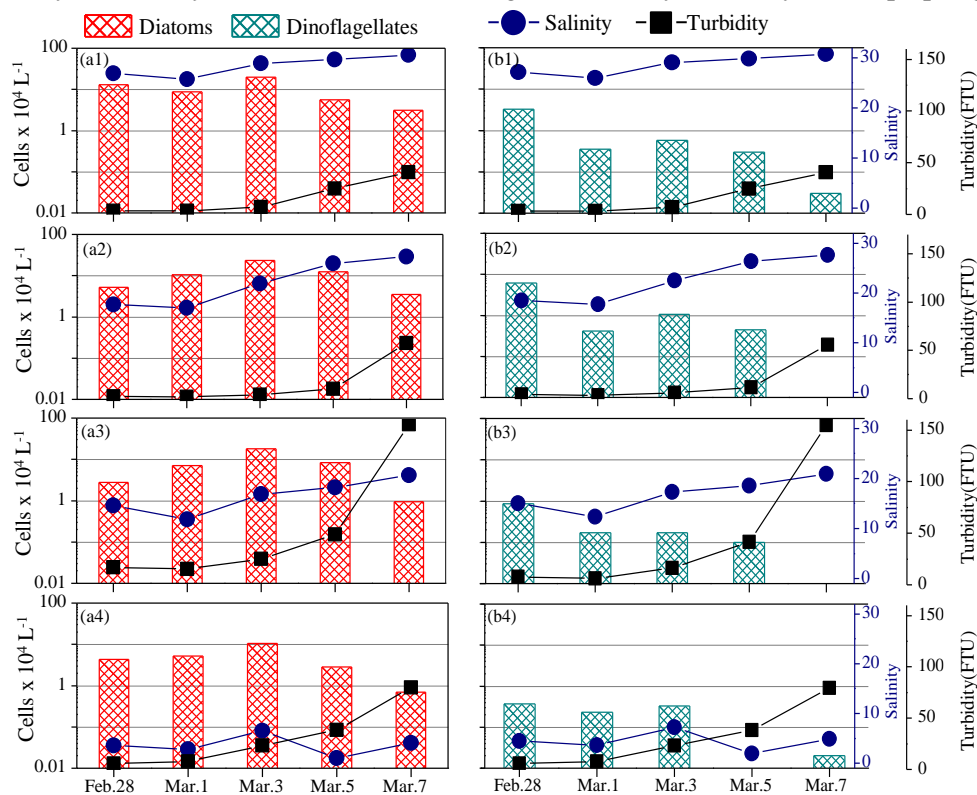


Figure 6. Variation of a) diatoms and b) dinoflagellates abundance relation with salinity and turbidity during February 28-March 7, 2019. 1) K010, 2) K080, 3) K110 and 4) K170

## 5. CONCLUSIONS

The present study summarized the distribution of diatoms and dinoflagellates as well as the factors affecting on them in the tide dominated Tanintharyi river estuary, Myanmar. The distribution and abundance of diatoms and dinoflagellates were varied throughout the estuary depend on neap-spring tidal cycle and environmental factors. Further, diatoms was the dominant group over dinoflagellates in the Tanintharyi river estuary. Diatom abundance was highest during intermediate tide and decreased towards spring tide. On the contrary, dinoflagellates abundance was highest during neap tide and it decreased from neap tide to spring tide. On a spatial perspective, both diatoms and dinoflagellates distribution were maximum in the lower part of the estuary and they decreased towards the upper estuary. The results showed that the distribution of diatoms and dinoflagellates in the Tanintharyi river estuary were not only influenced by the salinity but also by the factors such as mixing and turbidity driven by the neap-spring tidal cycle. These findings will provide basic information on the distribution and abundance of diatoms and dinoflagellates in the estuarine ecosystem and will be useful

for estuarine production, hydrological variation of estuary and aquaculture in the estuaries of Myanmar including Tanintharyi River estuary.

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## REFERENCES

- Ananthan, G., Sampathkumar, P., Soundarapandian, P., and Kannan, L. (2008). Phytoplankton Composition and Community Structure of Ariyankuppam Estuary and Verampattinam Coast of Pondicherry. *Journal of Fisheries and Aquatic Science*, 3(1): 12–21. <https://doi.org/10.3923/jfas.2008.12.21>.
- Al-Kandari, M., Al-Yamani, F. Y., and Al-Rifaie, K. (2009). Marine Phtoplankton Atlas of Kuwait’s Waters. Kuwait.
- Aung, L. L., Zin, E. E., Theingi, P., Elvera, N., Aung, P. P., Han, T. T., and Skaland, R. G. (2017). Myanmar Climate Report. Norwegian Meterological Institute, (9): 105.
- Araña, R. V. E. (2007). Abundance and Distribution of Phytoplankton communities in the coastal water of Mt. Malindang, Misamis occidental. *Master thesis*. MSU – Iligan Institute of Technology.
- Azhikodan, G., and Yokoyama, K. (2016). Spatio-temporal variability of phytoplankton (Chlorophyll-a) in relation to salinity, suspended sediment concentration, and light intensity in a macrotidal estuary. *Continental Shelf Research*, 126: 15–26. <https://doi.org/10.1016/j.csr.2016.07.006>.
- Canini, N. D., Metillo, E. B., and Azanza, R. V. (2013). Monsoon-influenced phytoplankton community structure in a Philippine mangrove estuary. *Tropical Ecology*, 54(3): 331–343.
- Courrat, A., Lobry, J., Nicolas, D., Laffargue, P., Amara, R., Lepage, M., and Le Pape, O. (2009). Anthropogenic disturbance on nursery function of estuarine areas for marine species. *Estuarine, Coastal and Shelf Science*, 81(2): 179–190. <https://doi.org/10.1016/j.ecss.2008.10.017>.
- Domingues, R. B., Anselmo, T. P., Barbosa, A. B., Sommer, U., and Galvão, H. M. (2010). Tidal variability of phytoplankton and environmental drivers in the freshwater reaches of the Guadiana Estuary (SW Iberia). *International Review of Hydrobiology*, 95(4–5): 352–369. <https://doi.org/10.1002/iroh.201011230>.
- Gao, X., and Song, J. (2005). Phytoplankton distributions and their relationship with the environment in the Changjiang Estuary, China. *Marine Pollution Bulletin*, 50(3): 327–335. <https://doi.org/10.1016/j.marpolbul.2004.11.004>.
- Kasai, A., Kurikawa, Y., Ueno, M., Robert, D., and Yamashita, Y. (2010). Salt-wedge intrusion of seawater and its implication for phytoplankton dynamics in the Yura Estuary, Japan. *Estuarine, Coastal and Shelf Science*, 86(3): 408–414. <https://doi.org/10.1016/j.ecss.2009.06.001>.
- Lehman, P. W. (2007). The influence of phytoplankton community composition on primary productivity along the riverine to freshwater tidal continuum in the San Joaquin River, California. *Estuaries and Coasts*, 30(1): 82–93. <https://doi.org/10.1007/BF02782969>.
- LeGresley, M. and McDermott, G. (2010). Counting chamber methods for quantitative phytoplankton analysis - haemocytometer, Palmer-Maloney cell and Sedgewick-Rafter cell. *Inc: Karlson, B., Cusack, C. and Bresnan, E. (Eds.), Microscopic and molecular methods for quantitative phytoplankton analysis. UNESCO: 25 – 30.*
- Monbet, Y. (1992). Control of phytoplankton biomass in estuaries: A comparative analysis of microtidal and macrotidal estuaries. *Estuaries*, 15(4): 563–571. <https://doi.org/10.2307/1352398>.
- <https://www.weather-atlas.com/en/myanmar/myeik-climate>.
- Paerl, H. W., and Justic, D. (2012). Primary Producers: Phytoplankton Ecology and Trophic Dynamics in Coastal Waters. *Treatise on Estuarine and Coastal Science*, 6: 23–42. <https://doi.org/10.1016/B978-0-12-374711-2.00603-3>.
- Pednekar, S. M., Kerkar, V., and Matondkar, S. G. P. (2014). Spatiotemporal distribution in phytoplankton community with distinct salinity regimes along the mandovi estuary, Goa, India. *Turkish Journal of Botany*, 38(4): 800–818. <https://doi.org/10.3906/bot-1309-29>.
- Si Thu Hein and Lett Wai Nwe. (2014). Study on seasonal variation of phytoplankton in the water off Kyun-Su Island, (Myeik Archipelagos). *Myeik University Research Jorunal*, 7(1): 110 – 118.
- Suthers, I. M., and Rissik, D. (Eds.). (2009). Plankton: A guide to their ecology and monitoring for water quality. CSIRO PUBLISHING.
- Tomas, C. R. (1997). Identifying marine diatoms and dinoflagellates. Academic Press. *Inc. Harcourt Brace & Company.*
- Vajravelu, M., Martin, Y., Ayyappan, S., and Mayakrishnan, M. (2018). Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia*, 60(2): 114–127. <https://doi.org/10.1016/j.oceano.2017.08.003>.
- Wan Maznah, W. O., Rahmah, S., Lim, C. C., Lee, W. P., Fatema, K., and Isa, M. M. (2016). Effects of tidal events on the composition and distribution of phytoplankton in Merbok river estuary Kedah, Malaysia. *Tropical Ecology*, 57(2): 213–229.