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Fish Diversity and Distribution of Manakudy Mangroves, Kanyakumari District, Tamilnadu Southwest Coast of India in Relation to Environmental Variables

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ABSTRACT *This paper deals with the spatial distribution and diversity of fish and their relationships between physico-chemical parameters of the water and soil. Among the different ecosystems of mangrove fish faunal diversity, density and richness were the highest dominance index at Manakudy mangrove community. The similarities among the fish at different water parameters were determined using correlation coefficient. The diversity of fish fauna the total number of 43 species belonging to 23 families have been identified in the waterways at the study area. The presence of species like Lates calcarifer, Mugil cephalus, Etroplus suratensis, Hilsa ilisha and Chanos chanos is an indicator of the productive well being of mangrove ecosystem especially with Mugil cephalus which occurs only in mangrove waters. The species density was high during monsoon and pre-monsoon periods and low during summer and post-monsoon periods. Seasonal variation of environmental variables was observed, with high Air temperature, water temperature, salinity and Biological oxygen demand from summer season, whereas high Dissolved oxygen, nutrients like nitrate and nitrite from monsoon season. Fish species richness (36), density (2.5±0.2) and diversity (0.04±0.01) were recorded higher during monsoon season. In general high fish species diversity was recorded during post monsoon season. Water temperature and salinity were best influencing the fish assemblage of mangroves. The study depicted Manakudy mangrove habitat was endowed with diverse fisheries which were significantly influenced by environmental variables. Thus it is recommended that the habitat to be utilized with proper planning for better conservation and sustainable fishery potential.*

KEYWORDS : Diversity, density, richness of fish, water analysis, Manakudy mangrove

INTRODUCTION

Mangrove ecosystems are one of the most productive and bio-diverse wetlands on Earth providing a critical habitat for the diverse marine and terrestrial flora and fauna. The biological productivity of these regions is high due to heavy leaf production, litter fall and rapid decay to form detritus (Clough, 1992). Thus they are utilized by numerous fisheries of commercial importance as feeding ground. Moreover the entangled masses of mangrove roots provide security for numerous fishes from predators and hence are utilized as hiding ground (Dando, 1984). Consequently due to the utilization of these habitats as spawning, nursery, feeding, breeding and hiding ground by numerous ecologically important faunal communities. As a result faunal diversity of these habitats is found to be high and is also recognized to enhance the biodiversity of adjacent habitat as well. Further are known as the supplier of enormous ecological services for development of local community (Aluri Swapna *et al*., 2016). According to Teixeira (2005) studies on spatial temporal variation of biodiversity, especially of fish community are significant to determine environmental quality. Moreover aspects such as diversity, richness and evenness parameter are useful to analyse the communities from a specific environment (Ramamurthy *et al*., 2009). In Indian context mangrove ecosystems are of great significance, since they are known for its crucial role in coastal biodiversity of the country. Coastal lagoons are shallow water bodies lying parallel to the coastline and separated from the open sea by a narrow strip of land or sand bank. They are often highly productive and serve as a habitat for variety of plants and animals. They also function as nurseries for fishes and act as ideal sites for aquaculture. They, however, generally experience widely fluctuating physicochemical regimes that induce immense stress on the organisms inhabiting them. Therefore, an adequate knowledge of the prevailing physicochemical regime in a coastal lagoon is important for the understanding of its ecology and for its management.

Odum and Heald (1972) collected a large number of fishes, crabs and insect larvae from mangroves in southern Florida and identified fifty-three species of fishes, five species of Decapoda, five species of Amphipoda and 3–80 species each of Isopod, Cumacea, Mysidecca, Copepoda, Ostracoda, Mollusca, Ciliata and Chironomid larvae. About 400 species of fishes are reported to depend on mangrove habitat (World Resources, 1996-1997). A more comprehensive data produced by Rao (1987) indicates that mangrove ecosystems of the world have 193 plant species, 397 fishes, 259 crab species, 256 molluscan species, 450 insect species and more than 250 species of mammals and other associated species of plants and animals (Ramamurthy *et al*., 2012).

The mangrove forest at Manakudy is located on the southern extremity of Indian Peninsula (Lat 8^{0}2'N Long 77^{0}30'E) along the south west coast of India, about 10 km from Kanyakumari. Manakudy estuary which has an area of about 150 ha is situated about 8 kilometers northwest of Cape Comorin in Kanyakumari District. It is the confluence of river pazhayar, which has its origin from the Western Ghats. The Manakudy mangroves is abound with varied habitats that include shallow open waters, sandy beaches, muddy flats, mangrove forest, river delta and sea grass. Mangroves are a significant ecosystem in the estuary with a luxuriant growth on the mud flats. The litters on the mangrove floor undergo humification and mineralisation and the nutrients are leached into the mangrove water due to surface run-off adding to the productivity of the estuary. There is luxuriant growth of mangroves on the mud flats of Manakudy mangroves.

There may be other such impacts on fish communities that have not yet been noticed. Accumulated debris of boulders and broken coral can simulate 'reefs' in shallow coastal waters that can lead to a temporary increase in local fish diversity. Such a diverse fish community is however unstable and may soon succumb to predation. Some of the newer fish habitats and communities that the tsunami created in mangrove in particular are likely to adapt locally and diversify. Such mangroves are 'natural experiments' and would offer a lot of scope for the scientific study of succession in marine and coastal fish communities (Ramamurthy *et al.,* 2009). Unfortunately however, the mangroves are already being fished rather intensely as the fishermen have not been going to the sea. Elsewhere, the mangroves are being used as local garbage disposal pits. However till date no comprehensive information is available on the diversity and distribution of fish species and influence of environmental variables on fish assemblage of mangrove habitat of these remote islands. Therefore the present study was undertaken to assess the diversity of fish species inhabiting Manakudy mangrove and influence of environmental variables.

MATERIALS AND METHODS

The fish and water was collected from Manakudy mangroves situated at Kanyakumari district, Tamil Nadu, India. A sampling programme consisting of a series of monthly water quality survey was conducted for one year (2014 - 2015). The fishes were identified with the help of fish identification manuals of FAO fish identification sheets (1994). Physico-chemical characteristics of water were done according to the Standard Methods (APHA, 1998). The temperature and pH of the water were measured at the station itself. All the determinations were replicated thrice and the mean values were used to obtain representation of samples.

The individual and total fish fauna densities for different seasons, years, climatic season and regions of the mangrove were calculated. Guest *et al*. (2003) found that seine nets are more appropriate for determining the relative proportion of species in a water habitat and for estimating the density of most species. The data were converted and expressed in 100 m^2 area. The representative specimens were collected and preserved in 5% formalin. The fishes were identified consulting the references of Jones and Kumaran (1980). In order to investigate the variations in diversity of fish species and ecological groups during different seasons of the study period of the mangrove, the species diversity was calculated using Shannon wiener index (1949). Species richness was measured by the number of fish species recorded on different regions of the mangroves during the study periods. The species richness was also enumerated for all the fishes and water (Balaji, 2008).

Basic statistics Via arithmetic mean and standard deviation were calculated for all the replicate variables and are given as X±1 SD. Statistical analysis were performed by using window based statistical packages Via . Microsoft Excel, Minitab (Ryan *et al.,* 1992). Statistical inferences were made by following Sokal and Rohef (1981) and Zar (2000). The fish density, diversity, richness and environmental factors are correlated with the help of SPSS software. The P value of was indicate the statistically significant variable in correlation equation by using SPSS software.

RESULTS AND DISCUSSION

Atmospheric temperature varied between 30.9 and 32.1°C in post monsoon and pre monsoon respectively. The minimum (28.5°C) was recorded during monsoon season in November and the maximum (34.2°C) was observed during summer in May. Surface water temperature ranged from 28.3 to 31.3°C in post monsoon and pre monsoon respectively. The minimum (27.4°C) was recorded during monsoon season in November while the maximum (33.4°C) was during summer in May. The environmental parameters showed variations in different seasons in the study region depending on the topography. Salinity showed the highest values (29.1 ppt) in summer nearer to the coastal environment associated with low phosphorus (0.901 mg/l) concentrations. The lowest value of salinity (23.8 ppt) was noticed in monsoon seasons, accompanying high phosphorus (1.655 mg/l) concentration due to the freshwater zone of this aquatic environment. Low DO (5.1 mg/l) values in summer season may be due to the stagnant not conditions of the water with increasing waste load in the mangrove environment. This in turn enhances the concentrations of ammonia (7.3 mg/l) and nitrite (5.7 mg/l) at these monsoon periods. High nitrate (17 mg/l), inorganic phosphorus (1.091 mg/l) and organic phosphorus (0.620 mg/l) concentration observed in the monsoon periods indicates the impact of terrestrial runoff (Table 1).

Ramamurthy *et al*. (2008) reported that Muthupet mangrove water was slightly alkaline and contained high amounts of pH, total hardness, calcium, magnesium, chloride, total, inorganic and organic phosphate, ammonia, nitrite and nitrate in all the four seasons recorded. Estuarine mangrove waters in general have relatively low stocks of inorganic phosphorus and nitrogen (Alongi *et al.* 1992). In some cases, the degree of human impact seems to control nutrient profiles (Nedwell, 1975), while in others the degree of upland influence and the hydrology of the system appear to be of greater importance (Ovalle *et al* 1990, Ramamurthy and Raveendran, 2010). In the present study, the ecosystem was found to be nutrient rich and the ratio.s of N: P (9: 1) as well as TN: TP (7: 1) were low. The water pH, temperature and salinity fluctuations in the Manakudy mangrove are consistent with seasonal cycles. However, the influence of the Manakudy mangrove on hydrographic conditions was observed at the sampling stations. The spatial and temporal differences in physicochemical variations indicate the diversity of habitats that exist within this lagoon. Monsoon season and post monsoon have a lower temperature and salinity than the pre monsoon.

The present investigation total of 43 species of fishes belonging to 27 families has been identified in the different season of the study area. The highest numbers of fishes were recorded in the monsoon (192.6±3.4) season followed by pre monsoon (180.4±2.8), post monsoon (177.5±2.4) and summer (174.7±1.5) respectively. Earlier study by Devi and Rao (2007) of the mangrove regions recorded 290 fish species where the mangrove ecosystems of the whole islands was taken into consideration however the present study was restricted to a mangroves. In general high diversity and richness was recorded in monsoon season, while lowest was recorded in post monsoon season during the study period. Dry season was dominated by few fishes hence it was less diverse compared to the monsoon seasons where species of all origin are evenly represented. Similarly Castillo-Rivera (2002) also recorded greater fish diversity during rainy season than dry months in tropical estuarine system of Mexico.

The highest diversity of fishes was recorded in the Post monsoon (0.05±0.01) to compare with other season like summer (0.04±0.01), pre monsoon (0.04±0.01) and monsoon (0.04±0.01). In overall study the moderate fish diversity was recorded in all the season during the study period. Relationship between diversity of fish and the water quality variables revealed that the air temperature, water temperature, electrical conductivity, turbidity, total dissolved solid, alkalinity, nitrate, total hardness, calcium, magnesium, chloride, sulphate, salinity, silicate, sodium and potassium levels were negatively correlated. The pH, free CO_2, dissolved oxygen, ammonia, nitrate, total phosphorus, inorganic phosphorus, organic phosphorus, BOD and COD levels were positively correlated. No significant levels ($P>0.05$) are present in the water quality variables (Table 2). It is an agreement with the earlier studies stating abiotic factors to influence fish assemblages in estuaries (Kupschius and Tremain, 2001) including salinity (Wagner, 1999; Martino and Able, 2003), temperature (Maes, 2004) and dissolved oxygen (Weisberg, 1996; Eby and Crowder, 2004). Pombo (2005) and Nandan (2012) also found temperature and salinity significantly predicting the fish assemblages. According to Little (1988) salinity has been recognized as a key factor influencing the occurrence and composition of species in brackish water habitats in the tropics and subtropics. Nearly 80% of the fishery caught in the study was utilized by the coastal community for own consumption and was marketed seldom due to smaller size.

Density of fishes observed were slightly higher in monsoon (2.5±0.2) followed by pre monsoon (2.3±0.2), post monsoon (2.2±0.1) and summer (2.2±0.1) seasons. Correlations between density of fish and the water quality parameters revealed that the pH, air temperature, water temperature, electrical conductivity, turbidity, total dissolved solid, alkalinity, free CO_2, total hardness, calcium, magnesium, chloride, sulphate, salinity, silicate, sodium, potassium and COD levels were negatively correlated. The ammonia, nitrate, nitrite, total phosphorus, inorganic phosphorus and organic phosphorus levels were positively correlated. The dissolved oxygen (995**) and BOD (953*) were positively correlated with fish density and its significant level of $P<0.01$ and $P<0.05$ respectively (Table 3).

Highest richness of fish was observed in the monsoon (36) and summer (36) and followed by pre monsoon (35) and post monsoon (34) seasons of the study periods. Correlations between fish richness and the water quality parameters revealed that the pH, air temperature, water temperature, electrical conductivity, turbidity, alkalinity, free CO_2, ammonia, nitrate, total hardness, calcium, magnesium, chloride, salinity, silicate, sodium and potassium levels were positively correlated. The dissolved oxygen, nitrite, sulphate, total phosphorus, inorganic phosphorus, organic phosphorus, BOD and COD levels were negatively correlated. The total dissolved solid (959**) was positively correlated with fish richness and its significant level of $P<0.05$ (Table 4). The highest species richness was recorded in monsoon. Together with pre and post monsoon, the mangrove least influenced these seasons. This finding agrees with earlier findings that estuaries and lagoons have a smaller number of species than the surrounding regions (Allen, 1982). Fish assemblages it seasonal monsoons were similar. These seasons were also similar with respect to hydrographic conditions and the number of species.

Species richness based on the ICE index also shows a higher richness rating for the western side, but does not take into account any kind of population analysis data. It is based solely on the number of species seen and the total number of days was observed by Mallette Spencer (2013). This can be supported by studies comparing different ecosystems such as mangroves, seagrass beds and mudflats. Nagelkerken *et al*. (2000) reported that species richness was nearly four times greater in mangroves than seagrass beds, and nearly seven times greater than mudflat areas. So even such a low comparison between two similar ecosystems shows how unalike these the mangrove stands are. It is possible to once again attribute this to the lower diversity in the extractive zone than in the non-extractive zone, but the difference between these two local habitats should not be so great.

The present study was observed the fish diversity of Manakudy mangrove in relation to environmental variables. It was concluded that the mangrove was endowed with diverse and rich fish community and was found influenced by environmental variables at a significant level. From the present study, it could be concluded that the hydrography, nutrients and pollution are the major factors responsible for fluctuation in fish assemblages in the study area. Water temperature and salinity were the major parameters influencing the fish assemblage of the mangroves. Moreover it provides food source to the coastal community residing near the mangroves. Hence it is very much essential to monitor proper condition of the mangrove for better sustainable fishery in the future as well.

Table 1. Physico-chemical analysis of Manakudy mangrove water (2014 - 2015)

S. No	Parameters	Monsoon	Post-monsoon	Summer	Pre-monsoon
1	pH	7.6 ± 1.26	8.2 ± 1.84	8.7 ± 2.16	7.9 ± 1.54
2	Atmospheric Temp. (^{0}C)	28.5 ± 2.57	30.9 ± 2.18	34.2 ± 2.97	32.1 ± 2.14
3	Surface water Temp. (^{0}C)	27.4 ± 2.06	28.3 ± 2.11	33.4 ± 2.56	31.1 ± 2.17
4	EC (mho/cm)	288 ± 5.14	313 ± 5.06	392 ± 6.17	306 ± 5.84
5	Turbidity (NTU)	5.25 ± 3.08	6.12 ± 3.17	7.87 ± 2.87	6.51 ± 3.31
6	Total dissolved solids	854 ± 1.21	883 ± 1.81	910 ± 1.12	892 ± 1.65
7	Alkalinity	15.9 ± 1.28	20.8 ± 1.33	26.1 ± 1.18	21.7 ± 1.87
8	Free carbon dioxide	1.45 ± 2.14	1.69 ± 2.18	1.91 ± 2.45	1.58 ± 2.22
9	Dissolved Oxygen	6.5 ± 0.12	6.1 ± 0.65	5.1 ± 0.98	5.9 ± 0.87
10	Ammonia	7.3 ± 6.71	6.5 ± 6.12	5.8 ± 6.17	6.2 ± 6.42
11	Nitrate	17 ± 4.19	12 ± 4.67	9.1 ± 4.81	10 ± 4.27
12	Nitrite	5.7 ± 5.17	4.9 ± 5.26	3.4 ± 5.81	4.7 ± 5.28
13	Total hardness	1050 ±0.11	1125 ± 0.34	1210 ± 0.81	1150 ±0.22
14	Calcium	675 ± 0.47	697 ± 0.22	794 ± 0.84	710 ± 0.35
15	Magnesium	324 ± 0.18	345 ± 0.14	372 ± 0.31	354 ± 0.15
16	Chloride	124 ± 1.51	151 ± 1.87	195 ± 1.34	167 ± 1.28
17	Sulphate	15.7 ± 1.22	17.2 ± 1.42	18.7 ± 1.46	17.9 ± 1.85
18	Salinity (ppt)	23.8 ± 1.44	25.9 ± 1.31	29.1 ± 1.25	26.7 ± 1.13
19	Silicate	3.87 ± 1.17	4.13 ± 1.28	5.18 ± 1.54	4.54 ± 1.11
20	Total Phosphorus	1.655±0.15	1.340±0.28	0.901±0.84	1.420±0.24
21	Inorganic phosphorus	1.091±0.24	0.926±0.86	0.605±0.22	0.978±0.29
22	Organic phosphorus	0.620±0.33	0.480±0.14	0.301±0.56	0.495±0.41
23	BOD	8.8 ± 1.11	11.8 ± 1.42	14.2 ± 1.27	12.3 ± 1.38
24	COD	59.7 ± 1.63	66.8 ± 1.44	73.2 ± 1.64	67.4 ± 1.85

Monsoon (Oct-Dec); Post-Monsoon (Jan-Mar); Summer (Apr-June); Pre-Monsoon (July-Sep)

* Except pH and temperature, all values expressed in mg^{-1}

Table 2. Correlation between Fish Diversity and Environmental variables of Manakudy mangrove water (Oct. 2014 to Sep. 2015)

	Diversity	pH	Air temperature	Water temperature	EC	Turbidity	Total dissolved solids	Alkalinity	Free CO_2	Dissolved O_2	Ammonia	Nitrate	Nitrite	Total hardness	Calcium	Magnesium	Chloride	Sulphate	Salinity	Silicate	Total Phosphorus	Inorganic Phosphorus	Organic Phosphorus	Sodium	Potassium	BOD	COD
Diversity	1																										
pH	.142	1																									
Air temp	-.147	.878	1																								
Water temp	-.427	.767	.957*	1																							
EC	-.170	.946	.875	.857	1																						
Turbidity	-.194	.917	.984*	.959*	.945	1																					
TDS	-.050	.879	.994**	.922	.840	.965*	1																				
Alkalinity	-.052	.926	.993**	.924	.899	.985*	.992**	1																			
Free CO_2	.111	.999**	.890	.787	.954*	.929	.889	.935	1																		
DO	.236	-.919	-.962*	-.953*	-.969*	-.995**	-.933	-.964*	-.931	1																	
Ammonia	.052	-.850	-.989*	-.918	-.807	-.950*	-.998**	-.983*	-.861	.914	1																
Nitrate	-.005	-.773	-.953*	-.866	-.700	-.886	-.975*	-.941	-.782	.835	.986*	1															
Nitrite	.157	-.939	-.975*	-.941	-.960*	-.998**	-.956*	-.983*	-.950	.996**	.939	.868	1														
Total-hardne	-.088	.896	.998**	.938	.874	.981*	.997**	.997**	.906	-.957*	-.992**	-.958*	-.974*	1													

	Diversity	pH	Air temperature	Water temperature	EC	Turbidity	Total dissolved solids	Alkalinity	Free CO_2	Dissolved O_2	Ammonia	Nitrate	Nitrite	Total hardness	Calcium	Magnesium	Chloride	Sulphate	Salinity	Silicate	Total Phosphorus	Inorganic Phosphorus	Organic Phosphorus	Sodium	Potassium	BOD	COD
Calcium	-.282	.909	.921	.930	.986*	.975*	.882	.926	.922	-.992**	-.857	-.761	-.980*	.914	1												
Magnesium	-.125	.887	1.000**	.951*	.877	.984*	.995**	.995**	.898	-.962*	-.990**	-.954*	-.976*	.999**	.920	1											
Chloride	-.185	.878	.999**	.968*	.889	.990**	.987*	.990**	.891	-.972*	-.981*	-.939	-.981*	.995**	.936	.998**	1										
Sulphate	-.092	.842	.992**	.932	.812	.955*	.997**	.982*	.854	-.921	-.999**	-.983*	-.942	.993**	.866	.992**	.986*	1									
Salinity	-.145	.912	.995**	.954*	.917	.996**	.985*	.995**	.923	-.982*	-.974*	-.924	-.992**	.994**	.951*	.996**	.997**	.977*	1								
Silicate	-.350	.844	.969*	.990**	.919	.986*	.936	.952*	.861	-.985*	-.925	-.859	-.976*	.956*	.970*	.965*	.980*	.936	.977*	1							
Total-Po4	.023	-.985*	-.927	-.860	-.979*	-.967*	-.914	-.957*	-.990**	.972*	.888	.806	.981*	-.935	-.966*	-.932	-.932	-.886	-.957*	-.921	1						
Inorganic Po	.080	-.975*	-.905	-.857	-.993*	-.959*	-.882	-.934	-.981*	.973*	.853	.758	.975*	-.910	-.978*	-.909	-.914	-.854	-.941	-.920	.996**	1					
Organic Po4	.038	-.973*	-.961*	-.894	-.960*	-.984*	-.952*	-.983*	-.979*	.980*	.932	.863	.992**	-.968*	-.962*	-.965*	-.963*	-.931	-.981*	-.942	.994**	.983*	1				
Sodium	-.220	.915	.826	.828	.994**	.912	.782	.850	.924	-.946	-.745	-.625	-.929	.823	.975*	.828	.845	.752	.875	.893	-.952*	-.976*	-.925	1			
Potassium	-.245	.925	.912	.911	.993**	.970*	.874	.923	.936	-.989*	-.847	-.748	-.978*	.906	.999**	.912	.926	.854	.945	.958*	-.973*	-.986*	-.966*	.983*	1		
BOD	.007	.902	.988*	.901	.849	.962*	.998**	.994**	.910	-.931	-.994**	-.969*	-.957*	.995**	.881	.991**	.980*	.991**	.982*	.923	-.927	-.894	-.961*	.790	.876	1	
COD	.003	.934	.986*	.902	.890	.975*	.991**	.998**	.941	-.952*	-.982*	-.943	-.975*	.994**	.912	.990*	.981*	.979*	.989*	.933	-.956*	-.930	-.981*	.838	.910	.996**	1

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level.

Table 3. Correlation between Fish Density and Environmental variables of Manakudy mangrove water (Oct. 2014 to Sep. 2015)

	Density	pH	Air temp	Water temp	EC	Turbidity	TDS	Alkalinity	Free CO_2	Dissolved O_2	Ammonia	Nitrate	Nitrite	Total hardness	Calcium	Magnesium	Chloride	Sulphate	Salinity	Silica	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Sodium	Potassium	BOD	COD
Density	1																										
pH	-.881	1																									
Air temp	-.895	.878	1																								
Water temp	-.727	.767	.957*	1																							
EC	-.732	.946	.875	.857	1																						
Turbidity	-.847	.917	.984*	.959*	.945	1																					
TDS	-.936	.879	.994**	.922	.840	.965*	1																				
Alkalinity	-.926	.926	.993**	.924	.899	.985*	.992**	1																			
Free CO_2	-.879	.999**	.890	.787	.954*	.929	.889	.935	1																		
DO	.995**	-.919	-.962*	-.953*	-.969*	-.985**	-.933	-.964*	-.931	1																	
Ammonia	.934	-.850	-.989*	-.918	-.807	-.950*	-.998*	-.983*	-.861	.914	1																

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COD	BOD	Potassium	Sodium	OrganicPo4	InorganicPo	TotalPo4	Silicate	Salinity	Sulphate	Chloride	Magnesium	Calcium	Tot. hardn	Nitrite	Nitrate
-.944	.953*	-.740	-.658	.889	.805	.856	-.766	-.885	-.919	-.875	-.904	-.735	-.919	.851	.935
.934	.902	.925	.915	-.973*	-.975*	-.985*	.844	.912	.842	.878	.887	.909	.896	-.939	-.773
.986*	.988*	.912	.826	-.961*	-.905	-.927	.969*	.995**	.992**	.999**	1.000**	.921	.998**	-.975*	-.953*
.902	.901	.911	.828	-.894	-.857	-.860	.990**	.954*	.932	.968*	.951*	.930	.938	-.941	-.866
.890	.849	.993**	.994**	-.960*	-.993**	-.979*	.919	.917	.812	.889	.877	.986*	.874	-.960*	-.700
.975*	.962*	.970*	.912	-.984*	-.959*	-.967*	.986*	.996**	.955*	.990**	.984*	.975*	.981*	-.998**	-.886
.991**	.998**	.874	.782	-.952*	-.882	-.914	.936	.985*	.997**	.987*	.995**	.882	.997**	-.956*	-.975*
.998**	.994**	.923	.850	-.983*	-.934	-.957*	.952*	.995**	.982*	.990**	.995**	.926	.997**	-.983*	-.941
.941	.910	.936	.924	-.979*	-.981*	-.990*	.861	.923	.854	.891	.898	.922	.906	-.950	-.782
-.952*	-.931	-.989*	-.946	.980*	.973*	.972*	-.985*	-.982*	-.921	-.972*	-.962*	-.992**	-.957*	.996**	.835
-.982*	-.994**	-.847	-.745	.932	.853	.888	-.925	-.974*	-.999**	-.981*	-.990**	-.857	-.992**	.939	.986*
-.943	-.969*	-.748	-.625	.863	.758	.806	-.859	-.924	-.983*	-.939	-.954*	-.761	-.958*	.868	1
-.975*	-.957*	-.978*	-.929	.992**	.975*	.981*	-.976*	-.992**	-.942	-.981*	-.976*	-.980*	-.974*	1	
.994**	.995**	.906	.823	-.968*	-.910	-.935	.956*	.994**	.993**	.995**	.999**	.914	1		
.912	.881	.999**	.975*	-.962*	-.978*	-.966*	.970*	.951*	.866	.936	.920	1			
.990*	.991**	.912	.828	-.965*	-.909	-.932	.965*	.996**	.992**	.998**	1				
.981*	.980*	.926	.845	-.963*	-.914	-.932	.980*	.997**	.986*	1					
.979*	.991**	.854	.752	-.931	-.854	-.886	.936	.977*	1						
.989*	.982*	.945	.875	-.981*	-.941	-.957*	.977*	1							
.933	.923	.958*	.893	-.942	-.920	-.921	1								
-.956*	-.927	-.973*	-.952*	.994**	.996**	1									
-.930	-.894	-.986*	-.976*	.983*	1										
-.981*	-.961*	-.966*	-.925	1											
.838	.790	.983*	1												
.910	.876	1													
.996**	1														
1															

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level.

Table 4. Correlation between Fish Richness and Environmental variables of Manakudy mangrove water (Oct. 2014 to Sep. 2015)

TDS	Turbidity	EC	Water temp	Air temp	pH	Richness	
.959*	.180	.319	.312	.055	.023	1	Richness
.879	.917	.946	.767	.878	1		pH
.994**	.984*	.875	.957*	1			Air temp
.922	.959*	.857	1				Water temp
.840	.945	1					EC
.965*	1						Turbidity
1							TDS
							Alkalinity
							Free CO_2
							Dissolved O_2
							Ammonia
							Nitrate
							Nitrite
							Total hardness
							Calcium
							Magnesium
							Chloride
							Sulphate
							Salinity
							Silicate
							Total Phosphorus
							Inorganic Phosphorus
							Organic Phosphorus
							Sodium
							Potassium
							BOD
							COD

COD	BOD	K	Na	Organic Po4	Inorganic Po	Total Po4	Silicate	Salinity	SO4	Cl	Mg	Ca	Total hardne	NO2	NO3	NH4	DO	Free CO2	Alkalinity
-.042	-.090	.340	.402	-.086	-.208	-.125	.299	.099	-.048	.103	.039	.355	.007	-.173	.205	.082	-.261	.022	.006
.934	.902	.925	.915	-.973*	-.975*	-.985*	.844	.912	.842	.878	.887	.909	.896	-.939	-.773	-.850	-.919	.999**	.926
.986*	.988*	.912	.826	-.961*	-.905	-.927	.969*	.995**	.992**	.999**	1.000**	.921	.998**	-.975*	-.953*	-.989*	-.962*	.890	.993**
.902	.901	.911	.828	-.894	-.857	-.860	.990**	.954*	.932	.968*	.951*	.930	.938	-.941	-.866	-.918	-.953*	.787	.924
.890	.849	.993**	.994**	-.960*	-.993*	-.979*	.919	.917	.812	.889	.877	.986*	.874	-.960*	-.700	-.807	-.969*	.954*	.899
.975*	.962*	.970*	.912	-.984*	-.959*	-.967*	.986*	.996**	.955*	.990**	.984*	.975*	.981*	-.998**	-.886	-.950*	-.995**	.929	.985*
.991**	.998**	.874	.782	-.952*	-.882	-.914	.936	.985*	.997**	.987*	.995**	.882	.997**	-.956*	-.975*	-.998**	-.933	.889	.992**
.998**	.994**	.923	.850	-.983*	-.934	-.957*	.952*	.995**	.982*	.990**	.995**	.926	.997**	-.983*	-.941	-.983*	-.964*	.935	1
.941	.910	.936	.924	-.979*	-.981*	-.990*	.861	.923	.854	.891	.898	.922	.906	-.950	-.782	-.861	-.931	1	
-.952*	-.931	-.989*	-.946	.980*	.973*	.972*	-.985*	-.982*	-.921	-.972*	-.962*	-.992**	-.957*	.996**	.835	.914	1		
-.982*	-.994**	-.847	-.745	.932	.853	.888	-.925	-.974*	-.999**	-.981*	-.990**	-.857	-.992**	.939	.986*	1			
-.943	-.969*	-.748	-.625	.863	.758	.806	-.859	-.924	-.983*	-.939	-.954*	-.761	-.958*	.868	1				
-.975*	-.957*	-.978*	-.929	.992**	.975*	.981*	-.976*	-.992**	-.942	-.981*	-.976*	-.980*	-.974*	1					
.994**	.995**	.906	.823	-.968*	-.910	-.935	.956*	.994**	.993**	.995**	.999**	.914	1						
.912	.881	.999**	.975*	-.962*	-.978*	-.966*	.970*	.951*	.866	.936	.920	1							
.990*	.991**	.912	.828	-.965*	-.909	-.932	.965*	.996**	.992**	.998**	1								
.981*	.980*	.926	.845	-.963*	-.914	-.932	.980*	.997**	.986*	1									
.979*	.991**	.854	.752	-.931	-.854	-.886	.936	.977*	1										
.989*	.982*	.945	.875	-.981*	-.941	-.957*	.977*	1											
.933	.923	.958*	.893	-.942	-.920	-.921	1												
-.956*	-.927	-.973*	-.952*	.994**	.996**	1													
-.930	-.894	-.986*	-.976*	.983*	1														
-.981*	-.961*	-.966*	-.925	1															
.838	.790	.983*	1																
.910	.876	1																	
.996**	1																		
1																			

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level.

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