# P4 Assignment – STNDAN021

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## Background

The region chosen for this assignment is Thinadhoo Atoll in the Maldives, located on the Chagos-Laccadives ridge. Representing one of the largest atolls across the archipelago in the Indian Ocean, Thinadhoo Atoll has a unique surface morphology that is created by a combination of reef rims, outer reefs and lagoons (Rasheed et al., 2021). Similar to other atolls in the country, the Thinadhoo Atoll is known for it's steep and deep drop off zones on the outer reef area which creates an ideal environment for pelagic species such as apex predators such as tiger sharks *(Galeocerdo cuvier),* filter feeders such as the whale shark *(Rhincodon typus)* and a host of other smaller marine organisms inside the Atoll itself.

When considering bathymetry data, the Maldives is an exceptionally unique case as the underwater topography and seafloor features provide a better understanding of habitat distributions, key physical environments and current patterns. Simultaneously, these aspects play a big role in the functionality of the rich coral reef systems, teeming with life in the area. The chlorophyl concentration data across different outputs are a vital indicator of primary production in the area. This biological indicator provides scientists with a better understanding of how this is closely linked to the biodiverse marine ecosystem, water quality and overall ecological structure of a given area.

In assessing both bathymetry features and chlorophyl distribution data of the Thinadhoo Atoll, this gives scientists the ability to explore the interconnectedness of how oceanographic conditions such as light penetration and nutrient availability shape the unique marine environment found in the Maldives. Furthermore, analysing chlorophyll data from 1997-1998, can provide a better understanding on how these values may have changed overtime as a result of the impacts of climate change (e.g. ocean acidification). These impacts are particularly of interest in an area such as the Maldives that has undergone severe heat waves and coral bleaching events over the last decade (Cowburn et al., 2016).

## Figure & Data Analysis

### 1. Bathymetric data

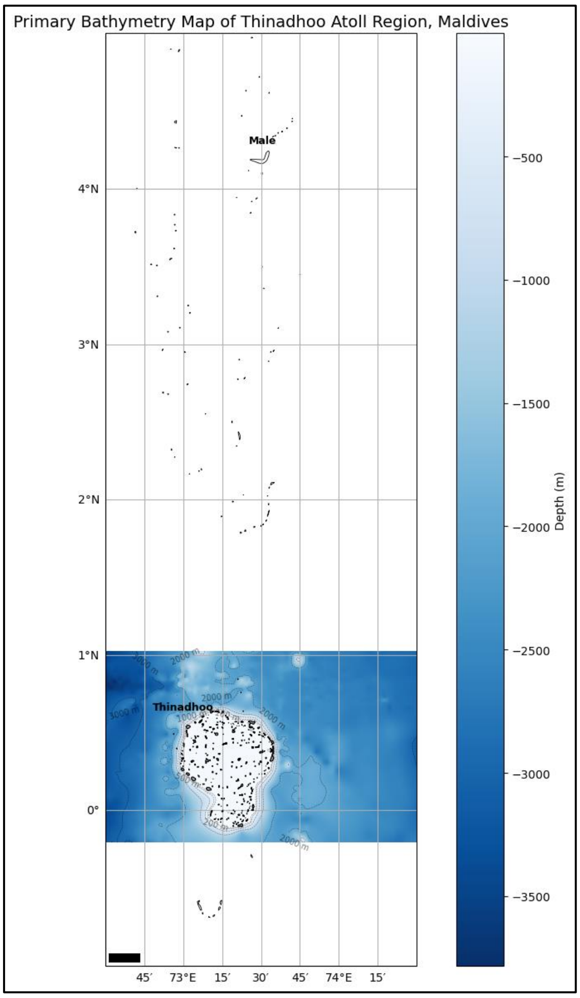


*Figure 1: Primary Bathymetry Map of Thinadhoo Atoll Region, Maldives*

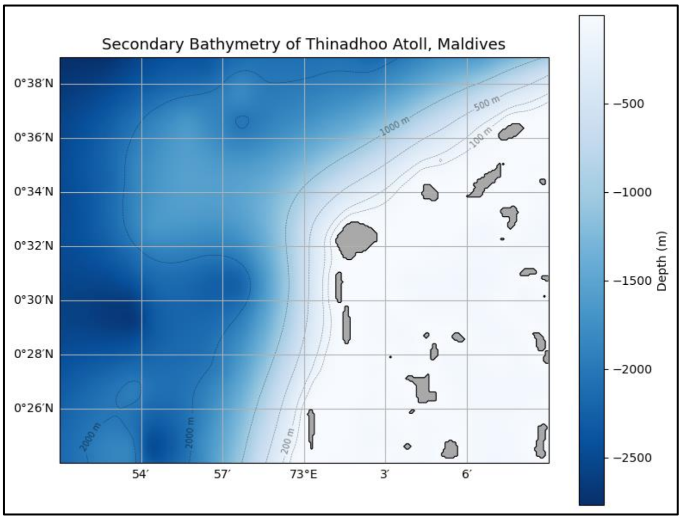


*Figure 2: Secondary Bathymetry of Thinadhoo Atoll, Maldives*

The two bathymetric maps above (see Figure 1 & 2), represent the region of Thinadhoo Atoll. Figure 1 shows a broader view that slightly overlaps the equator at 0º, representing the bathymetry of the Atoll across a section of the country and the capital city Malé. Figure 2 shows a close up of the western side of the Atoll to provide more details on the contour lines in relation to depth. Although both bathymetry maps slightly differ in scale and level of details, they are both useful to represent more detail on a topographic region with a steep drop off zone and more immediate surroundings, as seen in Figure 2. As seen in both Figures 1 and 2, the depth within the Atoll does not exceed 500m, this is primarily due to the shallow underlying central lagoon reef, shaped by the island formations and archipelago within the Atoll (Naylor A. K., 2015).

The depth range on the outer side of the Atoll, seen in both Figures 1 & 2, show a dramatic drop off zone from 200m down to over 2500m deep. This range in depth is commonly seen in oceanic atolls. The close contour lines indicate steepness of drop off zones, which defines to structure of the Atoll and where it lies on the Chagos-Laccadives ridge (Rasheed et al., 2021). The range in depth between the outer drop off and shallow lagoons within the Atoll, are areas of interest to study how large ranging depths are also characterised by high productivity and biodiversity within the contrasting marine ecosystems. The steep drops off zones influence current and water circulation moving through and surrounding the Atoll, this will play a major role in species richness and biodiversity within the lagoon area CITE. Currents driven into the Atoll can bring nutrient rich upwelling and high productivity that are at the base of all life in the marine ecosystem. The unique physical environment that creates key marine biodiverse hotspots in the Indian Ocean. Thus, the Bathymetric data is an important component to consider for phytoplankton development.

## 2. Chlorophyll Data

The concentration of chlorophyll is used as a proxy for phytoplankton biomass, which determines and indicates for the primary productivity in a given area. CITE

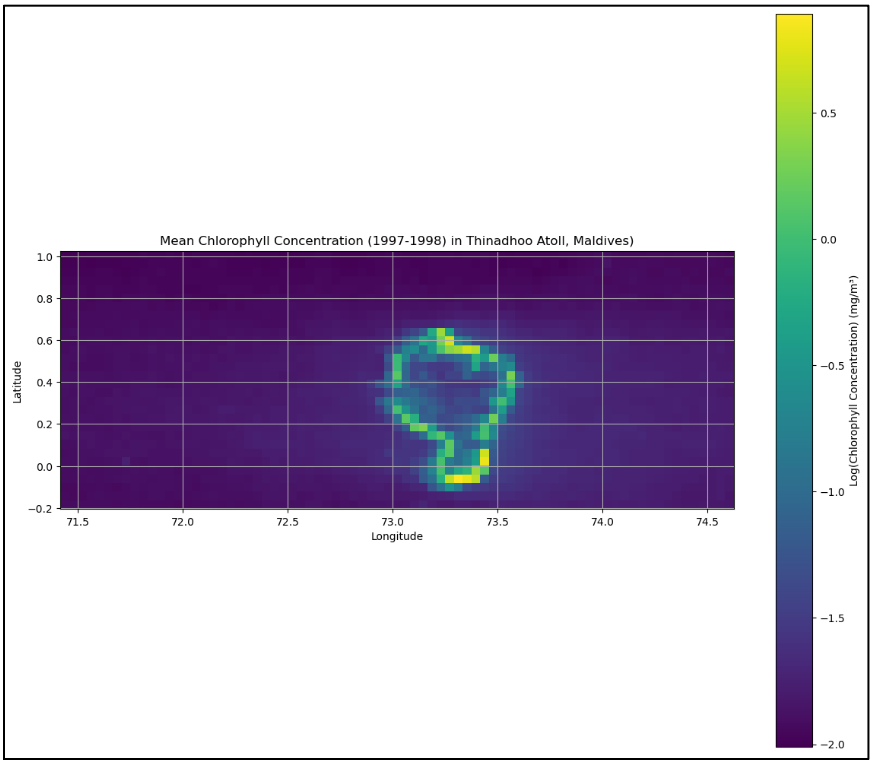


*Figure 3: A map showing the mean chlorophyll concentration in Thinadhoo Atoll, Maldives (1997-1998). This plot shows the spatial variability in chlorophyll levels around the region. The mean log-transformed chlorophyll concentration in the units of mg m$^{-3}$ across the Atoll region, whereby higher concentrations are shown in brighter colours (yellow) and lower concentrations are seen in darker colours (purple)*

Figure 3 represents a map of the mean chlorophyll concentration in the Thinadhoo Atoll region between 1997 and 1998 (see Figure 3 above). The spatial distribution of chlorophyl concentrations is generally seen to be higher is shallower areas as seen in the graph, with bright yellow colour features that indicate higher concentrations of over 0.5 log Chl/m$^3$ and surrounding deep water in purple which indicates the concentration is -2.0 log Chl/m$^3$, indicating that the concentration is very low. Areas in the shallow waters and reef ecosystems usually show higher levels of chlorophyll as they are more productive environments, the abundance if nutrients tend to be cycled in a coral reef ecosystem (Sathyendranath et al., 2004). This is also influenced by nutrient upwelling from deeper water; hence the outlining reef and shallow regions of the Atoll have the highest concentration of chlorophyl, as they will receive the most nutrients. Thus, providing an ideal condition for growth of phytoplankton.

In the darker coloured regions, where the depth dramatically increases, nutrient availability generally decreases in the absence of upwelling, which is evident in Figure 3. Previous studies and observation of similar studies across the world have shown a similar pattern whereby deeper water generally have lower primary productivity (Behrenfeld et al., 2006).

Although the data represents the mean over the period of 1997-1998, it is important to note that the Maldives experiences two monsoon seasons annually and channels within the Atoll streaming in strong currents, may influence these concentrations (Subramanian et al., 2013)

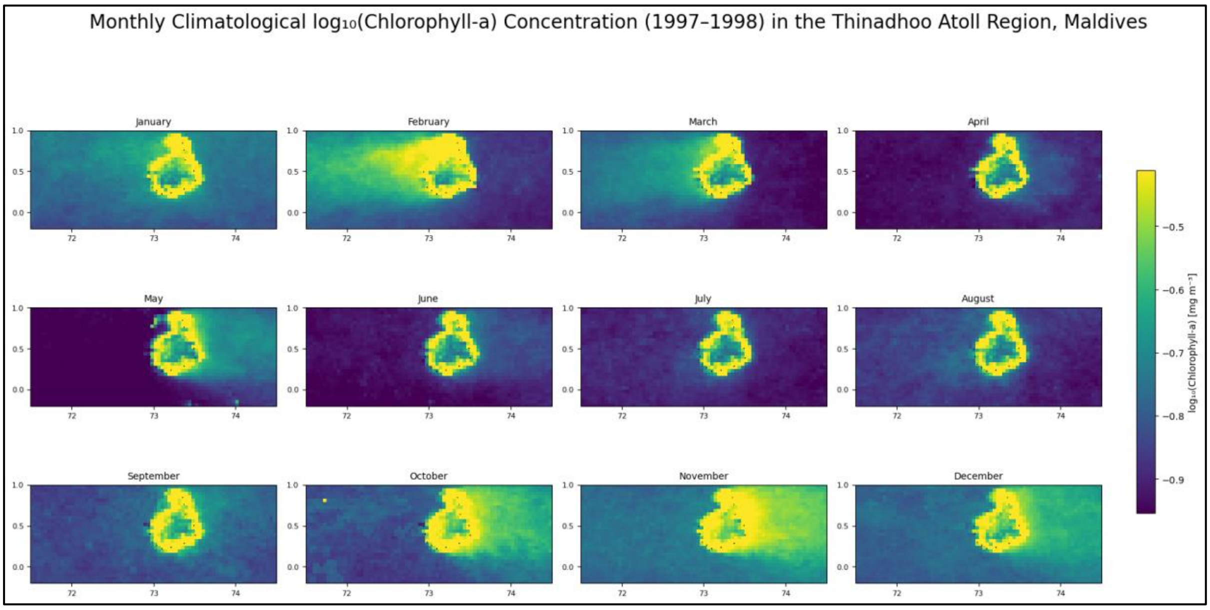


*Figure 4: Monthly climatological log$_{10}$(Chlorophyll-a) concentration (1997-1998) in the Thinadhoo Atoll Region, Maldives. This map represents the variation in chlorophyll concentration over January to December, whereby the colour scale represents the logarithmic values of concentration of chlorophyll in the units of mg m$^{-3}$. The higher concentrations can be seen within and around the atoll with various intensities and disbursement based on seasonal changes that reflect changes in productivity.*

Seasonal trends in the chlorophyll-a are seen changing over the months from January to December (see Figure 4). The clear trend of higher chlorophyll concentrations is seen between November and February, which is one of two monsoons seasoned experienced in the region, that may not always lead to higher rainfall yet experience high wind patterns during this period. The monsoon tends to bring strong upwellings which leads to high primary production from deeper surrounding oceans that promote phytoplankton growth (Behrenfeld et al., 2006). Between April and June, before the next monsoon season, the nutrient upwelling is less, and concentrations of chlorophyll are generally lower. The sea surface temperature is mostly warmer during this period which also results in less nutrient mixing (Sathyendranath et al., 2004). Furthermore, the chlorophyll concentrations tend to more dispersed on the outer areas near the Atoll where the wind and current patterns increase, and change based on the time of year and seasonality (Falkowski et al., 1998).

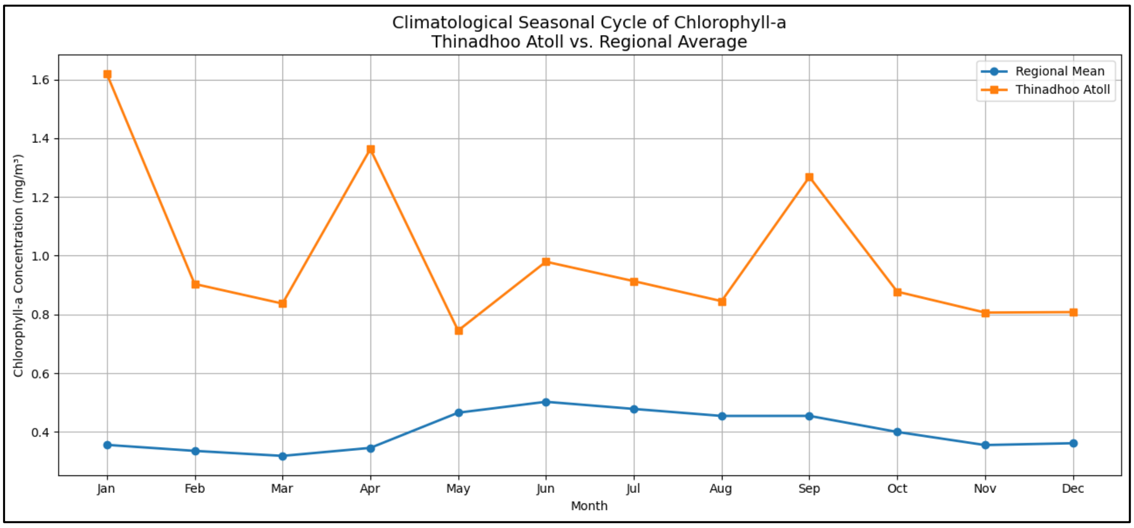


*Figure 5: Climatological seasonal cycle of chlorophyll-a concentration between the regional mean and Thinadhoo Atoll in the Maldives. This graph compares the monthly chlorophyll-a concentration in the units of mg m$^{-3,}$ showing the seasonal variation in productivity of the regional mean (line in blue) and Thinadhoo Atoll (line in orange) over the period of 1997-1998.*

The Thinadhoo Atoll shows consistently higher levels of chlorophyll-a concentrations from January to December in comparison to the regional mean (see Figure 5). Thinadhoo Atoll has more dramatic peaks in concentrations, which may correlate to favoured, localised conditions of the Atoll where growth of phytoplankton is optimised. This area may have more nutrient availability, influenced by upwellings and better light conditions that boost primary production in the area (Muller et al., 2005). The lower peaks in the regional mean may indicate that the nutrient cycling and reef ecosystem may influence the productivity in that area. These subdued fluctuations in the regional area indicate that the Thinadhoo Atoll may provide more favourable conditions for phytoplankton growth compared to broader regions.

## References

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