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Changes of Temperature, pH and Salinity of Nearshore Waters in an Island Environment

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Abstract- The present study on temperature and pH of two Islands of Andaman during the period 2009 to 2011 suggested that the temperature increased during the year 2010 compared to the years 2009 and 2011. Moreover, a unique kind of change were noted during the years 2009,2010, wherein the bottom water (10m) exhibited comparatively higher temperature than the surface waters in both the Islands. The bottom water moved upward vertically to the surface after a 30 day period, probably due to upwelling. Earlier reports on upwelling in the Bay of Bengal and the Andaman Sea suggested that atmospheric circulation and temperature were the foremost cause for coastal upwelling. However, the above two factors did not have much significance due to the smaller surface area of these Islands. The submarine groundwater discharge could be playing a pivotal role in coastal upwelling. The groundwater discharge can lead to displacement of water mass due to the difference in physico-chemical properties, resulting in the upward movement of it towards surface over a 30 day period. This phenomena was more prominent during the nonrainy season. These inferences should be further strengthened by continuous monitoring of the nearshore waters for a larger time scale.

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I. Introduction

The processes occurring under the ocean are magnificent and largely unexplored. Most of the physical and chemical processes occurring in the ocean system are unpredictable. These processes in the Island environments more complicated to comprehend than the normal nearshore environment due to the flatness of the intertidal region as well as a step like steep structure very close to the shore, in the shelf region. Further, the topographical structure of the ocean bottom along with the wind pattern, tidal oscillation, freshwater input, earthquake, etc., make this process more complicated and influences the physical and chemical parameters. Based on the literature survey, it was found that very few studies were carried out in the Island ecosystem in India, especially, in relation with temperature, pH and salinity concern. These parameters are considered as basic characteristics of any water body. So, to understand the variation of the occurrence of the above parameters in the Island environment, a study was conducted in the Protected Area, The Mahatma Gandhi Marine National Park. This location was selected because the anthropogenic interference was minimal. The study was conducted in two Islands, namely Jolly Buoy and RedSkin Islands, during the year 2009 to 2011. The Jolly Buoy Island is located in the south of Malay and the west of Rutland Island. The total area of Jolly Buoy Island is about 0.17 km^2. The coastlines are bordered by sandy beaches and rock. The Redskin Island is located between south of Chester Island and Grub Islands and west of the Hob Day Island. The total area is about 3.7 km^2 and the east coast of this island is flanked by mangrove vegetation and the west coast bordered by sand and sheet rocks. The shelf width of both the Islands varied between 50 to 500 m (Fig. 1).

II. Materials and Methods

The present study intended to understand the physical parameters and their variability with reference to time in the nearshore coral reef environment, i.e., Surface to 10m depth. Since, the study area covers most of the coral reef within 10-15m depth, the maximum depth of the bottom waters were fixed at 10m. The parameters, temperature, pH and salinity, were studied in two depths, i.e., in surface and in 10m depth. Four transects in Jolly Buoy (J1, J2, J3 and J4), and three transects (R1, R2 and R3) in RedSkin Island, were considered for this study, during 2009 – 2011. These parameters were measured insitu using Quanta Hydrolab. Here, it also recorded that the weather pattern of these Islands is unique which has nine month monsoonal rains and three months non rainy days. The average monsoonal rain per year comes around 3395mm. No extreme winter was observed in these Islands. Based on the above factors, the weather pattern was classified under three major systems. January to April was considered as Non Rainy Season (NRS), May-August considered as the South West Monsoon period (SWM) and September-December considered as North East Monsoon (NEM) period. There were 15days plus or minus normal shift of above mentioned seasonal variations.

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III. Results

Overall variation of surface temperature (Table 1, 2, 3 and 4) suggested that the year 2010 had a higher temperature than 2009 and 2011 (Fig.2A, 2B, 3A, 3B,4A, 4B,5A and 5B). The temperature in the year 2011, was lower than the previous two years. The 10m water column also had an almost similar temperature in all transects. Moreover, the monthly temperature data suggested that a shift of temperature was unambiguous during the period of 2009 and 2010. The average temperature rise observed in the year 2010 was 0.66°C in surface and 0.49°C in the bottom, comparing the years 2009 and 2010. However, the year 2011, exhibited a reduction of 0.12°C in the surface and 0.20°C in the bottom. The Redskin Island temperature (Table 5, 6, 7) for the study period was high during the year 2010 compared to the year 2009 and 2011 (Fig. 6A, 6B, 7A, 7B, 8A and 8B). The average temperature rise was of 0.53°C (Table 8), in the year 2010 in surface and 0.29°C rise in the bottom waters. However, the year 2011exhibited a reduction of 0.18°C in the surface and 0.32°C in the bottom.

The pH of the Jolly Buoy Island shows a constant increment from the year 2009 to 2011 (Fig.9A, 9B, 10A, 10B, 11A, 11B, 12A and 12B). The increment was significant towards higher pH, i.e., 7.51-7.93 on the surface and 7.53-7.94 in the bottom waters (Table 9). However, the year 2010 shows a slight increment (7.99 for surface and 8.05 for bottom waters) than the years 2009 and 2011. The Redskin also shows a similar type of variation in the range of 7.53-7.83 (Fig. 13A, 13B, 14A, 14B, 15A and 15B).

The salinity in Jolly Buoy Island (Table 10), suggested that the year 2011 (32.69PSU) had a higher salinity than 2009 (31.18-31.20PSU) and 2010 (31.42-31.35PSU). The increment was around 1.49PSU for the surface and 1.51PSU for bottom waters from the year 2009-2011 (Fig. 16A, 16B, 17A, 17B, 18A, 18B, 19A and 19B). The Redskin Island also shows an almost similar level of increment of salinity between the years 2009-2011 (Fig. 20A, 20B, 21A, 21B, 22A and 22B). The increment observed from the surface and bottom waters, respectively, were 1.47PSU and 1.32PSU.

IV. Discussions

The study of temperature, pH and salinity of the coral reef environment of Jolly Buoy and Redskin Island for the year 2009 to 2011, for the four traverses and three traverses, represented a unique pattern. Generally, the water temperature would be comparatively higher in the surface than the bottom waters, however, in the present study, it was observed that the surface had a low temperature and bottom (10m) had a comparatively higher temperature, in certain periods. Moreover, the monthly temperature data suggested that a shift of temperature from bottom to top had taken place from the surveying month to next month, i.e., for example, in Jolly Buoy, traverse 1 at 2010, the bottom water temperature in April 31.71°C, the surface water temperature in the month of May was 31.76°C in the same station (Fig.2A, 2B). This observation was unambiguous during the period of 2009 and 2010, especially during NRS. However, this variation was not observed in the year 2011. If this process had been considered as a local upwelling as per the reports[1,2,3,4,5], who mentioned that upwelling was observed along the coasts of the Bay of Bengal and the Andaman Sea, due to river discharge and wind thrust. However, the present study revealed that no fresh water input had taken place through major river discharge, because of the smaller surface area of this Island. Moreover, the concept of submarine groundwater discharge[6,7,8] might be effective in this location which may induce the coastal upwelling. Similarly, the same phenomenon may be effective in the Redskin Island also. This factor may be supported by the pH and salinity values. Quite interesting phenomena which were observed in this study was a constant increment of pH and salinity from the year 2009-2011. This increment was also noticeable level, i.e., almost 0.41units for pH and 1.32-1.51PSU for salinity. This increment was prominent in the year 2010, which suggested that the rain water factor alone did not provide alkaline elements to this water. This inference was made due to the fact that the year 2010 had the high temperature and low rainfall. The year 2009 also had lower rainfall and comparatively higher temperature in the bottom water than the surface during NRS. The above information suggested that the elsewhere discussions on the submarine groundwater discharge has an impact on nearshore area for the different physico-chemical parameters[9-16], may have an impact on this study area also. Further the year 2010 was also reported a significant coral bleaching in this part of the Island[17], also may have caused the dissolution of alkaline elements from the bleached coral skeletons through submarine groundwater discharge, which in turn increase the pH and salinity significantly. Mohan et al.,18 had mentioned about the increase in pH in the coastal waters due to the dissolution of bleached coral skeletons. This effect was continued even during the year 2011 and in turn provided higher pH and salinity. Although, no submarine groundwater discharge studies had been carried out this region, this assumption was made solely based on the temperature, pH and salinity differences between the years.

V. Conclusion

The present study on the temperature, pH, and salinity, of the waters of two Islands of Andaman and Nicobar archipelago concluded that the variation in this physical parameters from surface to 10m water column was linked with atmosphere-surface interaction, local

phenomena and also with the submarine groundwater discharge. This factor should be studied in detail to understand the effects of SGD (submarine groundwater discharge) on the nearshore environment of Island ecosystem. This ecosystem may have a higher tendency to be influenced by this factor due to the presence of fractured volcanic rocks along with carbonate deposits in the terrestrial environment.

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Declaration of Conflict of Interest
Authors declare no conflict of interest.

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Table 1: Variation of physical parameters in Jolly Buoy Island- Transect 1

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	26.97	26.97	7.56	7.57	31.30	31.20
Feb-09	27.43	27.91	7.54	7.51	31.20	31.30
Mar-09	27.90	29.57	7.51	7.39	31.40	31.40
Apr-09	29.53	30.12	7.39	7.27	31.30	31.30
May-09	30.27	29.21	7.26	7.49	31.20	31.20
June-09	29.53	28.68	7.40	7.79	31.10	31.10
Jul-09	28.70	30.00	7.80	6.50	32.00	32.00
Aug-09	29.50	28.39	6.50	7.74	31.40	31.30
Sep-09	28.93	28.48	7.75	7.73	31.00	31.00
Oct-09	28.52	29.33	7.74	7.93	31.00	30.90
Nov-09	29.35	28.56	7.93	7.80	30.90	30.70
Dec-09	28.59	28.68	7.82	7.77	30.90	30.70
Variation recorded in 2010						
Jan-10	28.70	29.07	7.80	7.92	30.70	30.70
Feb-10	29.10	29.60	7.91	7.82	30.80	30.90
Mar-10	29.79	30.50	7.85	7.86	30.90	31.20
Apr-10	30.55	31.71	7.86	8.10	31.20	31.30
May-10	31.76	30.52	8.10	7.91	31.40	31.70
Jun-10	30.57	28.91	7.91	8.29	31.70	31.60
Jul-10	28.91	28.53	8.27	8.30	31.60	31.60
Aug-10	28.56	28.34	8.27	8.30	31.55	31.60
Sep-10	28.21	28.14	8.29	8.31	31.50	31.60
Oct-10	29.81	29.78	7.97	7.90	31.50	31.50
Nov-10	28.39	28.38	7.95	7.92	31.10	31.10
Dec-10	28.10	28.05	7.60	7.60	32.00	32.00
Variation recorded in 2011						
Jan-11	27.90	27.90	7.80	7.78	31.90	31.80
Feb-11	27.75	27.75	7.93	7.92	31.90	31.90
Mar-11	28.98	28.47	7.87	7.84	32.97	32.97
Apr-11	28.96	28.99	7.95	7.90	32.99	32.92
May-11	30.25	30.14	8.02	8.02	33.13	33.12
Jun-11	29.74	29.67	8.03	8.02	33.21	33.17
Jul-11	29.24	29.20	8.05	8.01	33.30	33.22
Aug-11	27.94	27.93	8.37	8.25	32.97	32.87
Sep-11	27.77	27.79	8.70	8.76	32.49	32.49
Oct-11	28.00	27.79	8.46	8.38	32.51	32.65
Nov-11	29.55	29.50	7.28	7.12	31.91	31.91
Dec-11	28.09	28.09	6.89	6.90	32.87	32.87

Table 2: Variation of physical parameters in Jolly Buoy Island- Transect 2

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	Surface	5m	surface	5m	surface	5m
Jan-09	26.96	26.98	7.52	7.54	31.20	31.20
Feb-09	27.90	28.81	7.45	7.32	31.20	31.30
Mar-09	28.85	29.53	7.39	7.20	31.30	31.40
Apr-09	29.56	30.19	7.21	7.14	31.40	31.30
May-09	30.20	28.65	7.14	7.45	31.30	31.20
Jun-09	28.78	28.70	7.45	7.78	31.20	31.10
Jul-09	26.94	30.00	7.81	6.50	31.10	32.00
Aug-09	29.50	28.37	6.50	7.73	31.50	31.30
Sep-09	28.58	28.43	7.71	7.75	31.30	31.00
Oct-09	28.42	29.31	7.75	7.92	31.00	30.90
Nov-09	29.33	28.51	7.93	7.83	30.90	30.80
Dec-09	28.56	28.53	7.85	7.84	30.70	30.50
Variation recorded in 2010						
Jan-10	28.53	28.99	7.88	7.93	30.50	30.70
Feb-10	29.02	29.35	7.93	8.05	30.70	31.00
Mar-10	29.53	30.56	8.08	7.86	31.00	31.20
Apr-10	30.57	31.69	7.85	8.12	31.20	31.30
May-10	31.85	30.50	8.13	8.03	31.30	31.70
Jun-10	30.50	29.31	8.03	8.19	31.70	31.70
Jul-10	29.50	28.71	8.10	8.27	31.61	31.60
Aug-10	29.00	28.41	8.20	8.31	31.61	31.60
Sep-10	28.14	28.11	8.35	8.35	31.60	31.60
Oct-10	29.80	29.75	8.06	8.09	31.50	31.50
Nov-10	28.29	28.38	8.04	8.04	31.10	31.10
Dec-10	28.13	28.09	7.63	7.60	31.90	32.00
Variation recorded in 2011						
Jan-11	27.83	27.83	7.96	7.91	31.90	31.90
Feb-11	27.71	27.68	8.01	7.95	31.90	32.00
Mar-11	28.51	28.55	8.06	7.96	33.04	33.04
Apr-11	28.93	28.93	8.02	7.99	32.99	32.90
May-11	30.08	29.94	8.03	7.99	33.12	33.11
Jun-11	29.71	29.62	8.13	8.10	33.18	33.17
Jul-11	29.33	29.30	8.22	8.20	33.23	33.23
Aug-11	27.97	27.94	8.36	8.28	32.94	32.87
Sep-11	27.75	27.79	8.84	8.85	32.49	32.56
Oct-11	28.02	28.00	8.64	8.61	32.65	32.65
Nov-11	29.50	29.48	7.24	7.21	31.98	31.98
Dec-11	28.07	28.07	6.27	6.32	32.87	32.87

Table 3: Variation of physical parameters in Jolly Buoy Island- Transect 3

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	26.96	26.98	7.52	7.54	31.20	31.20
Feb-09	27.10	27.24	7.49	7.46	31.20	31.30
Mar-09	27.25	29.49	7.46	7.25	31.30	31.40
Apr-09	29.77	30.16	7.32	7.16	31.40	31.30
May-09	31.42	29.82	7.22	7.47	31.20	31.20
Jun-09	29.85	28.66	7.46	8.31	31.20	31.10
Jul-09	28.67	30.00	7.81	6.50	31.20	32.00
Aug-09	30.00	28.40	6.40	7.71	31.50	31.40
Sep-09	28.89	28.43	7.75	7.76	31.30	31.00
Oct-09	28.51	29.30	7.81	7.93	31.00	30.90
Nov-09	29.30	28.56	7.94	7.85	30.90	30.70
Dec-09	28.47	28.58	7.98	7.83	30.50	30.40
Variation recorded in 2010						
Jan-10	28.80	29.06	7.80	7.92	30.50	30.80
Feb-10	29.10	29.48	7.88	8.07	30.80	31.00
Mar-10	29.80	30.46	7.49	7.86	31.00	31.20
Apr-10	30.52	31.67	7.86	8.11	31.20	31.30
May-10	31.86	30.49	8.02	8.33	31.40	31.70
Jun-10	30.58	29.30	8.27	8.33	31.70	31.70
Jul-10	29.48	28.70	8.22	8.32	31.70	31.70
Aug-10	28.90	28.40	8.28	8.33	31.70	31.70
Sep-10	28.12	28.10	8.30	8.34	31.70	31.70
Oct-10	29.73	29.70	8.33	8.47	31.50	31.50
Nov-10	28.33	28.33	8.17	8.08	31.40	31.30
Dec-10	28.12	28.09	7.63	7.61	32.10	32.10
Variation recorded in 2011						
Jan-11	27.90	27.91	8.07	8.04	31.90	31.90
Feb-11	27.75	27.71	7.93	8.00	31.90	32.00
Mar-11	28.52	28.44	7.18	8.12	33.12	33.04
Apr-11	28.95	28.89	7.89	8.01	32.99	32.99
May-11	30.61	30.05	7.98	7.97	33.06	33.04
Jun-11	29.98	29.69	8.08	8.13	33.18	33.18
Jul-11	29.35	29.33	8.18	8.28	33.30	33.30
Aug-11	27.99	27.96	8.20	8.24	32.87	32.87
Sep-11	27.74	27.84	8.70	8.87	32.42	32.64
Oct-11	28.29	28.07	8.27	8.14	32.74	32.65
Nov-11	29.40	29.36	7.17	7.17	32.27	32.27
Dec-11	28.02	28.01	7.62	7.55	32.94	32.94

Table 4: Variation of physical parameters in Jolly Buoy Island- Transect 4

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	26.96	26.98	7.52	7.54	31.20	31.20
Feb-09	27.41	27.85	7.46	7.38	31.20	31.30
Mar-09	27.86	29.73	7.41	7.39	31.30	31.40
Apr-09	29.76	30.27	7.39	7.22	31.40	31.30
May-09	31.40	29.42	7.30	7.48	31.30	31.20
Jun-09	29.52	28.62	7.55	7.81	31.30	31.10
Jul-09	28.73	30.50	7.83	6.50	31.20	32.00
Aug-09	30.50	28.48	6.50	7.71	32.00	31.40
Sep-09	29.19	28.41	7.81	7.77	31.30	31.10
Oct-09	28.59	29.31	7.75	7.93	31.00	30.90
Nov-09	29.32	28.58	7.93	7.75	30.90	30.70
Dec-09	28.56	28.63	7.75	7.73	30.80	30.70
Variation recorded in 2010						
Jan-10	29.10	28.95	7.77	7.86	30.50	30.80
Feb-10	29.42	29.73	7.87	7.85	30.80	30.90
Mar-10	29.79	30.51	7.86	7.86	30.90	31.20
Apr-10	30.51	31.74	7.86	8.06	31.20	31.30
May-10	32.33	30.60	8.09	7.76	31.30	31.60
Jun-10	30.77	29.37	7.80	8.02	31.60	31.55
Jul-10	29.80	28.76	8.00	8.15	31.60	31.53
Aug-10	29.40	28.45	8.20	8.22	31.50	31.52
Sep-10	28.18	28.14	8.29	8.29	31.50	31.50
Oct-10	29.83	29.84	7.93	7.92	31.50	31.40
Nov-10	28.49	28.41	7.84	7.81	31.20	31.20
Dec-10	28.12	28.10	7.64	7.62	32.80	31.90
Variation recorded in 2011						
Jan-11	27.91	27.91	7.75	7.75	31.90	31.80
Feb-11	27.74	27.71	7.89	7.88	31.90	31.90
Mar-11	29.38	28.65	7.85	7.80	33.01	32.97
Apr-11	29.00	28.99	7.87	7.87	32.99	32.99
May-11	30.16	30.10	8.08	8.01	33.07	33.12
Jun-11	29.71	29.69	8.06	8.26	33.15	33.18
Jul-11	29.26	29.28	8.03	8.50	33.22	33.23
Aug-11	28.10	28.05	8.33	8.19	32.80	32.80
Sep-11	27.73	27.82	8.64	8.69	32.42	32.49
Oct-11	28.34	28.02	7.89	7.77	32.66	32.58
Nov-11	29.55	29.52	7.12	7.09	31.98	31.98
Dec-11	28.09	28.08	6.71	6.65	32.95	32.95

Table 5: Variation of physical parameters in Redskin Island-Transect 1

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	27.12	27.17	7.56	7.58	31.40	31.40
Feb-09	27.86	28.70	7.80	7.81	31.30	31.30
Mar-09	28.60	30.07	8.10	8.12	31.30	31.30
Apr-09	30.12	30.45	8.10	7.47	31.20	31.40
May-09	30.65	29.24	8.10	7.29	31.04	31.20
Jun-09	28.66	28.73	7.27	7.67	30.70	31.20
Jul-09	28.96	30.50	7.68	6.50	31.10	32.00
Aug-09	30.00	29.08	6.40	7.62	32.00	29.60
Sep-09	28.94	28.83	7.59	7.61	29.20	30.80
Oct-09	28.91	29.51	7.62	8.36	30.60	31.00
Nov-09	29.76	28.65	7.87	7.58	31.00	31.00
Dec-09	28.87	28.70	7.59	7.54	30.90	31.20
Variation recorded in 2010						
Jan-10	28.85	29.10	7.52	7.81	31.20	31.00
Feb-10	29.45	29.70	7.83	7.80	31.00	31.20
Mar-10	29.75	30.73	7.81	7.73	31.20	31.30
Apr-10	31.48	31.67	7.72	7.97	31.40	31.30
May-10	32.47	30.09	7.97	8.13	31.30	31.40
Jun-10	31.20	29.30	7.99	8.20	31.40	31.40
Jul-10	29.80	28.91	8.01	8.24	31.40	31.50
Aug-10	28.50	28.51	8.03	8.28	31.50	31.50
Sep-10	28.31	28.33	8.00	8.01	31.10	31.10
Oct-10	29.90	29.67	7.73	7.74	31.60	31.70
Nov-10	28.80	28.35	7.71	7.68	31.30	31.40
Dec-10	28.18	28.18	7.70	7.63	32.10	32.00
Variation recorded in 2011						
Jan-11	28.19	28.01	7.73	7.71	31.90	31.90
Feb-11	27.77	27.74	7.72	7.65	32.10	32.10
Mar-11	29.15	28.65	7.78	7.74	33.07	33.12
Apr-11	29.62	29.15	7.76	7.60	32.95	32.92
May-11	30.38	30.29	8.03	8.03	33.20	33.20
Jun-11	29.08	29.13	8.06	8.08	31.61	31.67
Jul-11	29.68	29.36	7.84	8.81	33.25	33.23
Aug-11	28.68	28.34	8.00	7.93	32.61	32.66
Sep-11	27.75	27.83	8.37	8.33	32.70	32.34
Oct-11	28.68	28.32	8.04	8.01	32.24	32.30
Nov-11	30.17	29.50	7.22	7.14	32.38	32.27
Dec-11	28.49	28.15	7.01	7.59	33.11	33.02

Table 6: Variation of physical parameters in Redskin Island- Transect 2

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	27.20	27.15	7.56	7.55	31.40	31.40
Feb-09	27.85	28.20	7.57	7.61	31.30	31.30
Mar-09	28.50	30.02	7.60	7.68	31.30	31.30
Apr-09	30.15	30.69	7.68	7.45	31.30	31.30
May-09	30.75	28.75	7.46	7.31	31.30	31.10
Jun-09	28.57	28.74	7.38	7.68	30.50	31.10
Jul-09	28.74	31.00	7.68	6.50	31.10	33.00
Aug-09	30.50	28.54	6.40	7.64	33.00	31.30
Sep-09	28.93	28.81	7.62	7.64	29.30	30.90
Oct-09	28.85	29.44	7.66	7.88	30.60	31.00
Nov-09	30.09	28.77	7.88	7.57	30.90	30.90
Dec-09	28.93	28.82	7.59	7.57	30.90	31.20
Variation recorded in 2010						
Jan-10	28.87	29.13	7.57	7.78	31.20	30.90
Feb-10	29.65	29.80	7.75	7.60	30.90	31.20
Mar-10	29.85	30.69	7.78	7.75	31.40	31.30
Apr-10	31.70	31.82	7.75	7.92	31.20	31.30
May-10	32.54	30.41	7.91	7.85	31.30	31.45
Jun-10	30.76	28.99	8.00	7.78	31.40	31.60
Jul-10	28.99	28.78	7.78	8.02	31.50	31.60
Aug-10	28.57	28.57	8.26	8.27	31.50	31.50
Sep-10	28.24	28.25	8.01	7.97	31.00	31.00
Oct-10	29.87	29.75	7.72	7.70	31.60	31.70
Nov-10	28.50	28.33	7.64	7.62	31.40	31.50
Dec-10	28.17	28.19	7.63	7.63	32.10	32.00
Variation recorded in 2011						
Jan-11	28.24	28.04	7.70	7.65	32.00	31.90
Feb-11	27.96	27.73	7.70	7.63	32.10	32.10
Mar-11	29.24	28.56	7.70	7.70	33.08	33.12
Apr-11	29.47	29.47	7.68	7.69	32.94	32.94
May-11	30.38	30.22	8.06	8.06	33.13	33.05
Jun-11	29.05	29.19	7.97	8.03	31.52	31.67
Jul-11	29.67	29.50	7.83	8.85	33.24	33.24
Aug-11	28.50	28.41	7.95	7.96	32.60	32.59
Sep-11	27.66	27.81	7.82	8.40	31.97	32.27
Oct-11	28.66	28.39	8.05	8.03	32.09	32.30
Nov-11	29.98	29.61	7.16	7.12	32.44	32.43
Dec-11	28.28	28.14	6.60	7.54	33.25	33.10

Table 7: Variation of physical parameters in Redskin Island- Transect 3

Variation recorded in 2009						
Month	Temperature in ºC		pH		Salinity in PSU	
	surface	5m	surface	5m	surface	5m
Jan-09	27.50	27.20	7.54	7.55	31.40	31.30
Feb-09	28.00	28.50	7.56	7.51	31.30	31.30
Mar-09	28.60	30.20	7.58	7.47	31.30	31.30
Apr-09	30.05	30.50	7.61	7.35	31.30	31.30
May-09	30.68	29.23	7.37	7.29	31.40	31.40
Jun-09	29.01	28.74	7.32	7.69	31.00	31.10
Jul-09	28.74	30.50	7.70	6.50	31.10	32.00
Aug-09	30.50	28.55	6.60	7.65	32.00	31.10
Sep-09	28.80	28.87	7.65	7.68	31.00	30.90
Oct-09	28.81	29.47	7.69	7.85	30.80	31.00
Nov-09	29.47	28.72	7.85	7.62	31.00	30.80
Dec-09	28.74	28.81	7.63	7.58	30.80	31.00
Variation recorded in 2010						
Jan-10	28.78	29.20	7.60	7.74	31.10	30.90
Feb-10	29.21	29.25	7.75	7.70	30.90	31.20
Mar-10	29.35	30.47	7.39	7.79	31.30	31.30
Apr-10	30.51	32.50	7.79	7.81	31.30	31.40
May-10	32.14	30.89	7.83	7.64	31.40	31.50
Jun-10	30.89	29.03	7.62	8.14	31.50	31.60
Jul-10	29.02	28.79	8.13	8.09	31.60	31.60
Aug-10	28.56	28.55	8.02	8.05	31.60	31.60
Sep-10	28.34	28.21	8.17	8.19	30.80	31.30
Oct-10	29.77	29.65	7.66	7.68	31.70	31.70
Nov-10	28.57	28.45	7.58	7.56	31.50	31.50
Dec-10	28.25	28.20	7.96	7.87	32.10	32.10
Variation recorded in 2011						
Jan-11	28.01	28.02	7.59	7.57	31.90	31.90
Feb-11	27.76	27.76	7.65	7.59	32.00	32.00
Mar-11	28.71	28.66	7.68	7.67	33.12	33.05
Apr-11	29.03	28.99	7.69	7.65	32.99	32.92
May-11	30.46	30.25	8.11	8.06	33.06	33.05
Jun-11	29.17	29.17	7.97	7.98	31.74	31.67
Jul-11	29.46	29.47	7.87	7.86	33.16	33.16
Aug-11	28.30	28.33	8.19	8.09	32.52	32.59
Sep-11	27.82	27.83	7.89	7.97	32.20	32.34
Oct-11	28.23	28.24	8.12	8.14	32.37	32.44
Nov-11	30.17	29.51	7.01	7.45	32.60	32.42
Dec-11	28.16	28.16	6.58	6.51	32.95	32.50

Table 8: Average Temperature variation in Jolly Buoy and Redskin Island during 2009-2011

Average Temperature in ºC Recorded in Jolly Buoy Island						
Transect	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	28.77	29.37	28.68	28.83	29.29	28.60
T2	28.63	29.41	28.62	28.83	29.32	28.59
T3	28.85	29.45	28.71	28.80	29.32	28.61
T4	28.98	29.65	28.75	28.9	29.38	28.65
Total Average	28.81	29.47	28.69	28.84	29.33	28.61
Average Temperature in ºC Recorded in Redskin Island						
	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	29.04	29.72	28.97	29.14	29.38	28.71
T2	29.09	29.64	28.92	29.08	29.39	28.76
T3	29.08	29.45	28.77	29.11	29.43	28.70
Total Average	29.07	29.60	28.89	29.11	29.40	28.72

Table 9: Average pH variation in Jolly Buoy and Redskin Island during 2009-2011

Average pH Recorded in Jolly Buoy Island						
	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	7.52	7.98	7.95	7.54	8.02	7.91
T2	7.48	8.02	7.98	7.50	8.07	7.95
T3	7.51	8.02	7.94	7.56	8.15	8.04
T4	7.52	7.93	7.85	7.52	7.95	7.87
Total Average	7.51	7.99	7.93	7.53	8.05	7.94
Average pH Recorded in Redskin Island						
	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	7.64	7.84	7.80	7.60	7.94	7.89
T2	7.51	7.82	7.69	7.51	7.82	7.89
T3	7.51	7.79	7.70	7.48	7.86	7.71
Total Average	7.55	7.82	7.73	7.53	7.87	7.83

Table 10: Average Salinity variation in Jolly Buoy and Redskin Island during 2009-2011

Average Salinity in PSU Recorded in Jolly Buoy Island						
	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	31.23	31.33	32.68	31.18	31.40	32.66
T2	31.18	31.31	32.69	31.17	31.42	32.69
T3	31.16	31.39	32.72	31.16	31.48	32.74
T4	31.24	31.37	32.67	31.19	31.37	32.67
Total Average	31.20	31.35	32.69	31.18	31.42	32.69
Average Salinity in PSU Recorded in Redskin Island						
	Surface-Average			10m-Average		
	2009	2010	2011	2009	2010	2011
T1	30.98	31.38	32.59	31.12	31.40	32.56
T2	31.08	31.38	32.53	31.32	31.42	32.56
T3	31.20	31.40	32.55	31.21	31.48	32.50
Total Average	31.09	31.39	32.56	31.22	31.43	32.54

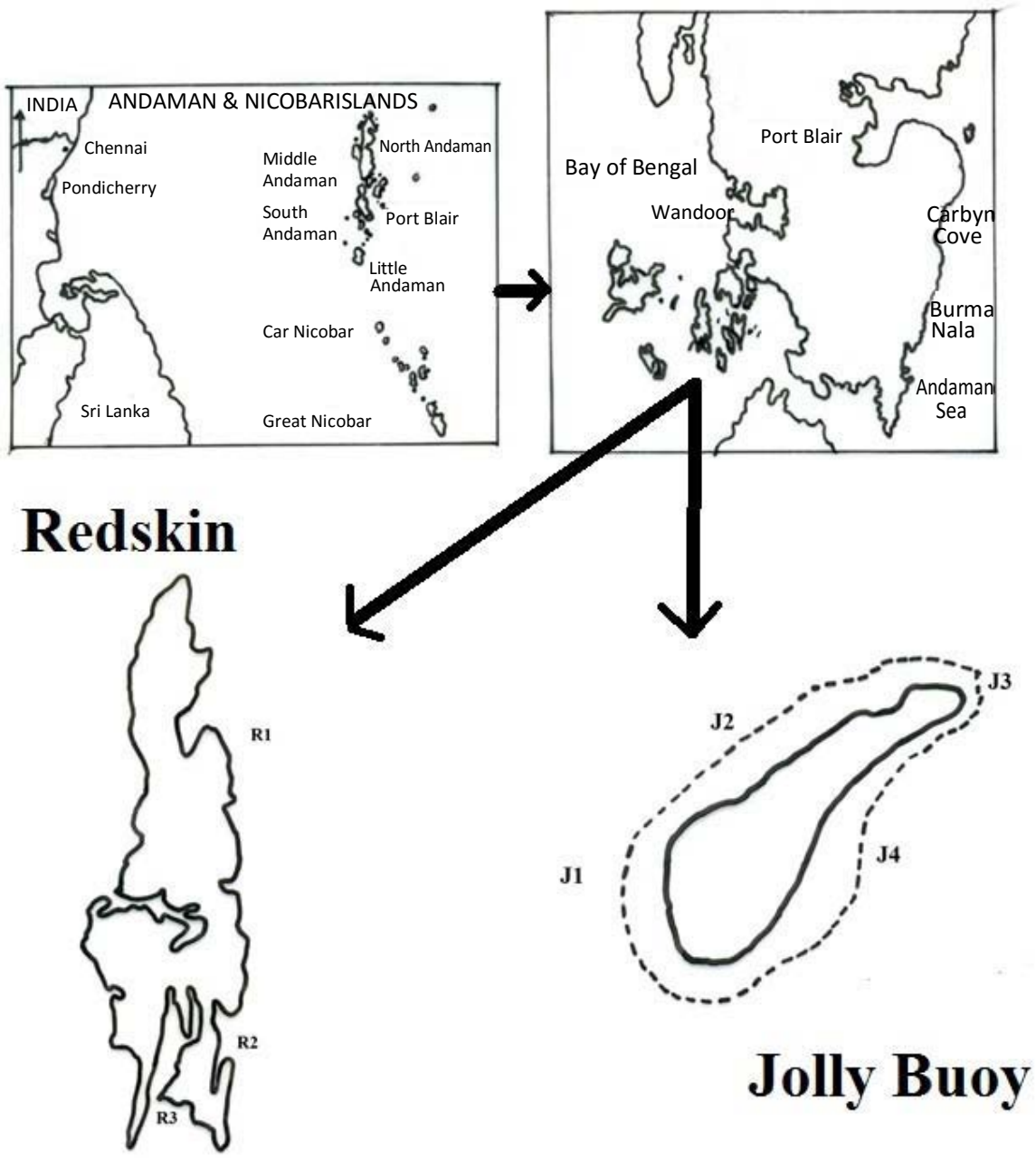

Fig. 1: Study Area

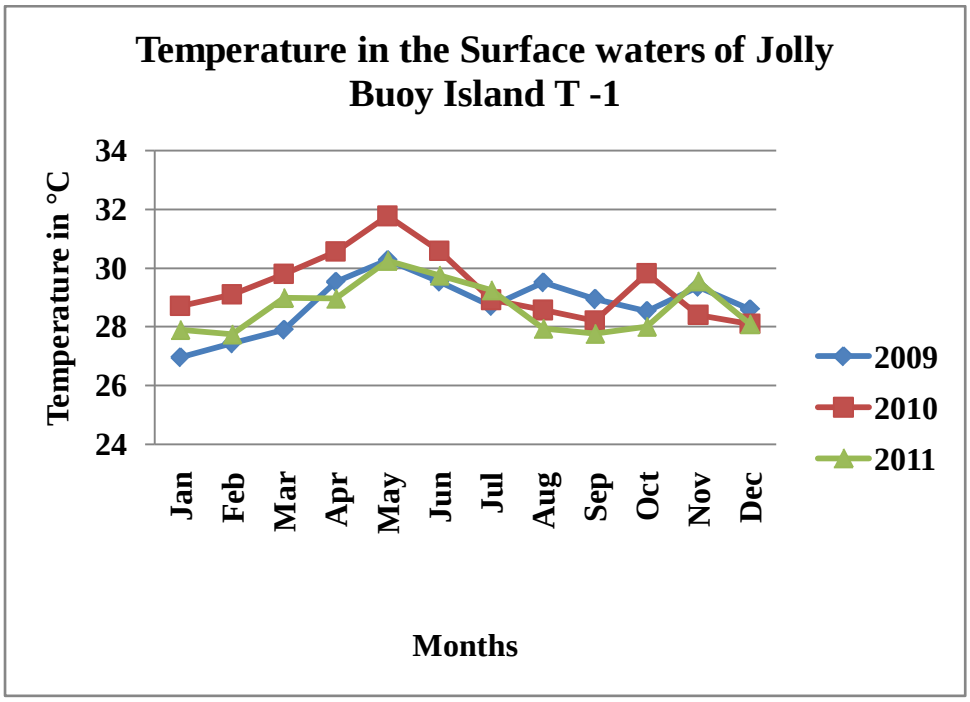

Fig. 2: A. Temperature in Transect 1 of Jolly Buoy Island-Surface Waters

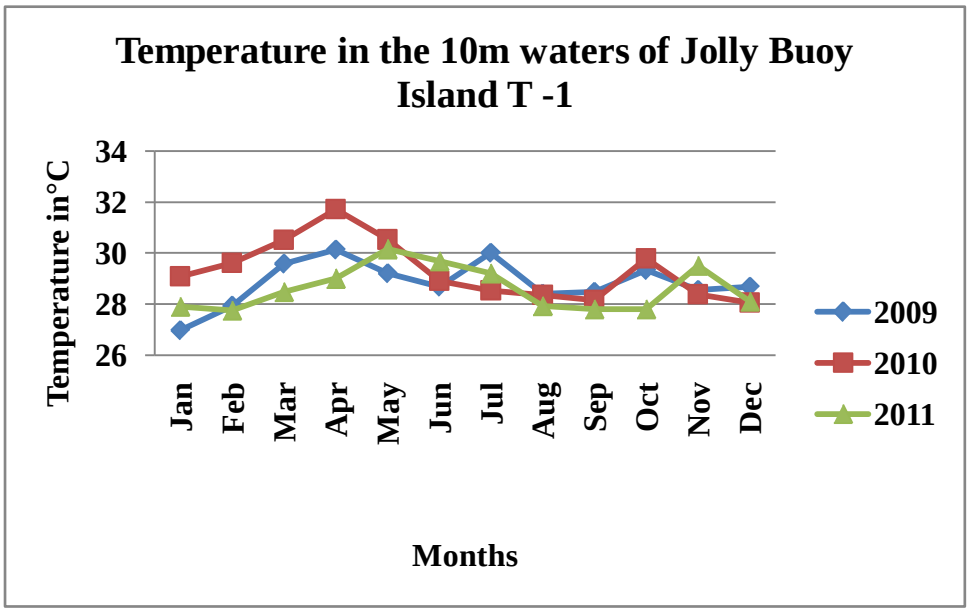

Fig. 2: B. Temperature in Transect 1 of Jolly Buoy Island-10m Waters

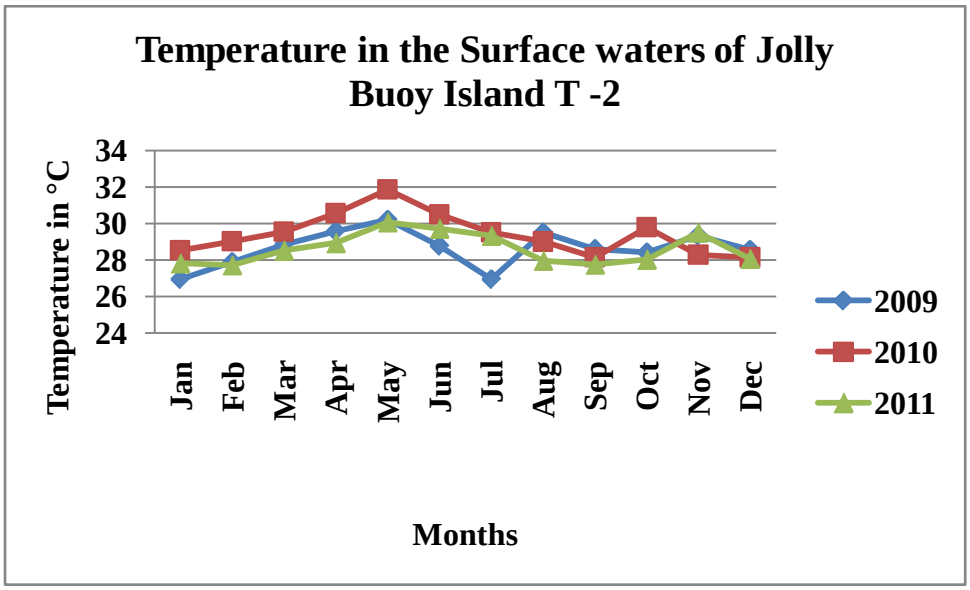

Fig. 3: A. Temperature in Transect 2 of Jolly Buoy Island-Surface Waters

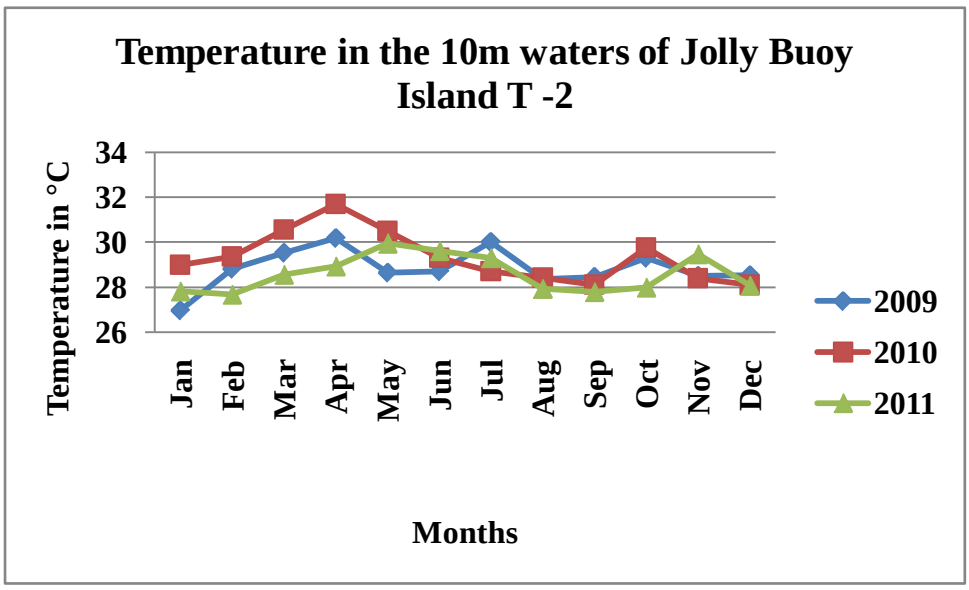

Fig. 3: B. Temperature in Transect 2 of Jolly Buoy Island-10m Waters

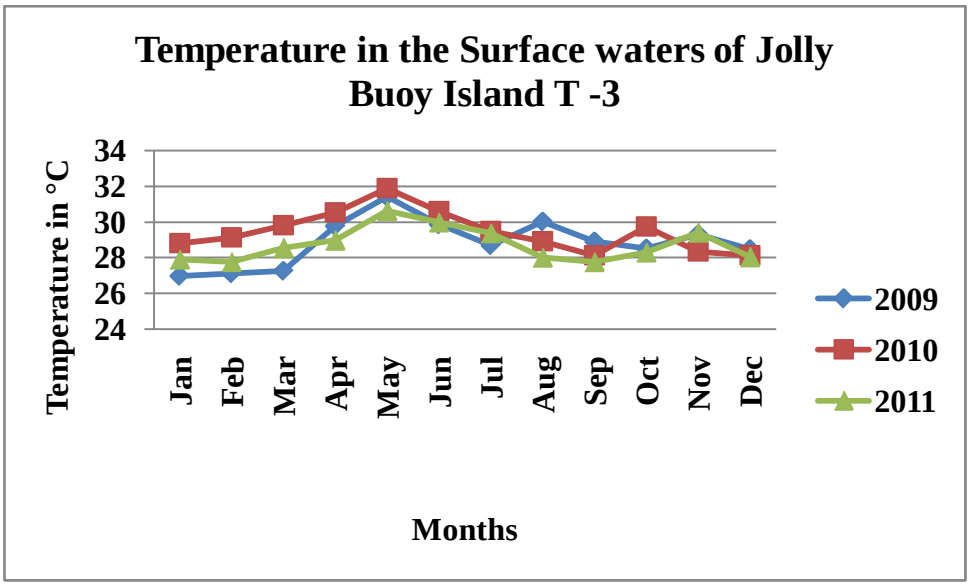

Fig. 4: A. Temperature in Transect 3 of Jolly Buoy Island-Surface Waters

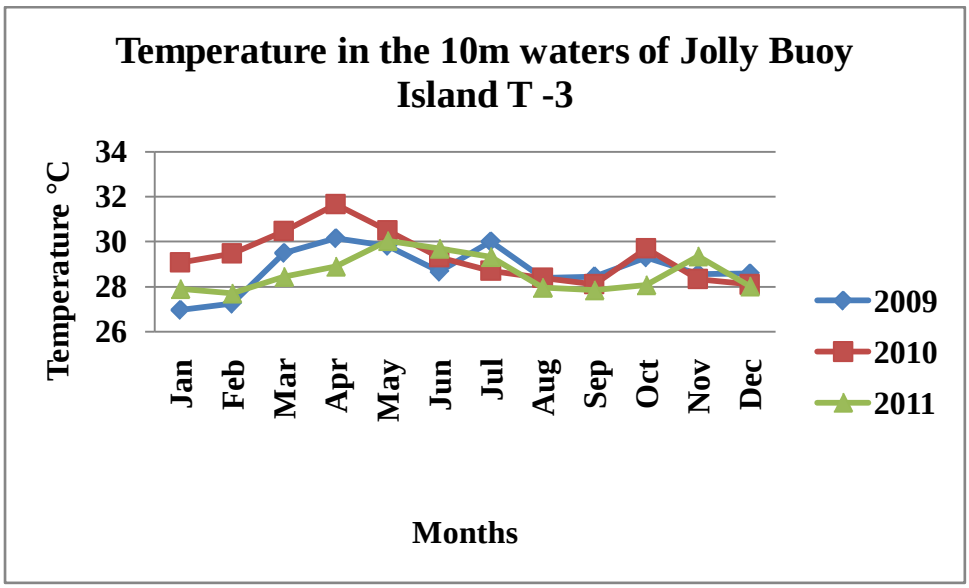

Fig. 4: B. Temperature in Transect 3 of Jolly Buoy Island-10m Waters

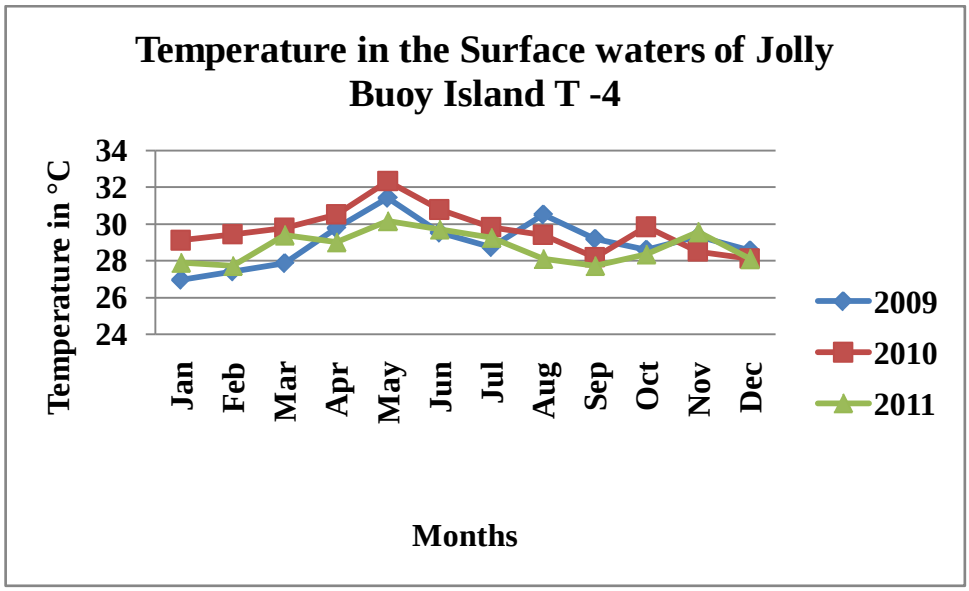

Fig. 5: A. Temperature in Transect 4 of Jolly Buoy Island-Surface Waters

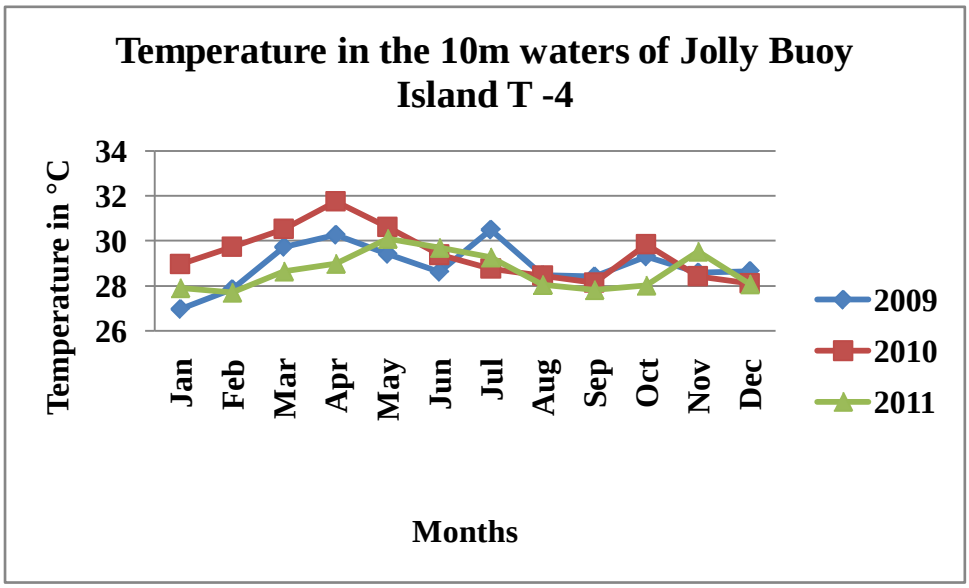

Fig. 5: B. Temperature in Transect 4 of Jolly Buoy Island-10m Waters

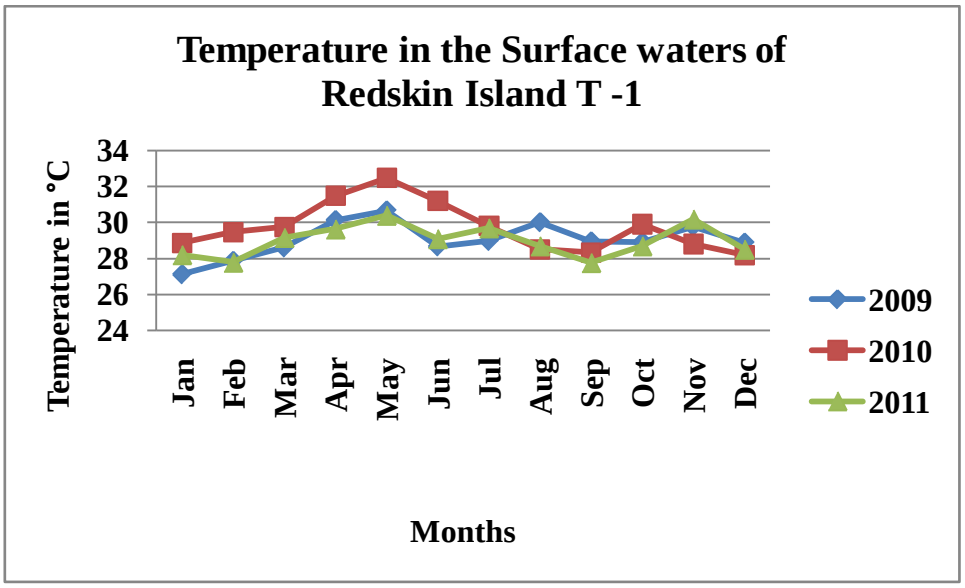

Fig. 6: A. Temperature in Transect 1 of Redskin Island-Surface Waters

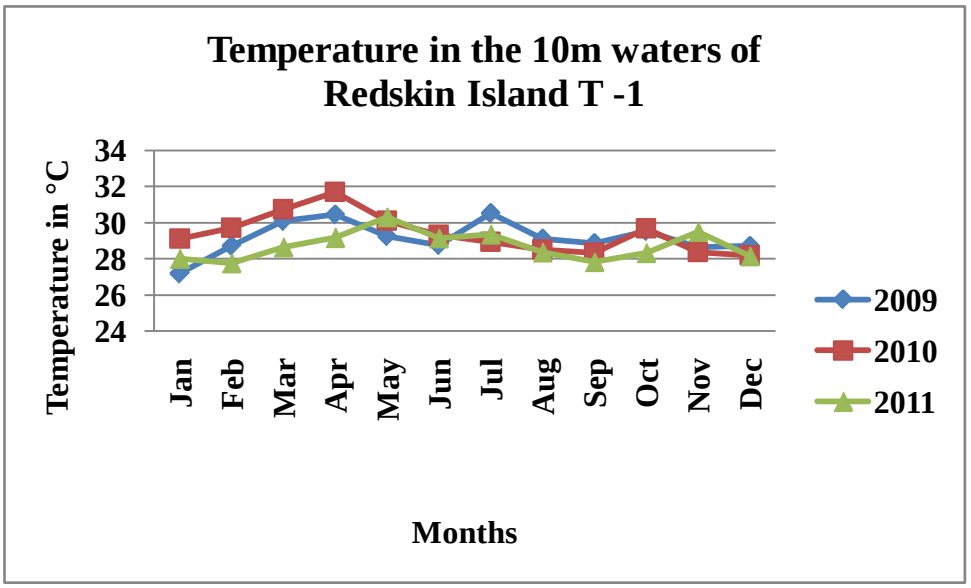

Fig. 6: B. Temperature in Transect 1 of Redskin Island-10m Waters

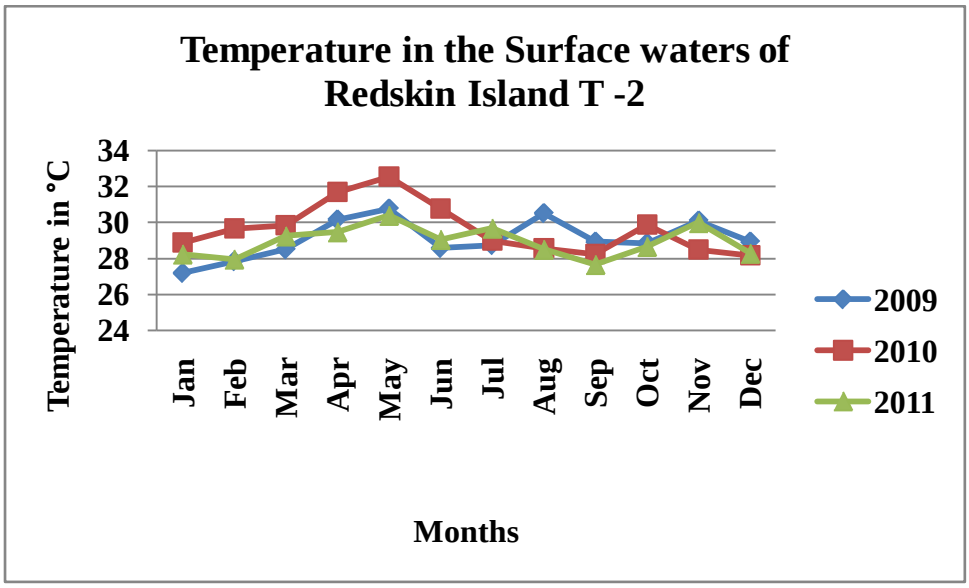

Fig. 7: A. Temperature in Transect 2 of Redskin Island-Surface Waters

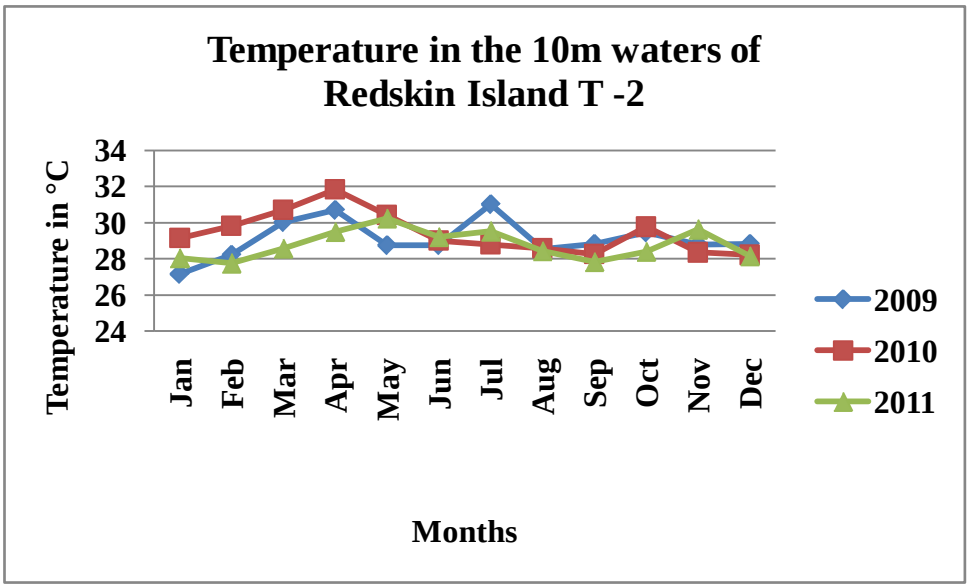

Fig. 7: B. Temperature in Transect 2 of Redskin Island-10m Waters

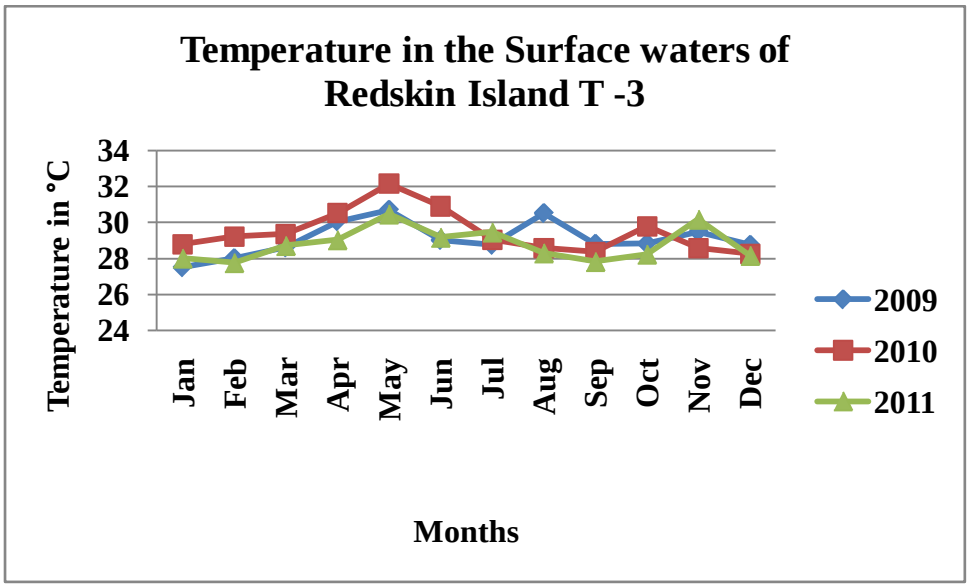

Fig. 8: A. Temperature in Transect 3 of Redskin Island-Surface Waters

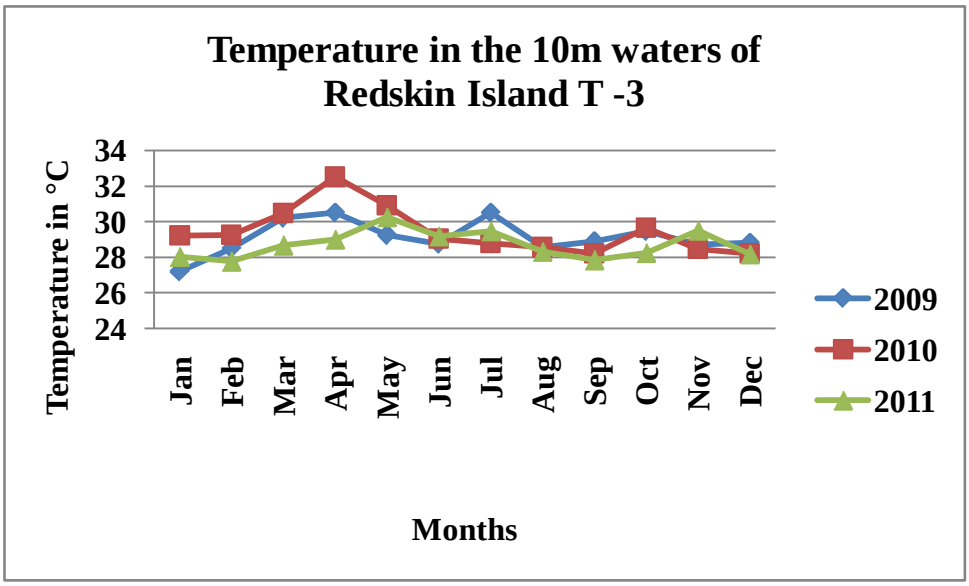

Fig. 8: B. Temperature in Transect 3 of Redskin Island-10m Waters

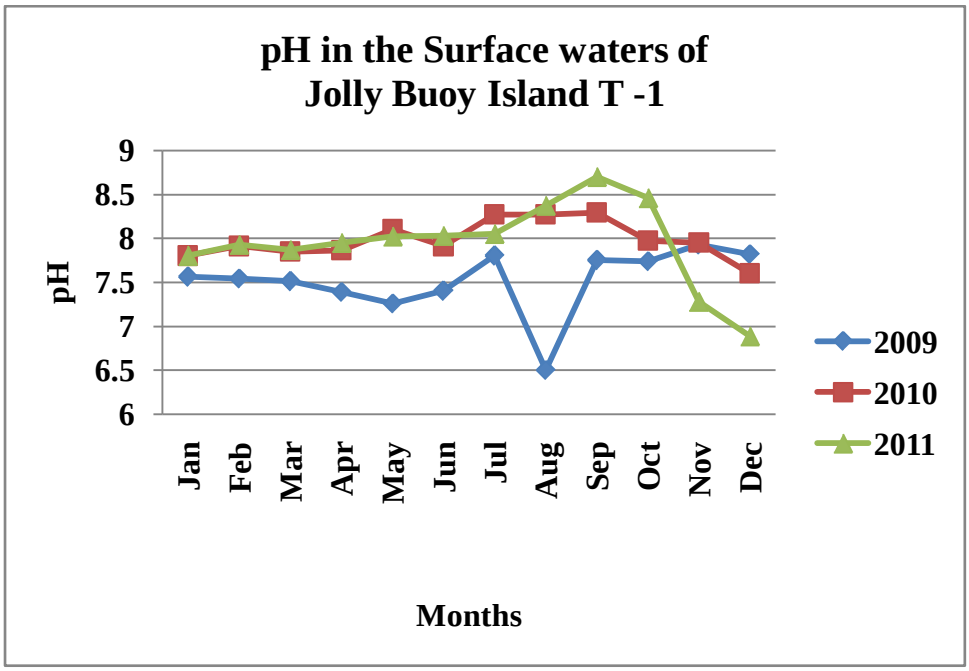

Fig. 9: A. pH in Transect 1 of Jolly Buoy Island-Surface Waters

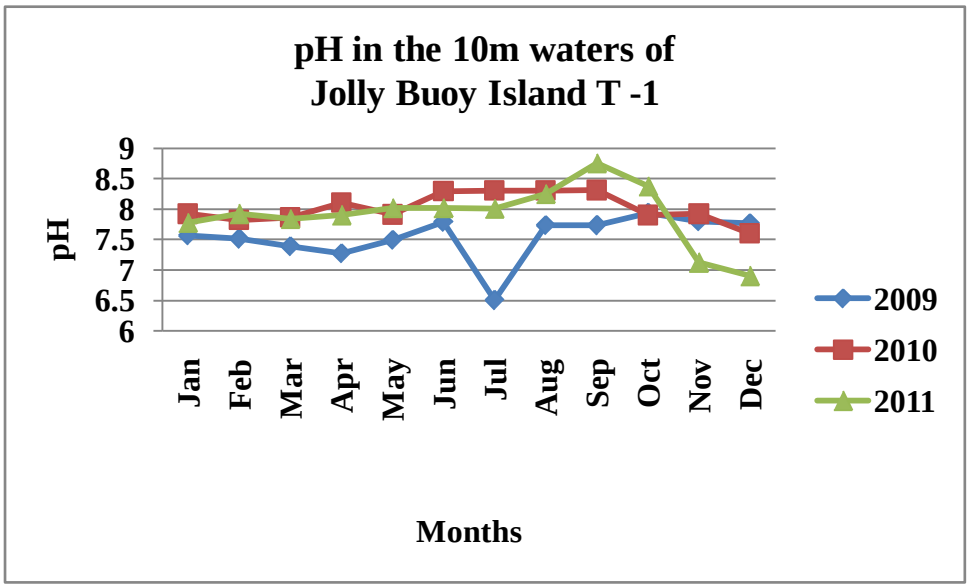

Fig. 9: B. pH in Transect 1 of Jolly Buoy Island-10m Waters

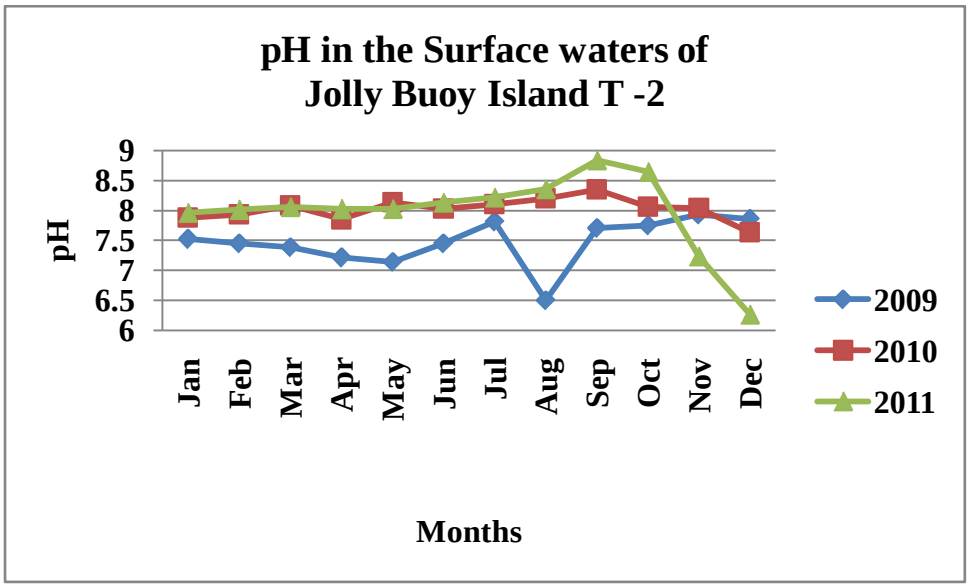

Fig. 10: A. pH in Transect 2 of Jolly Buoy Island-Surface Waters

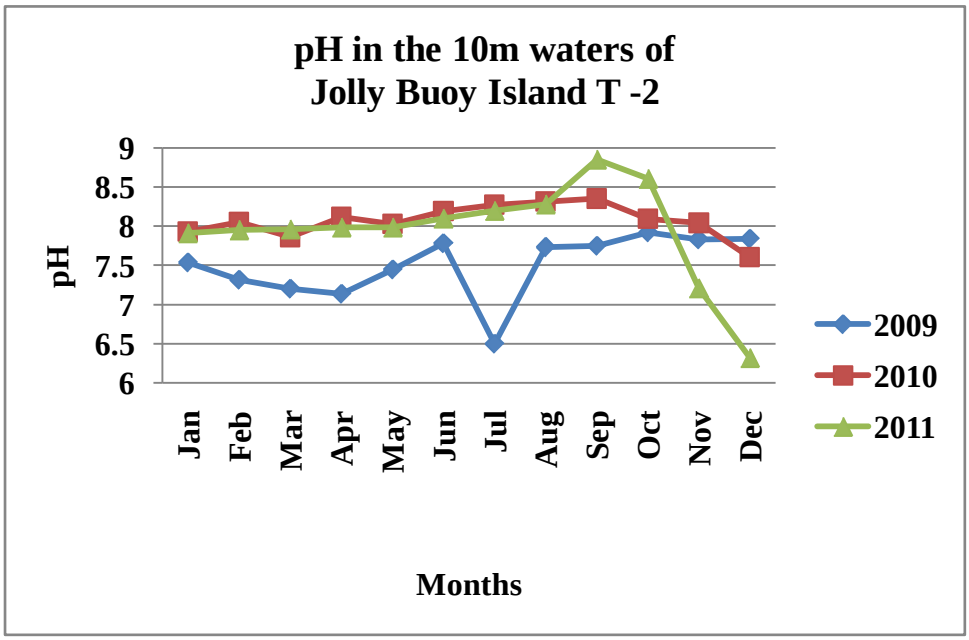

Fig. 10: B. pH in Transect 2 of Jolly Buoy Island-10m Waters

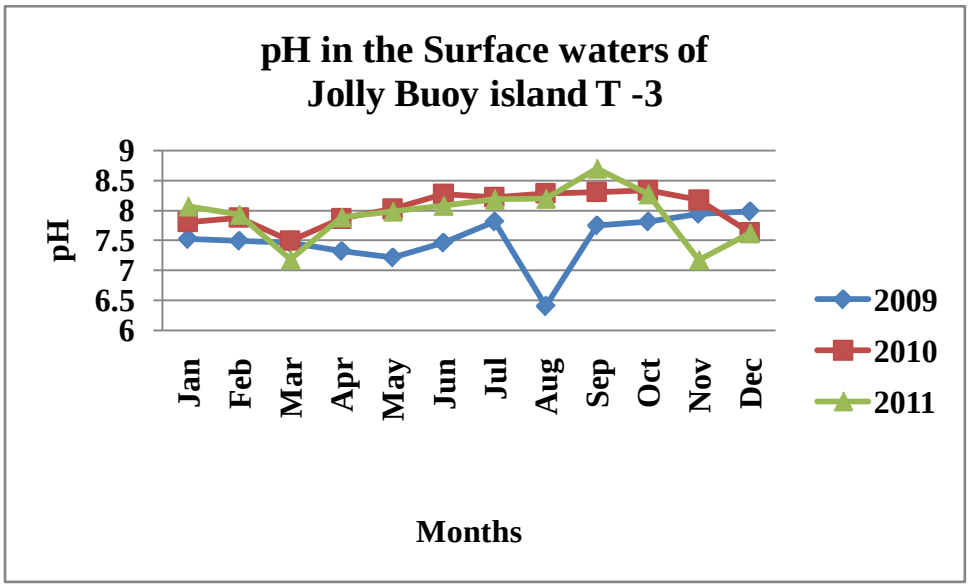

Fig. 11: A. pH in Transect 3 of Jolly Buoy Island-Surface Waters

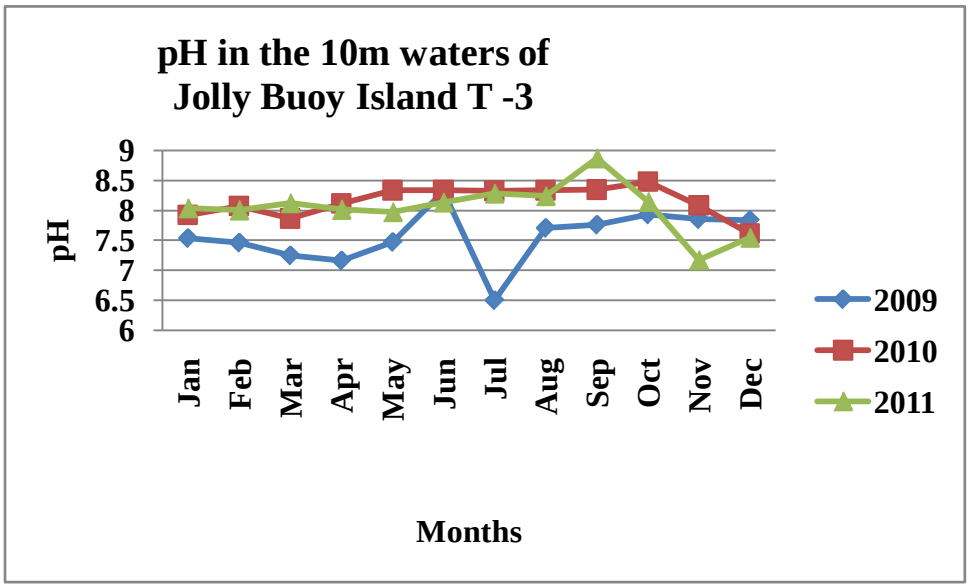

Fig. 11: B. pH in Transect 3 of Jolly Buoy Island-10m Waters

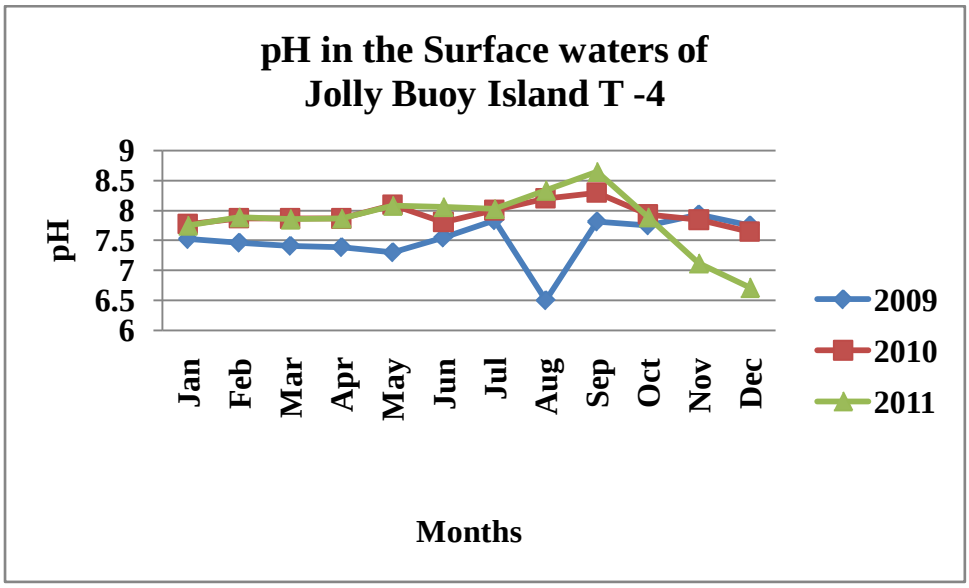

Fig. 12: A. pH in Transect 4 of Jolly Buoy Island-Surface Waters

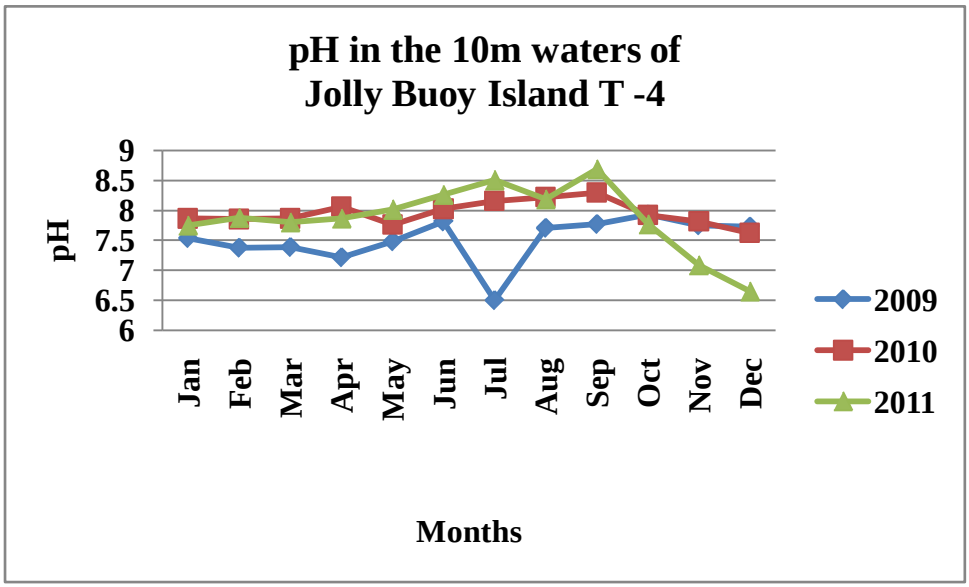

Fig. 12: B. pH in Transect 4 of Jolly Buoy Island-10m Waters

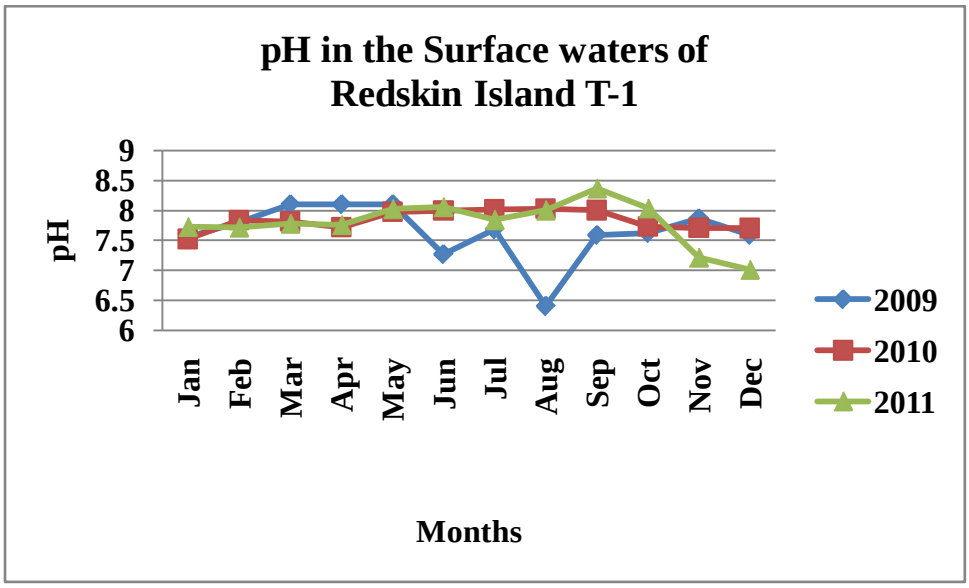

Fig. 13: A. pH in Transect 1 of Redskin Island-Surface Waters

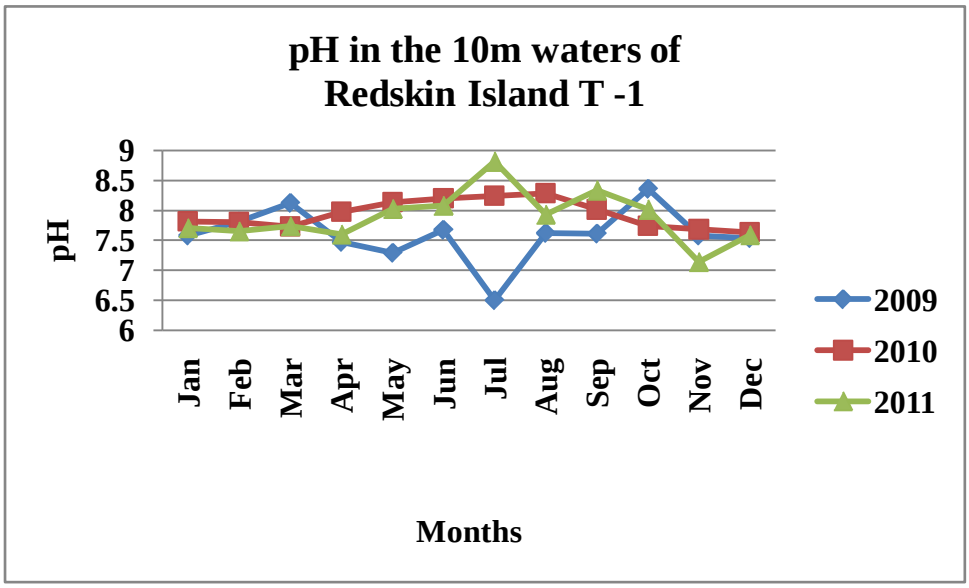

Fig. 13: B. pH in Transect 1 of Redskin Island-10m Waters

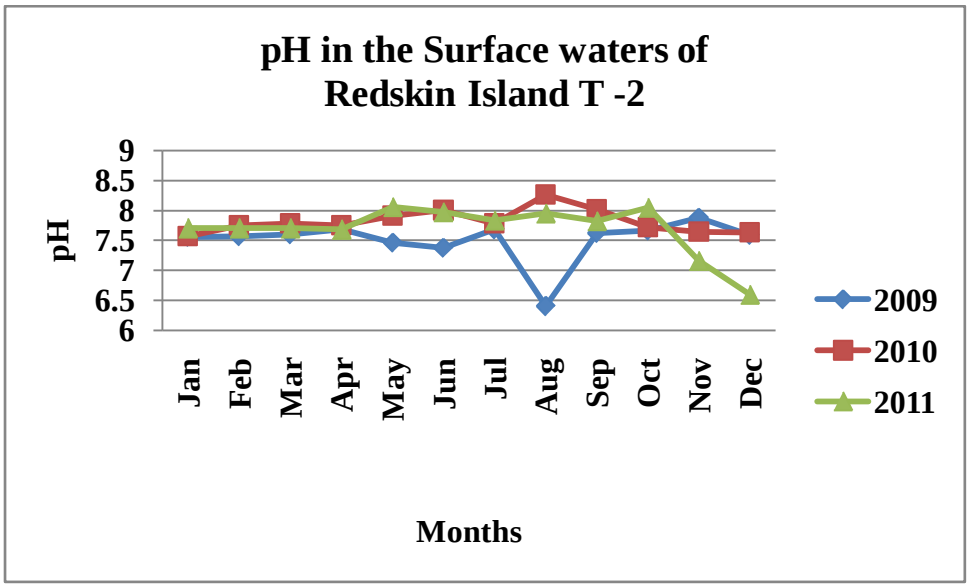

Fig. 14: A. pH in Transect 2 of Redskin Island-Surface Waters

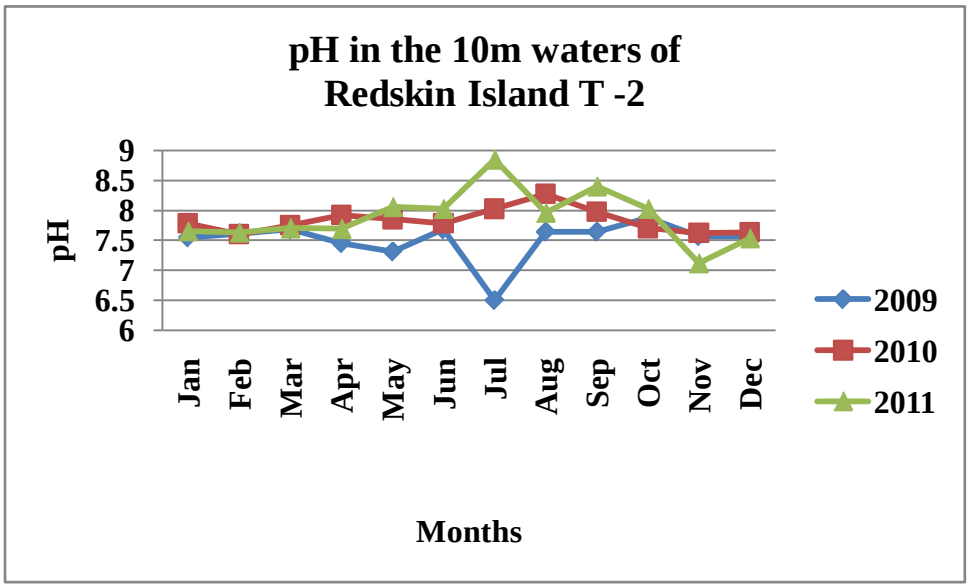

Fig. 14: B. pH in Transect 2 of Redskin Island-10m Waters

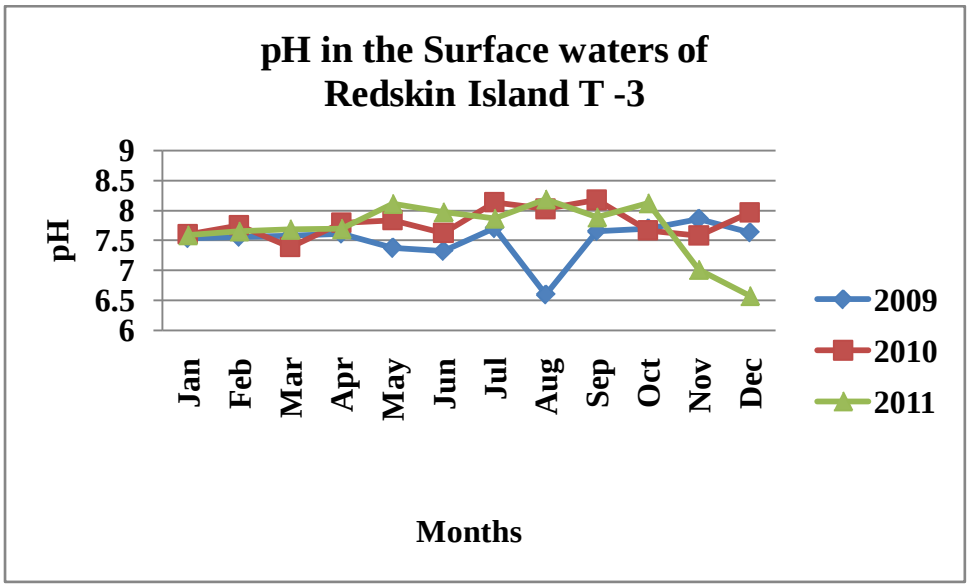

Fig. 15: A. pH in Transect 3 of Redskin Island-Surface Waters

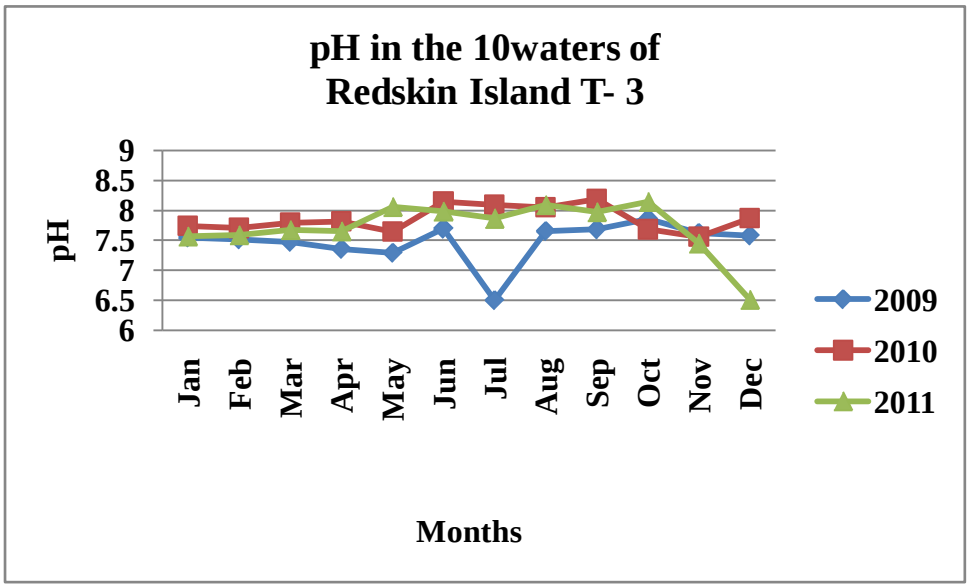

Fig. 15: B. pH in Transect 3 of Redskin Island-10m Waters

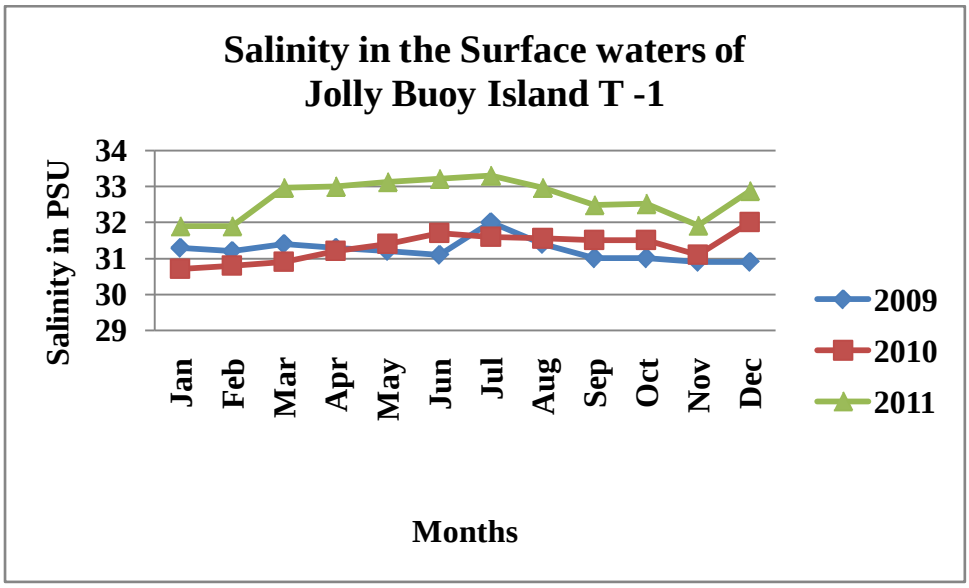

Fig. 16: A. Salinity in Transect 1 of Jolly Buoy Island-Surface Waters

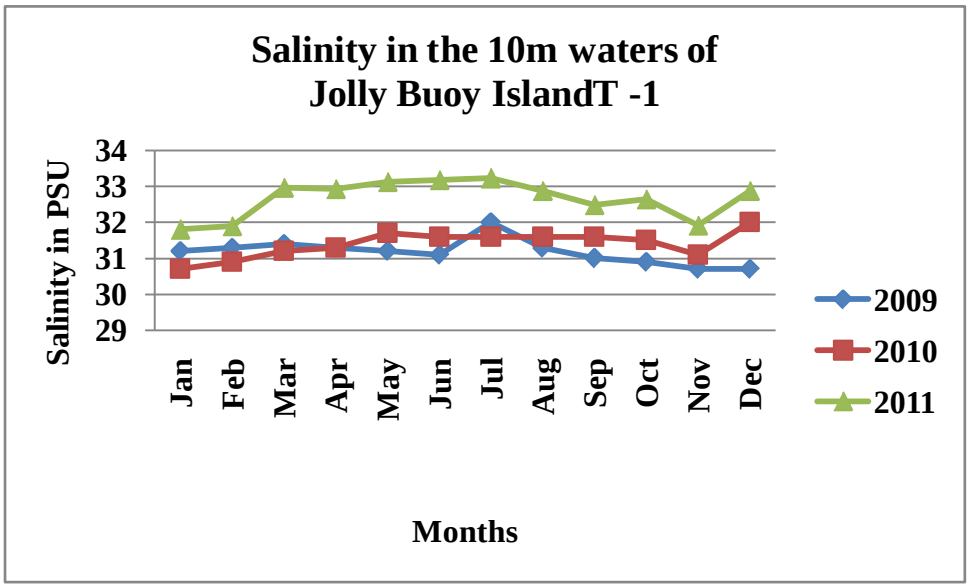

Fig. 16: B. Salinity in Transect 1 of Jolly Buoy Island-10m Waters

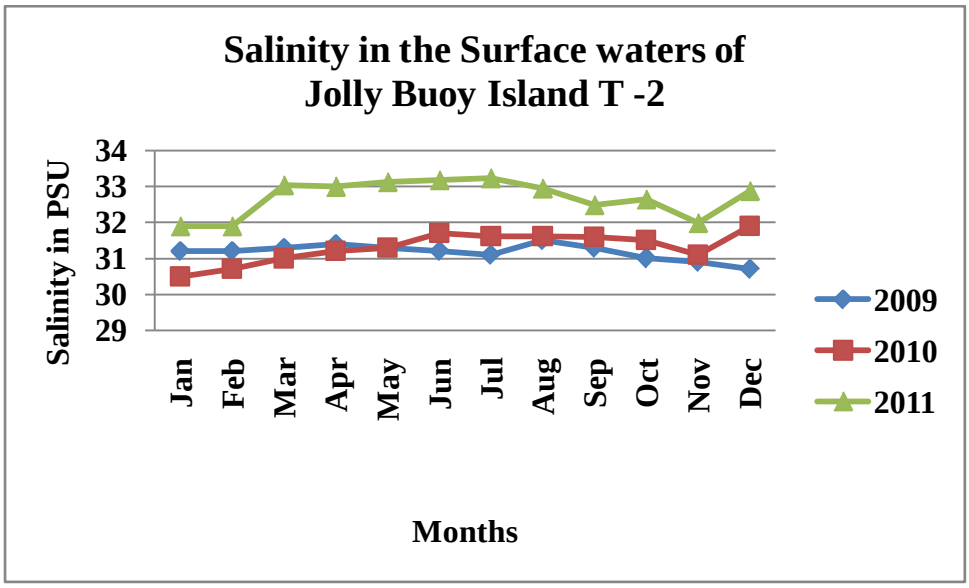

Fig. 17: A. Salinity in Transect 2 of Jolly Buoy Island-Surface Waters

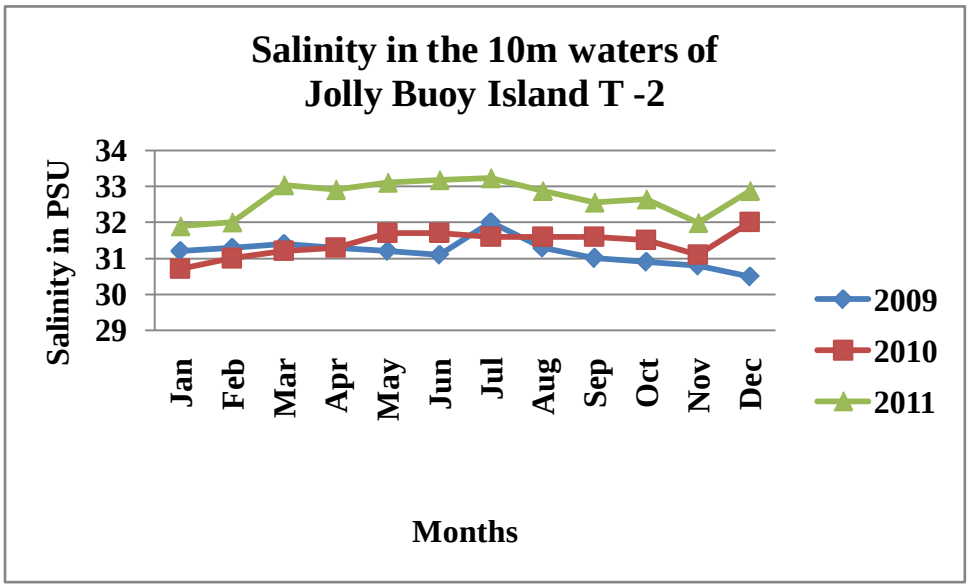

Fig. 17: B. Salinity in Transect 2 of Jolly Buoy Island-10m Waters

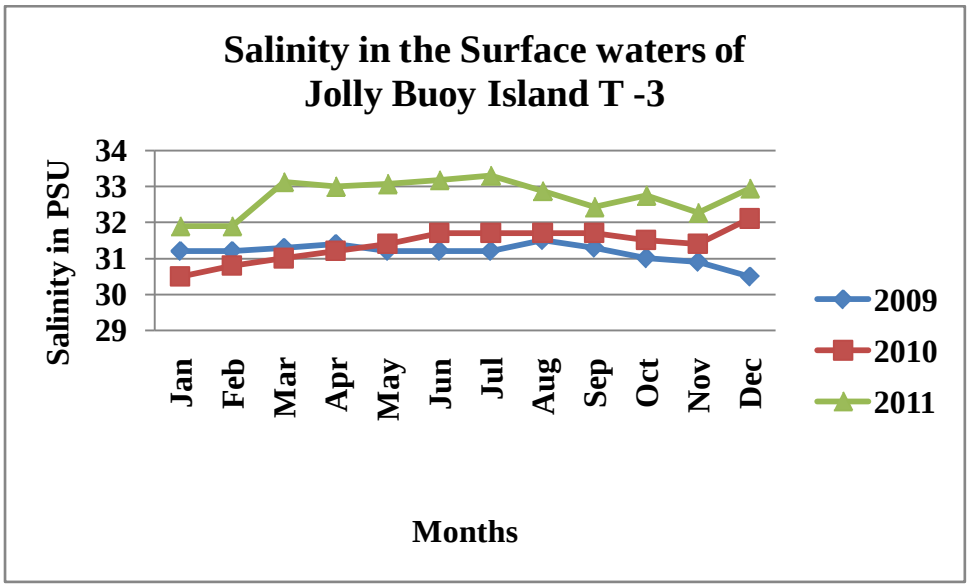

Fig. 18: A. Salinity in Transect 3 of Jolly Buoy Island-Surface Waters

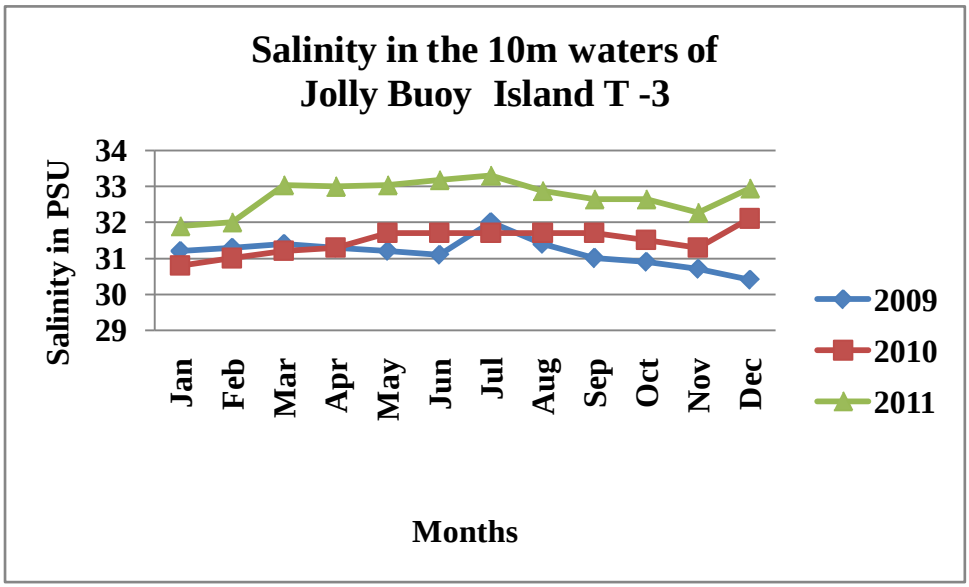

Fig. 18: B. Salinity in Transect 3 of Jolly Buoy Island-10m Waters

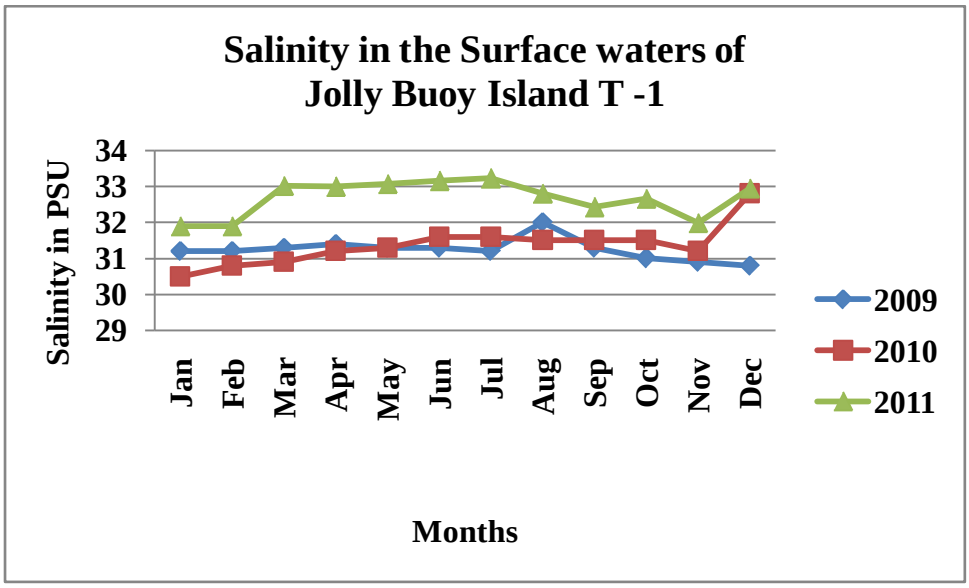

Fig. 19: A. Salinity in Transect 4 of Jolly Buoy Island-Surface Waters

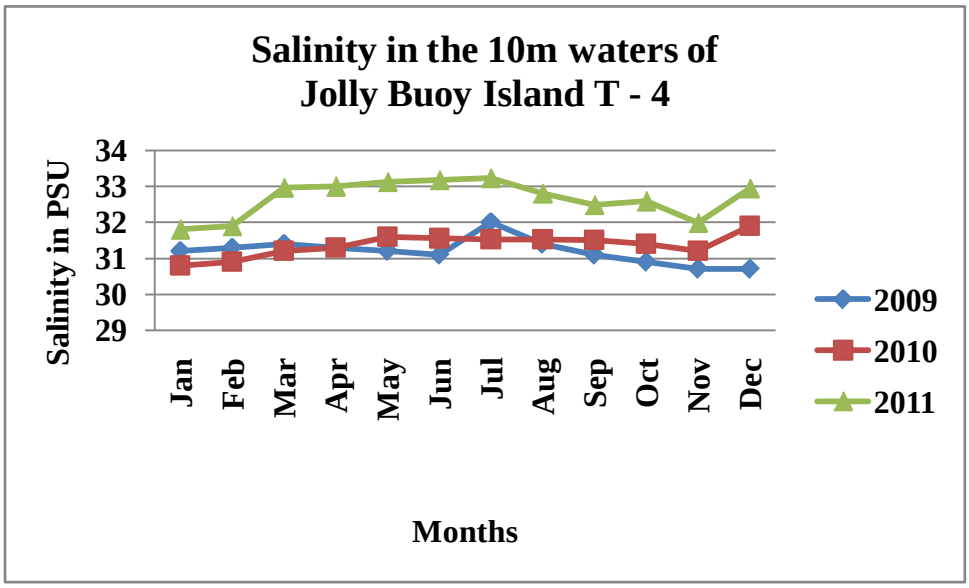

Fig. 19: B. Salinity in Transect 4 of Jolly Buoy Island-10m Waters

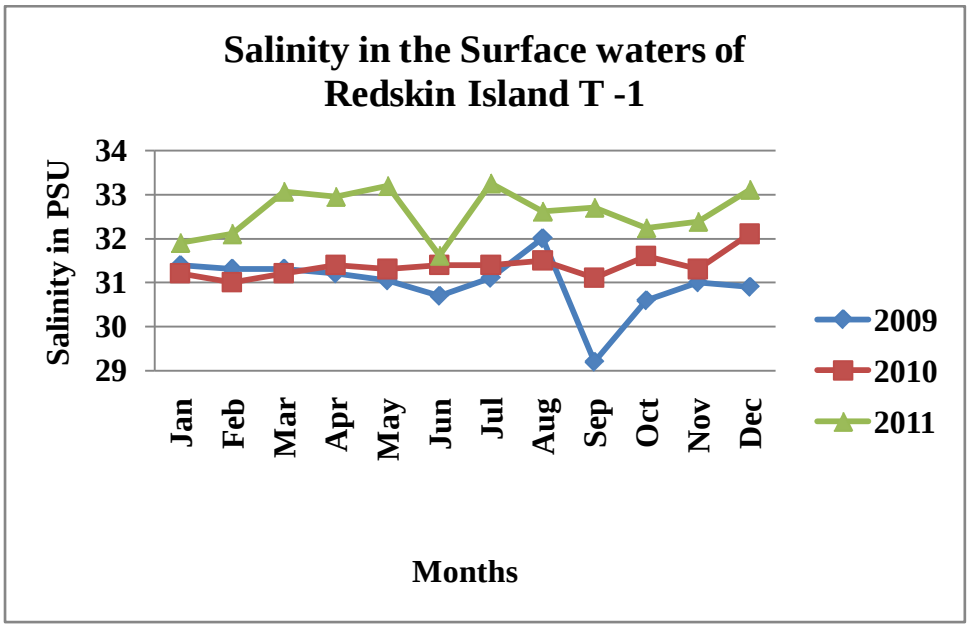

Fig. 20: A. Salinity in Transect 1 of Redskin Island-Surface Waters

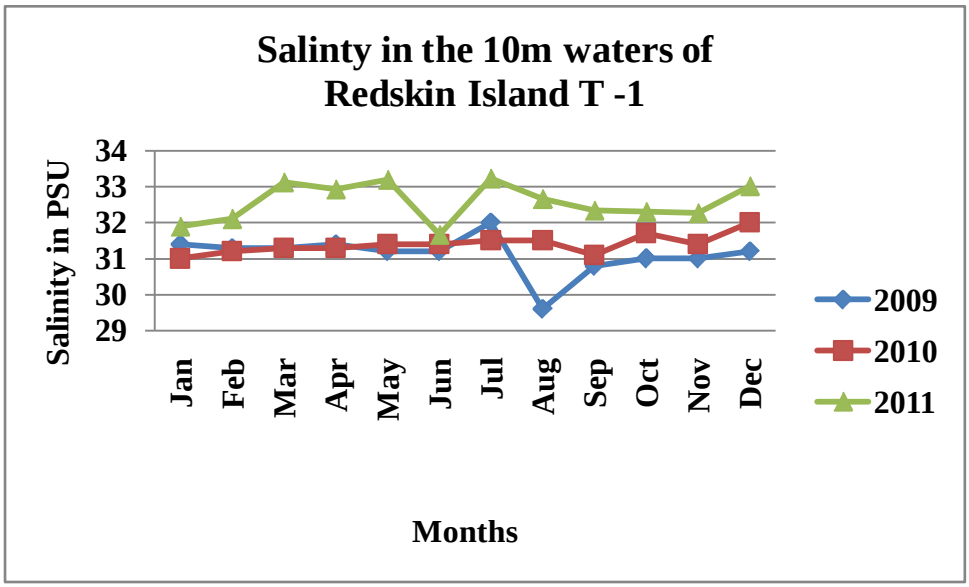

Fig. 20: B. Salinity in Transect 1 of Redskin Island-10m Waters

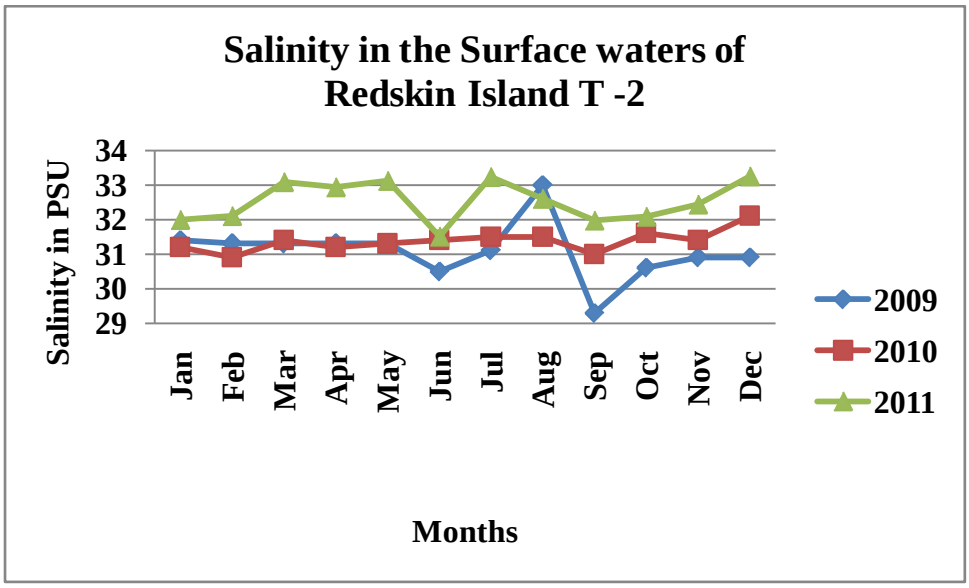

Fig. 21: A. Salinity in Transect 2 of Redskin Island-Surface Waters

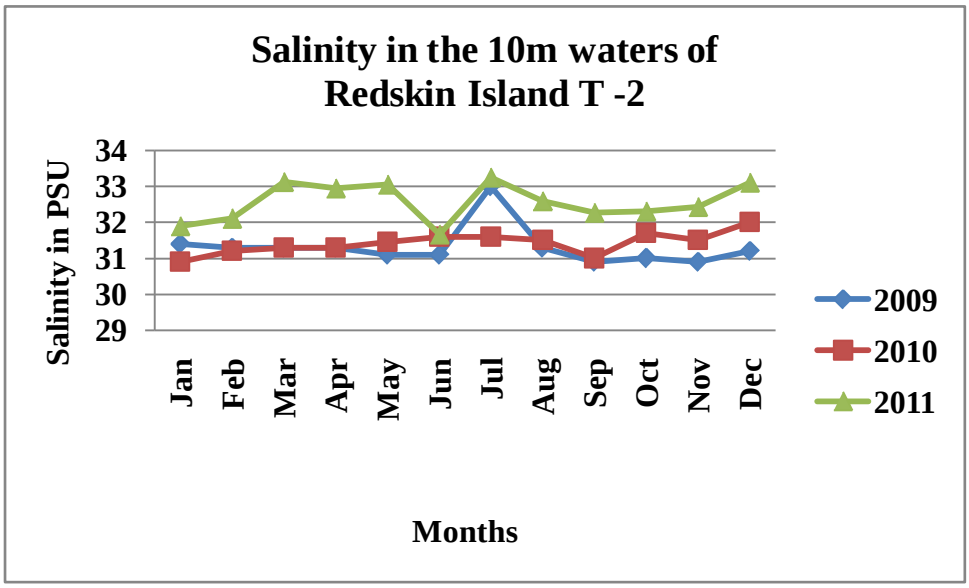

Fig. 21: B. Salinity in Transect 2 of Redskin Island-10m Waters

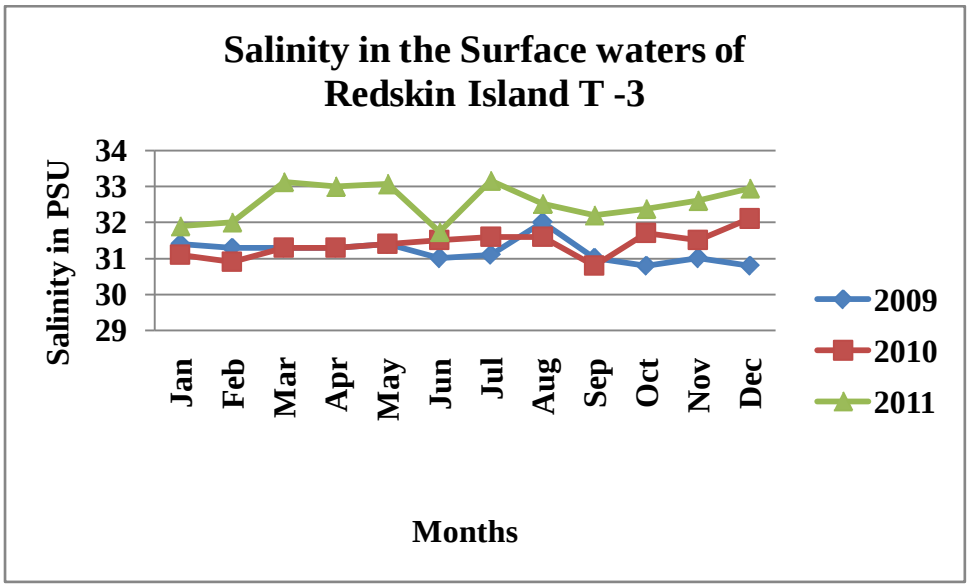

Fig. 22: A. Salinity in Transect 3 of Redskin Island-Surface Waters

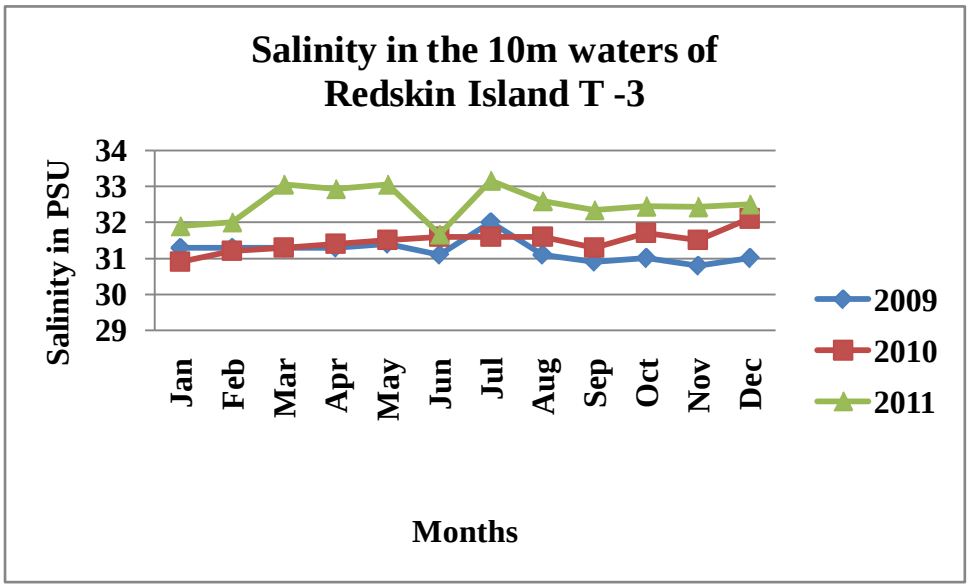

Fig. 22: B. Salinity in Transect 3 of Redskin Island-10m Waters