Summary and Conclusion

The present study was carried out in the Tiruchendur coastal waters, which is located in Gulf of Mannar, Southeast coast of India. Three different traditional fishing grounds were fixed in this coastal water to collect water samples, phytoplankton and zooplankton and fish catch samples for the two years. The detailed information on different environmental parameters such as physical factors, nutrient dynamics, primary productivity, secondary and tertiary productivity pattern in the traditional fishing grounds off Tiruchendur coast was collected. Attempts were made to understand the general hydrobiological conditions and their role on fishery productivity in the fishing grounds.

Amali Nagar is a fishing village located in Tiruchendur coastal town (Lat: 8°.29’.19.1” N and Long: 78°.7’.26.62” E) in the Thoothukudi District of Tamil Nadu. It is situated on the bank of Gulf of Mannar, Southeast Coast of India. Three traditional fishing grounds were chosen for investigation: Station 1 is located about 3.7 km from the shore at 10 meter depth. Station 2 is located about 14.1 km from the shore at 30 meter depth and station 3 is located about 17.3 km from the shore at 32 meter depth and it is the important potential fishing ground for pelagic fishes such as sardine, anchovy, Indian mackerel, seer fishes and Lates calcarifer.

Physico-chemical characteristics of fishing grounds exhibited high degree of spatial and temporal variability except pH and N/P ratio. Rainfall played an important role on temporal and spatial variations of DO, salinity and nutrients in the study area. Sea surface temperature of all the three fishing grounds was varying between 25 and 31.7°C. A bimodal type of oscillation in SST and salinity could be observed in all stations during first year though it did not persist in the second year of study. Temporal and spatial variations of salinity distribution were recorded at the three fishing grounds. Based on the annual variations in rainfall phenomenon, unimodel and bimodal oscillation in salinity was reported.
in the study. Salinity exhibited a positive correlation with SST, euphotic zone, Secchi depth and negative correlation with the Dissolved oxygen, pH, and TDS. The mixing of two water masses from Palk and Gulf of Mannar is of great importance in bringing about similarity in the hydrological conditions during certain seasons of the year and also changes the salinity condition in the fishing grounds. Southwest Monsoon Current, brought saline water into Bay of Bengal and caused the high-level salinity in Gulf of Mannar during Southwest monsoon. The DO varied from 4.15 to 6.3mg/l while a higher level of DO content was observed during from October to December which in turn could be attributed to the input of DO rich fresh water during the northeast monsoon. The runoff brought nutrient rich water to the coastal waters and hence supported the biological productivity. Collectively, the temporal and spatial variation of all the nutrients in fishing grounds was observed to show highly significant negative correlation with salinity. Nutrient concentration was comparatively low in station 3 than station 1 and station 2 due to nutrients brought by rainfall runoff.

The results indicated that the hydrographical and biological features of this coastal ecosystem influenced the phytoplankton community dynamics by determining their species composition and seasonal changes in the species composition. Results of chlorophyll ‘a’ and primary productivity revealed that the chlorophyll ‘a’ concentration showed a distinct seasonal variation with a close positive relationship with primary productivity. The Chlorophyll ‘a’ varied from 0.4 to 6.8 mg/m$^3$. High values of chlorophyll ‘a’ were recorded during summer and low values were observed during monsoon and post monsoon seasons. Chlorophyll ‘a’ value increased from post monsoon to summer (January to May) and then decreased until northeast monsoon through the post monsoon. A similar trend was noted in the second year of study period as well. Gross primary productivity varied from 13.8 to 28.7 mg C/m$^2$/day. The observed peak primary productivity value matches with chlorophyll value and phytoplankton density.
Phytoplankton population density varied from $2.85 \times 10^4$ cells/l in the three fishing grounds. The maximum and minimum values were recorded during summer and post monsoon seasons respectively. The phytoplankton primary production in the fishing grounds off Tiruchendur coastal waters is limited by the availability of nutrients. Atmospheric temperature, sea surface temperature and salinity were also controlling the phytoplankton production in the fishing grounds. One of the important observations was that none of the individual species reached bloom levels throughout the two year study period.

A total of 73 species of phytoplankton were recorded during 2009 consisting of 47 to 50 species of Diatoms (68%), 9 to 10 species of Dinoflagellates (14%), 7 species of Pyrrophyceae (10%), 3 species of Dictophyceae (3%), 2 species of Cyanophyceae and 1 species of Prasinophyceae (1%). Among these three stations, high population density was recorded at station 2, followed by station 1 and 3.

During 2010, a total of 70 species were recorded consisting of 70% Diatoms, 13% Dinoflagellates, 10% Pyrrophyceae, 4% Dictophyceae and 3% Cyanophyceae. Only one species of Prasinophyceae was recorded at station 3 and this could not be noted in station 1 and 2. The Principal Component Analyses (PCA) for the zooplankton seasonal diversity was investigated using the four seasonal datasets to understand the statistical significance among the four seasons viz., post monsoon, summer season, southwest monsoon and northeast monsoon. Two different principal components (PC) were segregated in all the seasons homogeneously including routine and opportunistic species.

The overall results and statistical analyses led to infer that changes in rainfall and freshwater discharge from the land and Punnaikayal estuary played a decisive role in the phytoplankton dynamics off Tiruchendur coast. While considering all the three fishing grounds together, both high and low nutrients were observed in the present study with
seasonal changes. So, it was speculated that *Biddulphia sinensis*, *Coscinodiscus ecentricus*, *Chatoceros spp*, *Gonyaulax spinifera* and *Skeletonema spp* were adapt to various nutrients regimes of the Gulf of Mannar and flourish. Precisely physical factors viz. atmospheric temperature and sea surface temperature, salinity, light transparency and depth of the euphotic zone exerted important role in phytoplankton species production and distribution.

The zooplankton composition recorded in the three fishing grounds during the study consists of members of Copepods, Harpacticoida, Cyclopoida, Ciliata, Decapoda, Gastropoda, and Crustaceans such as crab, shrimps, cirripedia and Foraminifera. The hydrographical conditions particularly the water temperature and salinity of fishing ground waters contributing high population density of zooplankton during summer season. It was observed that, significant variaritions in zooplankton abundance between four seasons, however, zooplankton abundance did not showed any variations among the three stations.

At station 1, zooplankton population density recorded ranged from 9800 to 23250 nos/l. Similarly, at station 2, the population density varied from 7435 to 22455 nos/l. The zooplankton population density varied from 8460 to 21350 nos/l in station 3. In both the stations 1 and 2, the maximum and minimum value were recorded in summer and post monsoon seasons respectively. However, the maximum population density was recorded during northeast monsoon in station 3. Results revealed that a bimodal abundance of zooplankton density in all the three stations. The recorded high population density of zooplankton in the summer season was due to optimum level of chlorophyll 'a' and primary productivity and elevated salinity and all these factors collectively, supporting the maximum zooplankton population density.

Statistical analyses showed that, physical parameters and biological parameters significantly (positive) correlated with zooplankton density; however, chemical parameters exhibited significant negative correlation with zooplankton productivity in station 1 and 2.
The nutrients did not show any relations with secondary production in station 3. From this, it was understood that, macro nutrients were not playing any role on zooplankton production in station 3. The other micronutrients may be supporting the zooplankton production in station 3. The physical parameters such as atmospheric temperature, sea surface temperature and salinity were playing significant role on the secondary productivity in all the three stations. Rainfall did not play any role on zooplankton productivity in all the three stations. Among the nutrients, nitrogenous species were significantly correlated with zooplankton production in station 1 and 2. Silicate exhibited significant (negative) relations with zooplankton production at station 1 only. Phosphate element did not show any role on the secondary productivity during the study. The Principal Component Analyses (PCA) for the zooplankton seasonal diversity was investigated using the four seasonal datasets to understand the statistical significance among the four seasons viz., post monsoon, summer season, southwest monsoon and northeast monsoon. Two different principal components (PC) were segregated in all the seasons homogeneously.

In the present study, total of 49 species of zooplankton have been documented. Among these copepods were predominating species in three stations and significantly contributing to the pelagic fishery. Crustacean’s crabs were second dominant group next to copepods. During the present investigation, high population density was recorded during summer months with low level of nutrient concentration. Subsequently, low zooplankton density with high level of nutrients was recorded during monsoon season. The optimum range of light intensity, surface temperature, salinity and chlorophyll ‘a’ in the water column were contributing significantly to the zooplankton productivity. Zooplanktons are playing an important role in creating a link between phytoplankton and higher trophic levels. Seasonal pattern of zooplankton diversity in the study area differed from that of the northern Gulf of Mannar. The nutrient rich waters enters into GoM from the Southern part of Bay of Bengal.
during northeast monsoon and fresh water discharge from Tamirabarani River combined
together causing rich nutrients concentration promoting secondary productivity in fishing
grounds. Since this study formed the baseline data in the Tiruchendur coastal waters, it could
be useful for the further research and for the sustainable fishery management.

A total of 31 commercially important fishes were caught from the sampling boats
during the study which included 9 species of pelagic, 16 species of demersal, 4 species of
crustaceans and 2 species are available in mid water and benthic region. *Sardinella longiceps*,
*Escualosa thoracata*, *Rastrelliger kanagurta*, *Lethrinus ramak*, *Fenneropenaeus indicus*,
*Panilurus homorus*, *Epinephelus sp*, *Scomberomorus commerson* and *Portunus pelagicus*
were the dominant species caught during the study.

In Tiruchendur coastal waters, the fish catch was observed to exhibit significant
temporal and spatial variations. At station 1, fish catch varied from 477 to 954 kg/month and
maximum fish catch was recorded during post monsoon season in the month of February,
2009 and minimum catch was recorded during south west monsoon in the month of
September, 2009. A total of 15,395 kg of fish catch was recorded at station 1 during 2009-10.
At station 2, the fish catch varied from 442 to 846 kg/month with maximum fish catch was
recorded during post monsoon season in February, 2009 and minimum catch was recorded
during summer in May, 2010. A total of 15,013.5 kg of fish catch was recorded at station 2
and declining trend of fish catch was noticed in the second year than the first year, during
which 1114.5 kg of fish catch was decreased.

At station 3, fish catch recorded varied between 509 to 1048 kg/month and maximum
fish catch was recorded during post monsoon season in January (2009) and minimum catch
was recorded during November (2010). During the study period, maximum fish catch was
recorded during post monsoon season than other seasons. Comparatively, more fishery
productivity was noticed at station-3 and about 17073.65 kg of fish catch was recorded
during (2009-10) the study. Very marginal reduction in fish catch (40.85kg) was noticed in station-3 during second year. From the catch per unit effort and fish catch data, it is tacit that, fish catch and CPUE follow a similar trend over the months, which indicates that fishing effort has positive impact on catch.

From the statistical analyses, it was understood that, correlations between hydro-biological parameters and pelagic fish catch data were inconsistent due to lagging period. Fish catch was significantly varied between different seasons and between stations. Due to the complex and dynamic nature of the coastal environment, physicochemical and biological parameters also varied significantly from season to season and between stations. Fishes used to spawn throughout the year in this region, however, summer months (April to May) could be considered as peak spawning season. Primary productivity was high during summer season, supporting secondary productivity as well during that period. Rich abundance of phytoplankton and zooplankton during summer months are generally utilized by various fish larvae. Thus, a favourable hydro-biological condition is vital for successful survival of fish larvae, which may consequently affect fish yield. These larvae have grown further and after six months they recruit to the fishery during post monsoon.

From the study, it is understood that low concentration of inorganic nutrients in the summer months are sufficient to support the spawning of fishes and for the primary and secondary productivity. Though summer months are being the peak spawning seasons, most of the fishes are spawning throughout year. The favorable hydro-biological condition persisted in the summer months are vital for successful recruitment of larvae fish which may consequently supporting the fishery yield and recruiting the fishery during post monsoons. The fishing ground 3 is the rocky areas called “paars” support variety of pelagic and demershal fishes. Higher catch and CPUE during Jan and Aug-Sep, and low during April and October-December were noticed due to favorable environmental conditions. Current fishery
yields and effort are close to the maximum sustainable yield suggesting that the fishery is attained the sustainable level.

The results of the present study let predict a maximum sustainable yield (MSY) of 665.7kg for station 1, at an optimum average CPUE of 10.6kg/h, which was close to the observed yield of 641kg. Similarly, at station 2, predicted maximum sustainable yield (MSY) of 699kg at an optimum average CPUE of 9kg/h. However, the predicted MSY of 976 kg for station 3, and observed average yield is 711kg with optimum CPUE of 11.16kg/h. From the Schaefer model, it was understood that, fishery has already attained the sustainable level in station 1 and 2. However, the CPUE may be increased at station 3 to get more yields.