Chapter 2 Habitat Characterization

According to a common definition, "Habitat corresponds to the resources and conditions present in an area that produce occupancy (including survival and reproduction) by a given organism" (Hall et al., 1997). The aim of habitat selection studies is often to identify various environmental, physical and ecological characteristics that make a place suitable for a species.

Various habitat characteristics were studied in detail to assess the habitat use and preference of the species in the study area. Salinity, pH, dissolved oxygen (DO), water temperature, water depth, and vegetation cover were studied in detail so as to determine the habitat requisites of the species.

Habitat Characteristics

Both Kumbharwada and Newport sites showed marked differences in terms of water availability, fresh water inflow, salinity, vegetation, habitat use and varying degree of anthropogenic pressure. Kumbharwada area is an admixture of saltpans, abandoned saltpans, sewage waste water ponds (freshwater). The ground water at Kumbharwada site is saline which aids salt pan owners to use ground water for salt farming. This geomorphology and hydrology have resulted in a mixture of seasonal, semi-permanent and permanent wetlands of variable salinity.

Newport site, on the other hand, is saline area with high degree of salt production activity compared to Kumbharwada salt pans. The area also has some abandoned salt pans which are not used for salt manufacturing. However, most part of the study area (379 hectares, 40%) is used for salt manufacturing. The area is totally devoid of vegetation except some outgrowth of *Prosopis* spp. on the peripheral bunds.

Salinity

Salinity is a measure of the content of salts in soil or water. Salts are highly soluble in surface and groundwater and can be transported with water movement. Large salt deposits are a natural feature of vast areas of the coastal landscape of Gujarat. This natural distribution of salt in the landscape is referred to as 'primary salinity'.

Kumbharwada Site

The Kumbharwada sewage ponds were less saline as compared to the Newport saltpans. Salinity in Kumbharwada area ranged from 11% (in September 2010) to 29% (in May 2012) during the entire study period. The average salinity in the first year (i.e. year 2009) ranged from 12% (in August) to 29% (in June). During the second year (year 2010) it ranged from 11% (September) to 23% (May). Similarly in the third year (2011) salinity ranged from 15% (September) to 27 (July). Mean salinity at Kumbharwada site was 29.7 % ± 2.4% (Table 1) (Fig. 1).

Table 1: Salinity at three different habitat types at Kumbharwada site

	Salinity at Kumbharwada site (in %)					
Year	**Sewage Ponds**	**Range**	**Abandoned Saltpans**	**Range**	**Used Saltpans**	**Range**
2009	19.5	16.6 - 21.6	24.5	21.3 - 27.3	40.8	38.5 - 41.7
2010	19.4	18.3 - 21.0	25.1	22.9 - 26.9	42.5	39.8 - 45.5
2011	20.2	18.2 - 22.8	30.9	28.5 - 32.6	41.9	40.3 - 43.9
2012	18.9	16.6 - 20.3	31.4	28.3 - 34.2	42.2	41.4 - 42.7

Notable difference was also observed among different habitat types within Kumbharwada site. Sewage ponds were least saline as compared to Abandoned saltpans and used saltpans

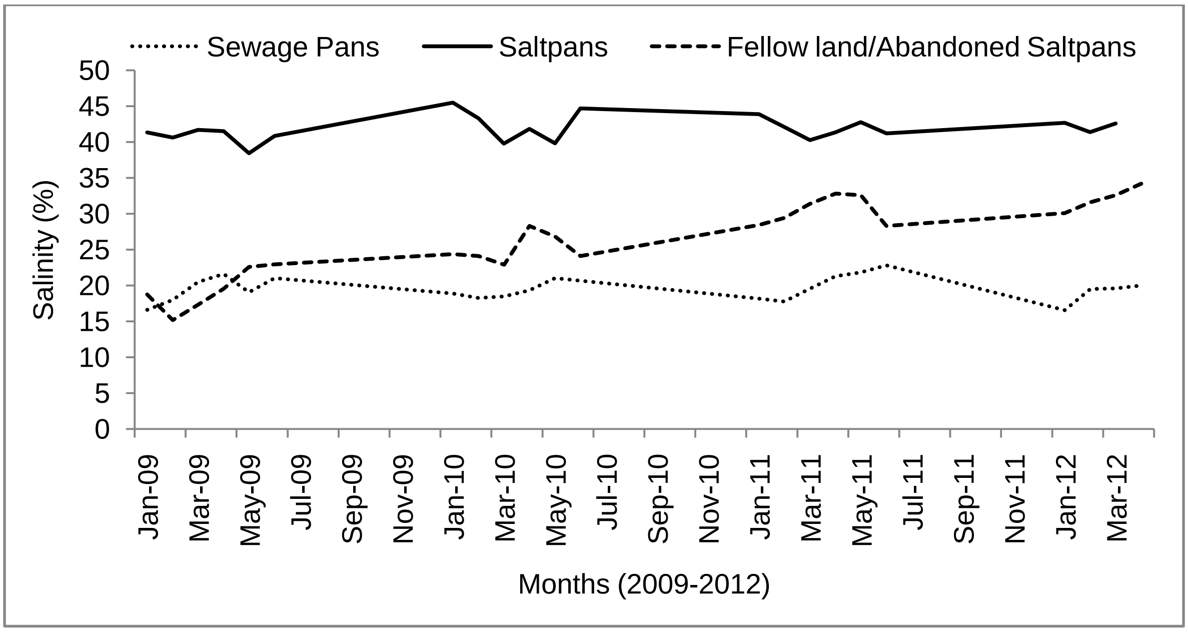

Fig 1: Salinity in three different habitat types in Kumbharwada site across the study period

The average salinity in the sewage ponds was 19.5 % (minimum 16.6% and maximum 22.8, SD = 1.7) while the salinity in Abandoned saltpans was 27.7% (minimum 21.3% and maximum 34.2, SD = 3.8). Highest salinity of 41.8% (minimum 38.5% and maximum 45.5, SD = 1.6) was observed in used saltpans (Fig. 2).

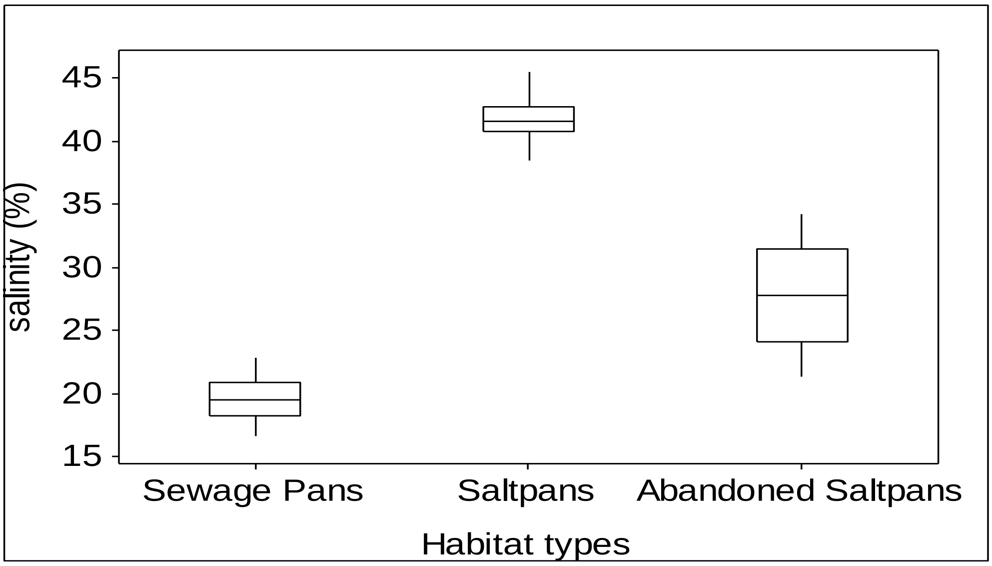

Fig 2: Boxplot diagram for salinity across different habitat types at Kumbharwada site

Salinity and Lesser Flamingos in Kumbharwada

Flamingos showed negative correlation with salinity in Sewage ponds and abandoned salt pans (r = -0.63, p=0.012).Used saltpans were not considered for salinity correlation as this habitat was mainly used for resting only during early morning (Fig. 3) (Plate 1 C).

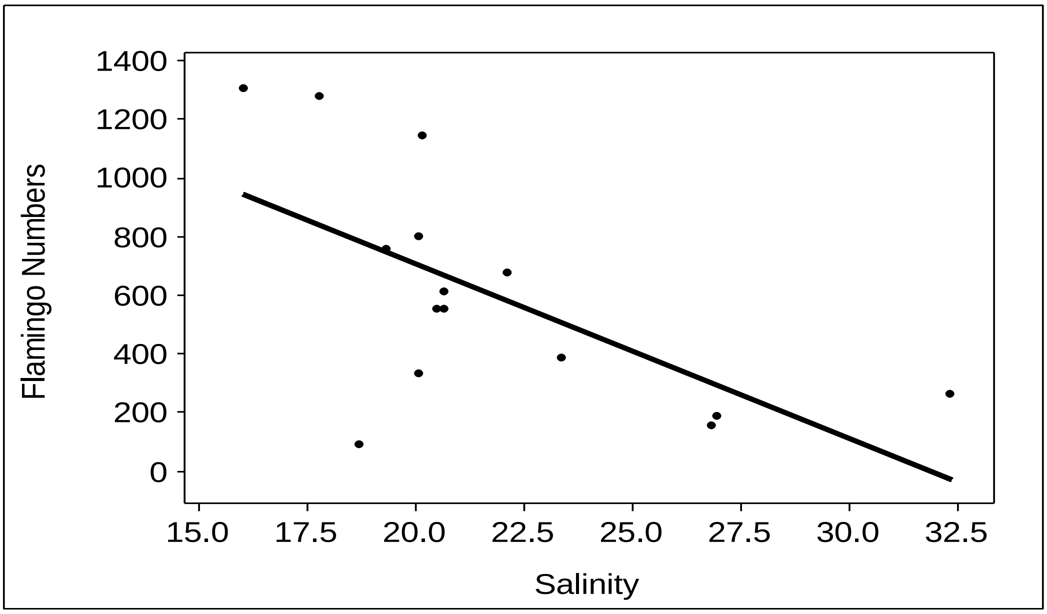

Fig 3: Scatter plot diagram to showing correlation between salinity and Flamingo population at Kumbharwada site

Newport site

Salinity at different habitats at Newport site was comparatively higher compared to Kumbharwada site due to its proximity to Gulf of Khambhat. The habitat at Newport saltpans was classified into used saltpans, abandoned saltpans and mudflats. The salinity in used saltpans ranged from 37.7 (May 2009) % to 44.0% (June 2010), in Abandoned saltpans, it ranged from 18.1% (Feb 2009) to 33.9% (June 2011) and in mudflats it ranged from 31.1% (January 2009) to 37.0% (June 2011) (Fig. 4). The mean salinity at Newport site was 34.3% ± 2.7 (SD) (Table 2).

Table 2: Salinity at three different habitat types at Newport site

	Salinity at Newport site					
Year	**Used Saltpans (%)**	**Range**	**Abandoned saltpans (%)**	**Range**	**Mudflats (%)**	**Range**
2009	40.0	37.7- 40.8	22.3	20.2 - 25.8	34.1	32.3 - 36.4
2010	42.3	40.3 - 44.0	28.0	27.0 - 31.2	33.1	31.1 - 35.3
2011	41.2	40.5 - 43.2	31.6	29.8 - 33.9	35.3	32.4 - 36.4
2012	41.6	40.1 - 42.8	32.7	31.2 - 33.0	32.3	31.8 - 32.8

Unlike Kumbharwada site, not much variation among different habitat types was observed at Newport site. Abandoned Saltpans were least saline as compared to mudflats and used saltpans. The average salinity in the abandoned saltpans was 27.9 % (minimum 18.1% and maximum 33.9, SD = 4.5) while the salinity in mudflats was 33.9% (minimum 31.1% and maximum 37.0, SD = 1.9). The highest salinity was recorded in used saltpans 41.2% (minimum 37.7% and maximum 44.0%, SD = 1.5) (Table 2) (Fig 4 & 5).

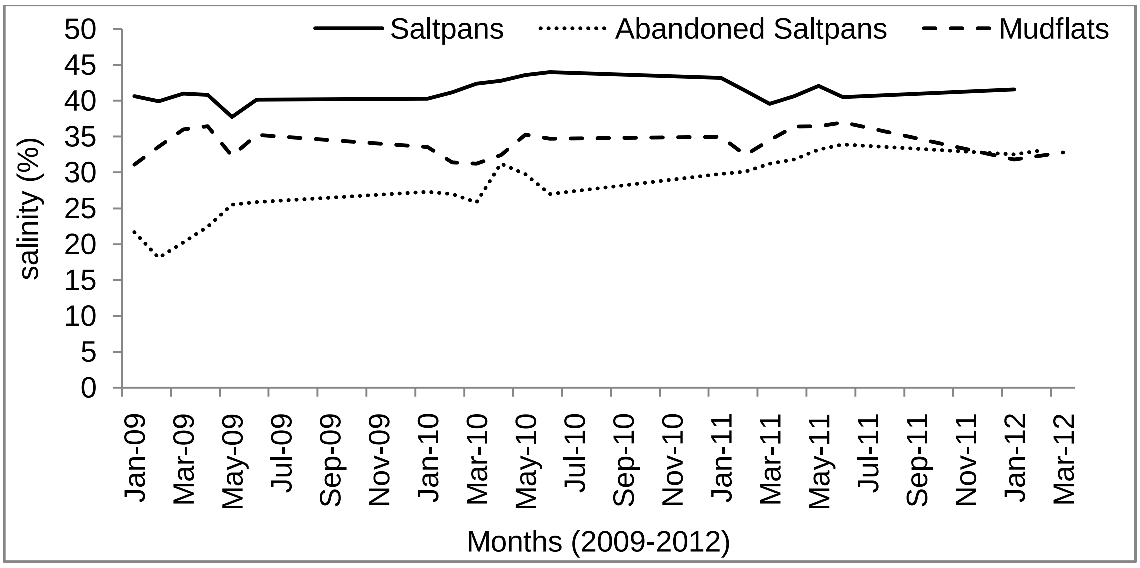

Fig 4: Salinity in three different habitat types in Kumbharwada site across the study period

Salinity and Lesser Flamingos at Newport site

It was observed that salinity at both Kumbharwada and Newport site was highest during pre-monsoon period (May-June) and was lowest during monsoon months (August-September). Lowest salinity was recorded during the monsoonal months (i.e. August-October) was mainly due to mixing of monsoonal rains with the saline water. The comparatively high values of salinity at the Newport site in comparison of Kumbharwada site during summer season suggested the combined effect of seepage from the saltpans surrounding the study location and the higher rate of evaporation at the shallow mudflats of creek region.

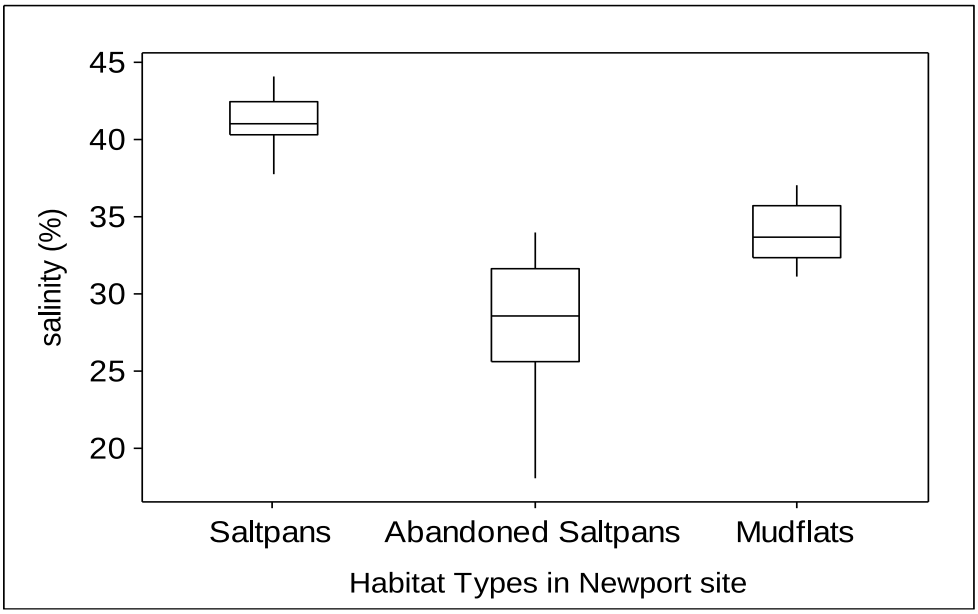

Fig 5: Boxplot diagram for salinity across different habitat types at Newport site

Flamingos did not show significant correlation with salinity at Newport site (r = -0.041, p=0.91). This is mainly because of the insignificant differences in salinity among various habitat types at Newport site. Also, the flamingos were more prone to anthropogenic activities during the later part of the study which has influenced the overall distribution pattern (r value) of flamingos in relation to salinity (Fig. 6).

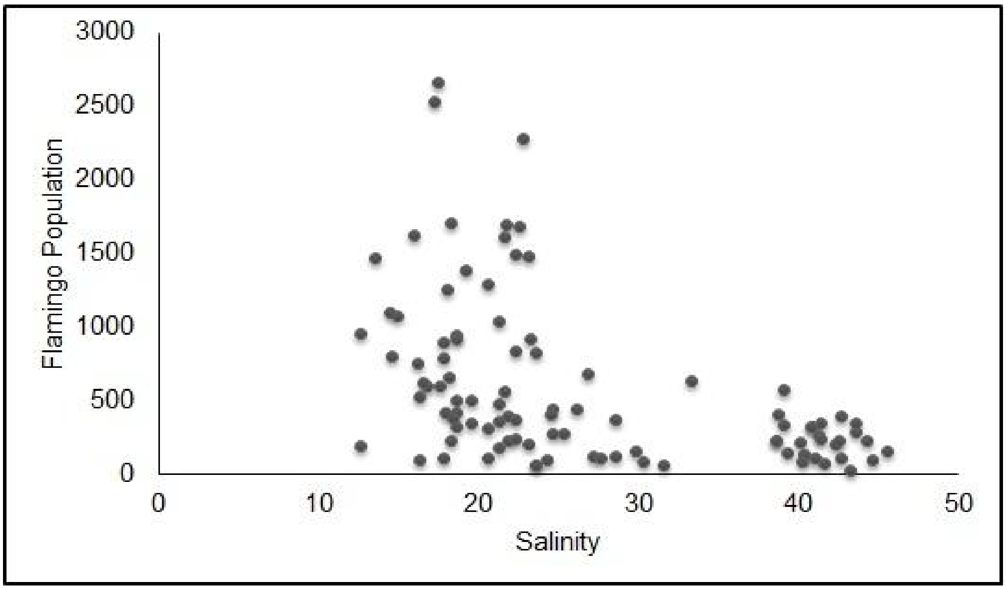

Fig 6: Scatter plot diagram showing correlation between salinity and Flamingo population at Newport site

However the flamingos were not recorded from the study area during the lowest salinity level as this was also the breeding period of the species and thus migrates to its breeding grounds in Little or Great Rann of Kachchh.

Dissolved Oxygen (DO)

The amount of dissolved oxygen often determines the number and types of organisms living in that body of water. Decay of organic material in water caused by either chemical processes or microbial action on untreated sewage or dead vegetation can severely reduce dissolved oxygen concentration.

DO at Kumbharwada Site

Kumbharwada being a polluted site, with loads of anthropogenic activities, the levels of Dissolved Oxygen was low compared to other such freshwater wetlands. The mean DO in Sewage ponds was 4.1 ± 0.4 (minimum 3.4 mg/lit and maximum 5.4 mg/lit). In Used saltpans habitat it was 3.7± 0.8 (minimum 2.4 mg/lit and maximum 5.1 mg/lit) and in Abandoned saltpans it was 4.8± 0.5 (minimum 3.9 mg/lit and maximum 6.1 mg/lit). The overall mean value of DO for Kumbharwada site was 4.2 mg/lit (Fig. 7).

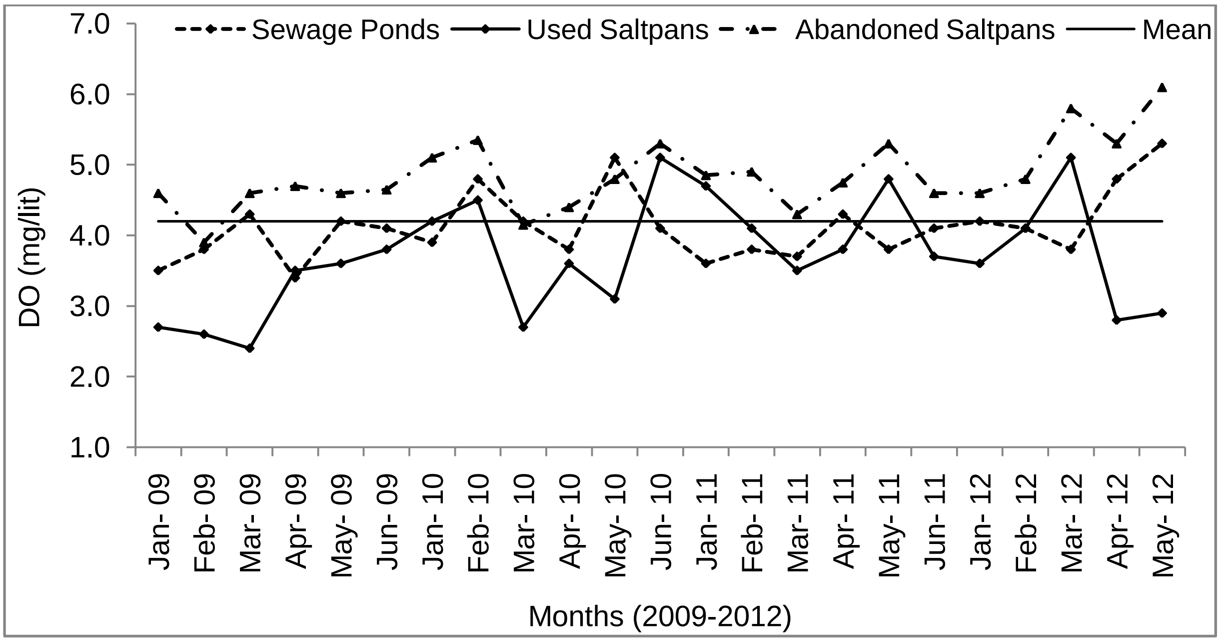

Fig.7: Variation in Dissolved Oxygen (DO) level in three different habitat types at Kumbharwada site

DO at Newport Site

Newport site being comparatively less polluted, the levels of Dissolved Oxygen were at par with other such coastal habitats. Mudflats at Newport site showed the highest DO levels across all habitat types in both Kumbharwada and Newport site.

The mean DO in Used saltpans habitat was 3.9 ± 0.6 (minimum 2.9 mg/lit and maximum 5.1 mg/lit). In Abandoned saltpans it was 4.8± 0.5 (minimum 3.8 mg/lit and maximum 5.7 mg/lit) and in coastal mudflats it was 5.6 ± 0.4 (minimum 4.7 mg/lit and maximum 6.3 mg/lit). The overall mean value of DO for Kumbharwada site was 4.8 mg/lit which was comparatively higher at Newport site (Fig. 8).

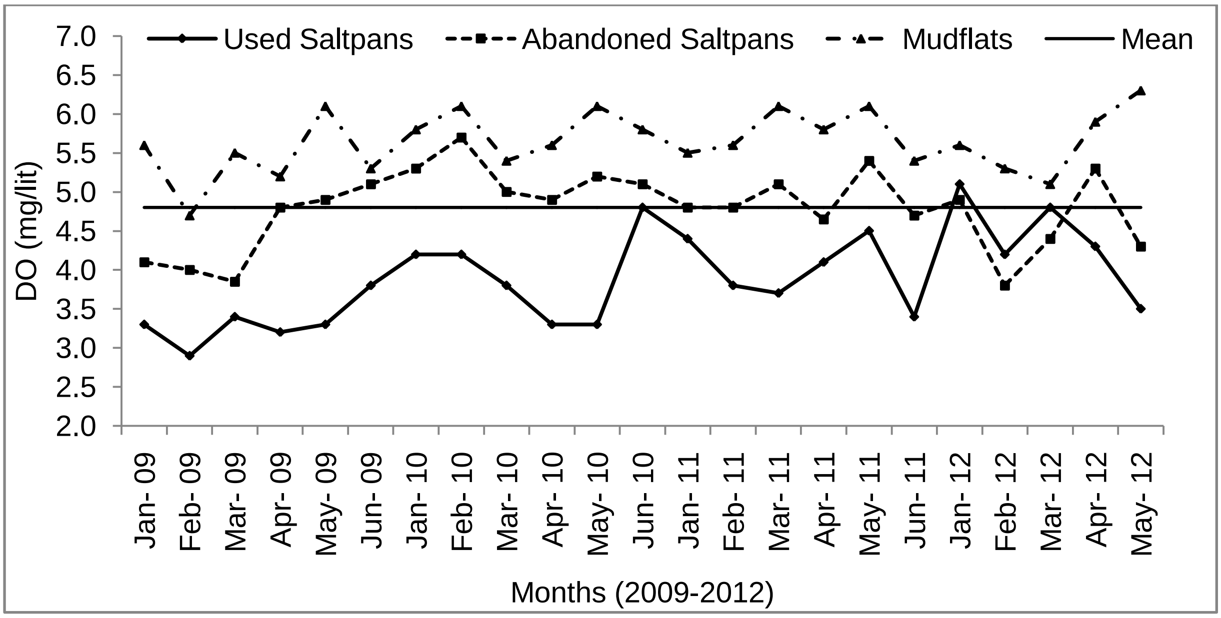

Fig.8: Variation in Dissolved Oxygen (DO) level in three different habitat types at Newport site

Flamingo numbers and Dissolved Oxygen

As general rule of thumb, DO levels in water body correlates with amount of Chlorophyll-a which results from phytoplankton biomass, in a water body when amount of phytoplankton increases, the amount of chlorophyll-a increases as well (Hardy 1973) and so does DO due to algal photosynthesis during daylight.

Moreover, DO concentration also depends on temperature and salinity (Weiss 1970). High temperature and salinity cause the oxygen to be relatively low (Ramberg 1987); higher the temperature, the lower the solubility of oxygen in seawater.

The DO values at sewage ponds habitat at Kumbharwada site, showed slightly positive correlation with flamingo numbers (r =0.48, p<0001). However, a weak correlation was observed in abandoned saltpan habitats (r = 0.032, p<0001). Used saltpans were mainly used for resting and self maintenance activities only and also these habitats showed depleted levels of DO (x̄=3.7 ± 0.8) which did not show correlations with flamingo numbers (Fig.9).

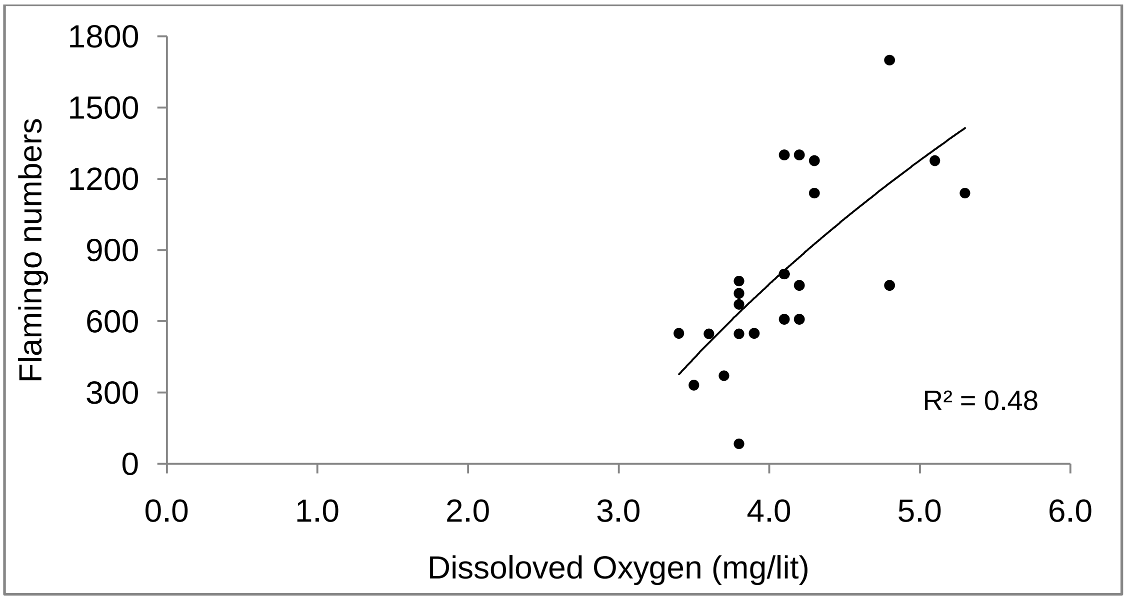

Fig.9: Scatter plot diagram showing correlation between Dissolved Oxygen (DO) level and Flamingo population in sewage ponds

Newport site being highly saline, the levels of dissolved oxygen were comparatively lower than Kumbharwada site. However, in abandoned saltpans habitat of Newport site, a moderate positive correlation was observed between flamingo population and DO levels (r = 0.43, p<0.001) (Fig.10).

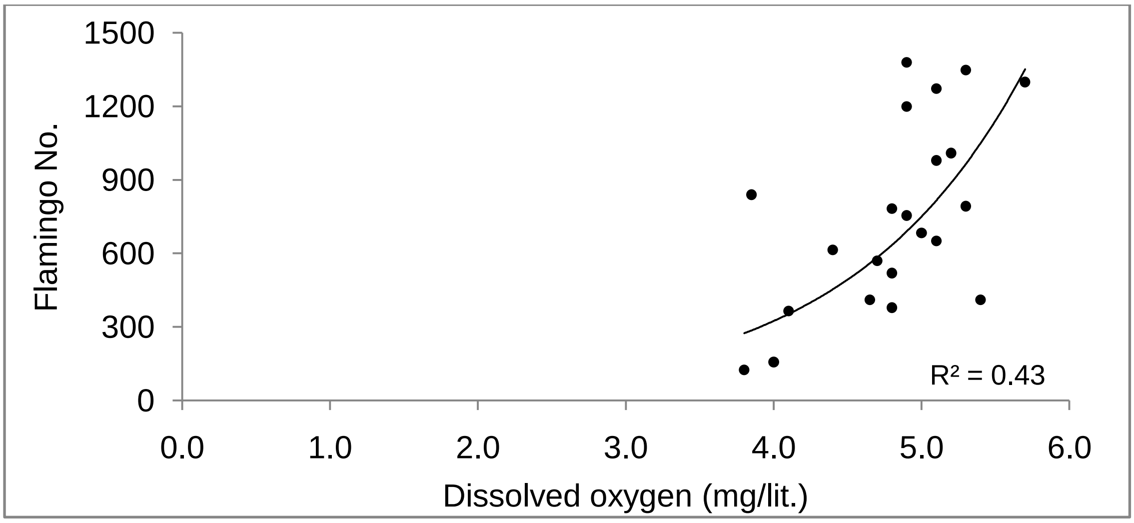

Fig.10: Scatter plot diagram showing correlation between Dissolved Oxygen (DO) level and Flamingo population in sewage ponds

Slight negative correlation (r = -0.13, p<0.001) was observed in used saltpans in Newport site which was mainly due to intensive salt production activities in adjoining areas which influenced the overall correlation between flamingo numbers and Dissolved oxygen levels.

pH

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.)

Kumbharwada site

The pH did not vary across the months and among different years in Kumbharwada site. In sewage ponds the pH ranged from 7.3 to 8.8 (mean= 8.3 ± 0.4). In used saltpans habitat it was 7.6 ± 0.4 (minimum 6.9 and maximum 8.7) and in Abandoned saltpans it was 7.9± 0.3 (minimum 7.2 and maximum 8.4). The overall mean value of pH for all sites of Kumbharwada was 7.9 mg/lit (Fig. 11).

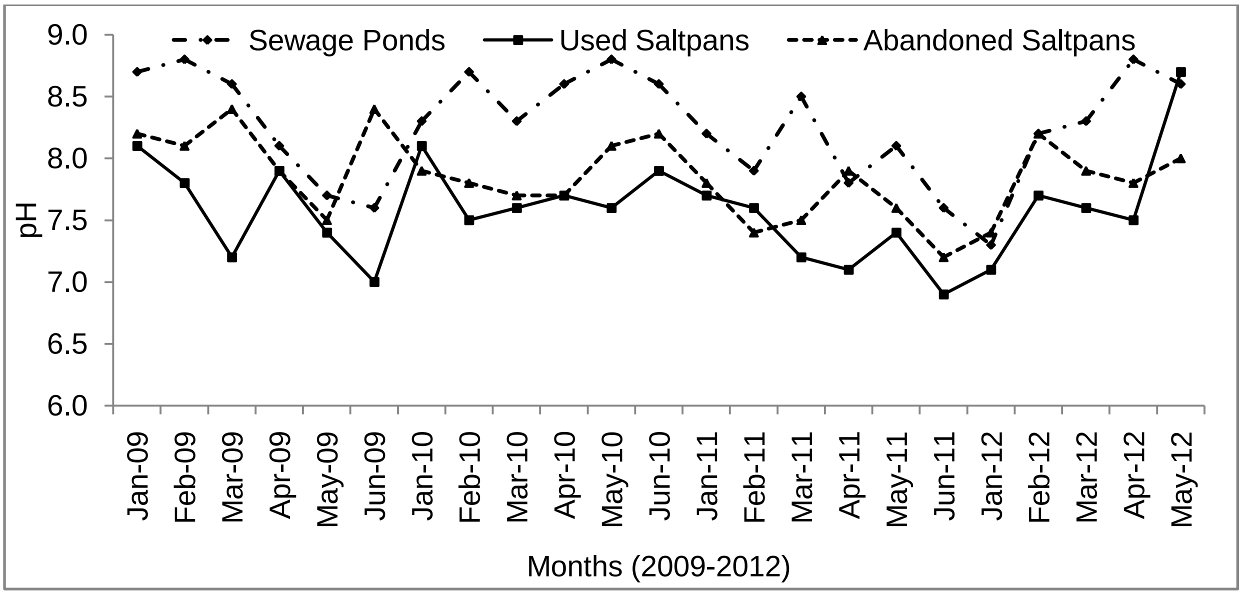

Fig 11: pH in three different habitat types at Kumbharwada site

Newport Site

Moderately low values of pH were observed at Newport site as compared to Kumbharwada site. In Newport site, the mean pH in used saltpan habitat was 7.7 ± 0.4 (min 7.1 and max 8.5). In abandoned saltpans, the pH was 8.0 ± 0.2 (min 7.6 and max 8.4) and in the mudflats the ph ranged from 7.2 - 8.2 (mean = 7.8 ± 0.3) (Fig. 12).

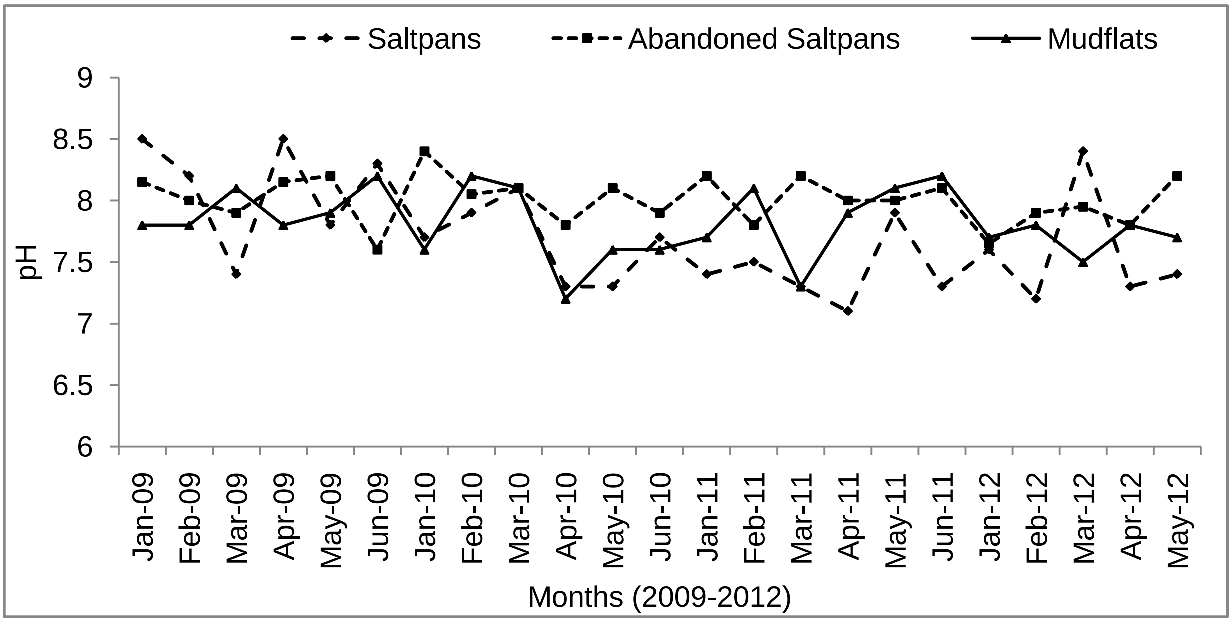

Fig 12: pH in three different habitat types at Newport site

Flamingo Population and pH

The pH at both Kumbharwada and Newport site was fairly constant, showing very small fluctuations (Fig. 11 & 12). The pH did not show any significant correlation with flamingo numbers at either of the sites.

Vegetation

The habitats used by the Flamingos in Gulf of Khambhat were mainly coastal and saline consisting of saltpans, abandoned saltpans and mudflats. Owing to the proximity to the sea and saline nature of ground water, the area does not support much of the floral diversity. Seven species of shrubs and grasses were recorded from the study area (both Kumbharwada and Newport Saltpans) (Table 3). The Newport saltpans had only sparse outgrowth of *Prosopis juliflora* (on the edges and bunds of saltpans) and *Avicenia marina* (mangrove species) as the area is very close to the gulf and is highly exploited by salt manufacturers. However, on the other side, i.e. Kumbharwada area showed comparatively higher diversity of plant/herb/shrubs. Hence, the study of effect of vegetation growth on flamingo's habitat selection was restricted to Kumbharwada site only.

Table 3: Plant species recorded from study area

Sr. No.	Plant species
1	*Cenchrus setugerus*
2	*Capparis decidua*
3	*salvadora persica*
4	*Zizyphus numularia*
5	*Prosopis juliflora*
6	*Porteresia coarctata*
7	*Portersia coarctata*

Two species of coastal grass viz. *Porteresia coarctata* and *Aeluropus lagopoides* were the dominant and abundant species in Kumbharwada area. The *Portersia coarctata* was the most dominant grass species in the sewage pond habitat of the study area and affected more than 59.7% of the feeding areas of Lesser Flamingos and was present amongst the feeding pools/puddles of Lesser Flamingos. The *Aeluropus lagopoides* was less dominant and its height varied from 11 cm to 34 cm (average 22.3 ± 5.15 cm). This species was present in the waste land area in the Kumbharwada site which was seldom used by flamingos (Table 4) (Fig. 13).

Table 4: Year wise change in % of *Porteresia coarctata* grass cover at Kumbharwada site (2009-2012)

Year	n	% Grass cover	Std. Dev	Min	Max
2009	45	42.13	9.20	28	68
2010	45	48.89	8.69	32	72
2011	45	54.84	7.93	40	76
2012	45	59.11	7.76	48	76

Vegetation (i.e. grass) cover was measured (every year) in KWSP1 and KWSP2. Vegetation cover was calculated by estimating percentage of bare land (visible earth) within 1m X 1m quadrats within Sewage Ponds habitat type (15 quadrates per habitat). The quadrates were laid every 20 meters and were marked with GPS so as to use the same sampling points every year.

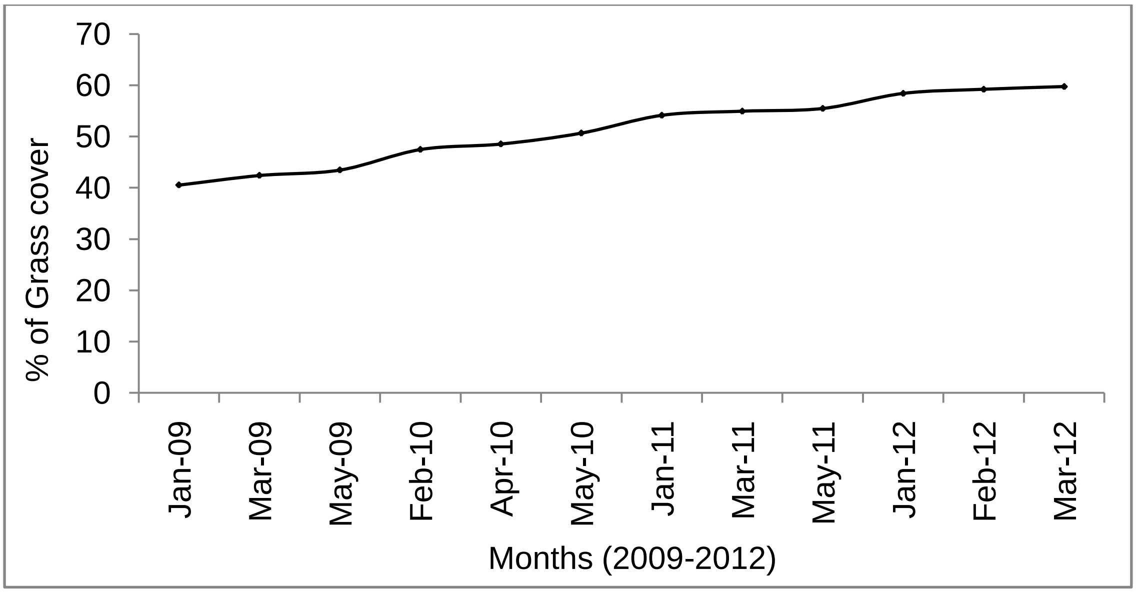

Fig 13: Percentage of grass cover in Sewage pond habitat of Kumbharwada site

Portersia coarctata

The grass *Portersia coarctata* is a salinity indicator species and was most dominant species recorded in Kumbharwada (Plate 3 A). In 2009, 42.13% ± 9.20 quadrate area was observed to be covered with grass and 57.87% was bare earth (Minimum 28% and maximum 68%). In 2010 the percentage of grass cover increased by 6.7% and 48.89 % ± 8.69 quadrate area was observed to be covered with grass (Minimum 32% and maximum 72%). Similar trend in increase was also recorded in year 2011 with percentage of grass cover increasing upto 54.84% ± 7.93 (Minimum 40% and maximum 76%). In 2012 59.11% ± 7.76 of earth was covered with grass and 40.89% was bare earth (Plate 2B, 4B).

The present trend in increase in grass cover in sewage ponds habitat of the Kumbharwada shows the decrease in the open water habitat for flamingos to feed in the sewage pond habitat (r^2=0.99, p=0.005) (Fig. 14).

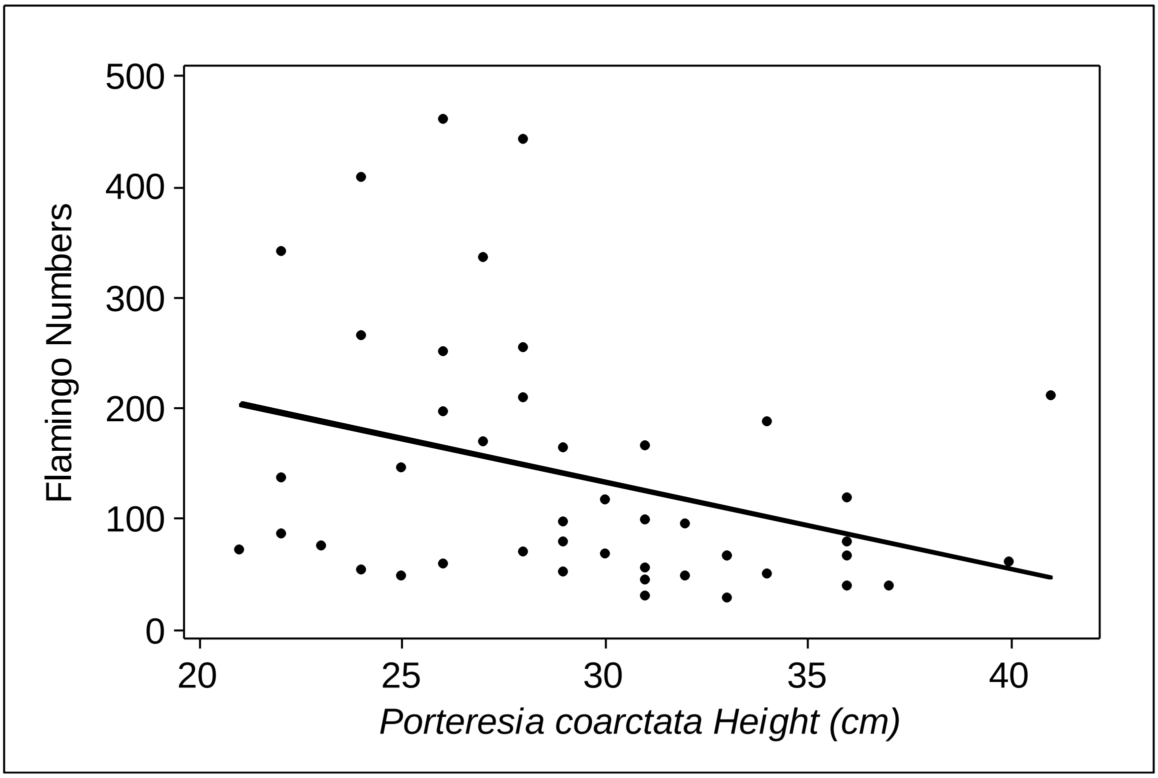

Fig 14: Scattered plot matrix for grass height and Flamingo numbers in Sewage pond habitat of Kumbharwada site

Aeluropus lagopoides

Also, *Aeluropus lagopoides* has occupied open water pools in the KWSP2 and was other dominant species in Kumbharwada site (Plate 3 B). In 2009, 51.3% ± 6.20 quadrate area was observed to be covered with grass and 48.7% was bare earth (Minimum 28% and maximum 64%). In 2010 the percentage of grass cover increased by 5.7% and 57.0 % ± 6.8 quadrate area was observed to be covered with grass (Minimum 36% and maximum 70%). Similar trend in increase was also recorded in year 2011 and in 2012 percentage grass cover increased up to 67.5% (Minimum 52% and maximum 78%) in 2012 (Fig. 15).

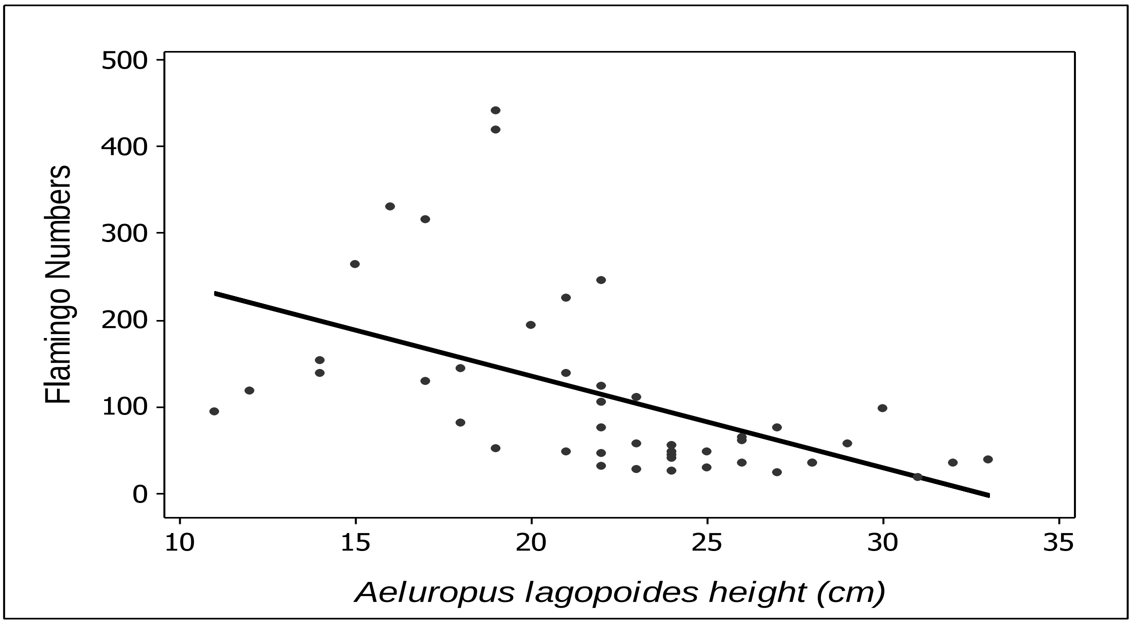

Fig 15: Scatter plot diagram for *Aeluropus lagopoides* height vs flamingo numbers

It was observed that feeding activity of the flamingos was significantly affected by *Porteresia coarctata* height and density. The height of *Porteresia coarctata* varied from 21 cm to 41 cm in the study area with an average of 29.46 ± 4.89 cm. The flamingos preferred puddles with grasses that had average height of 25-30 cm and avoided the places with tall grass patches. The reason could be the tall grasses species may be hindering bird's vision and thus ultimately would not allow flamingos to see its predators while feeding (Plate 2 A).

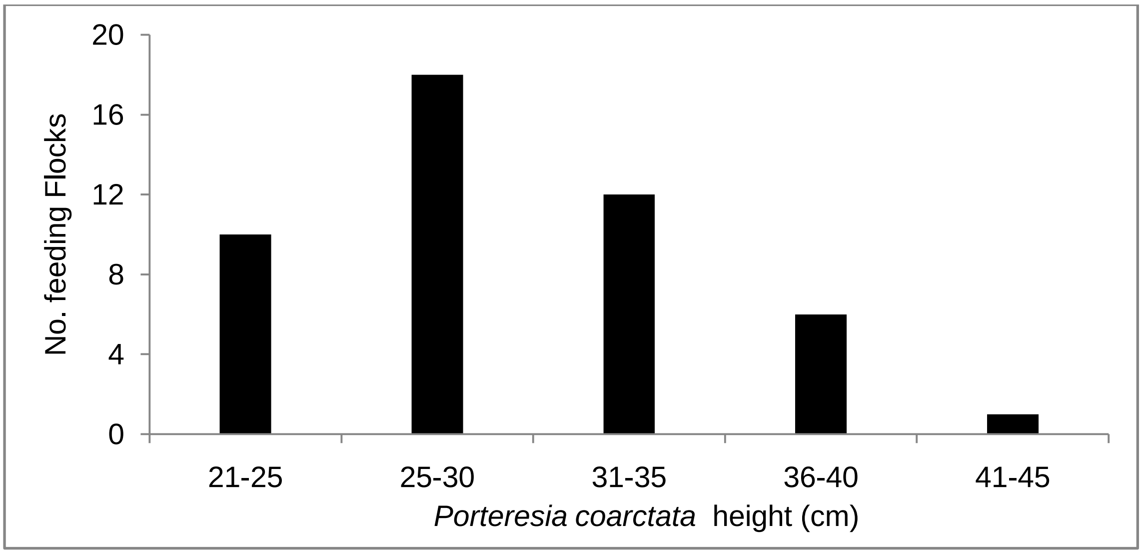

Fig 16: Height of P. coarctata and Number of feeding flocks of Flamingo

The result shows that areas (devoid of grass) with less tall *Porteresia coarctata* were preferred to areas with more grass height. 18 foraging flocks were recorded in areas where grass height was between 25 and 30 cm and 10 foraging flocks were observed at average grass height of 21-25 cm (Fig. 15). The grass height had a slightly significant affect on the foraging behavior of flamingos, however a very low (weak) negative correlation ($r = -034$, $p=0.02$) was observed between grass height and number of foraging flocks of flamingos (Plate 2 C).

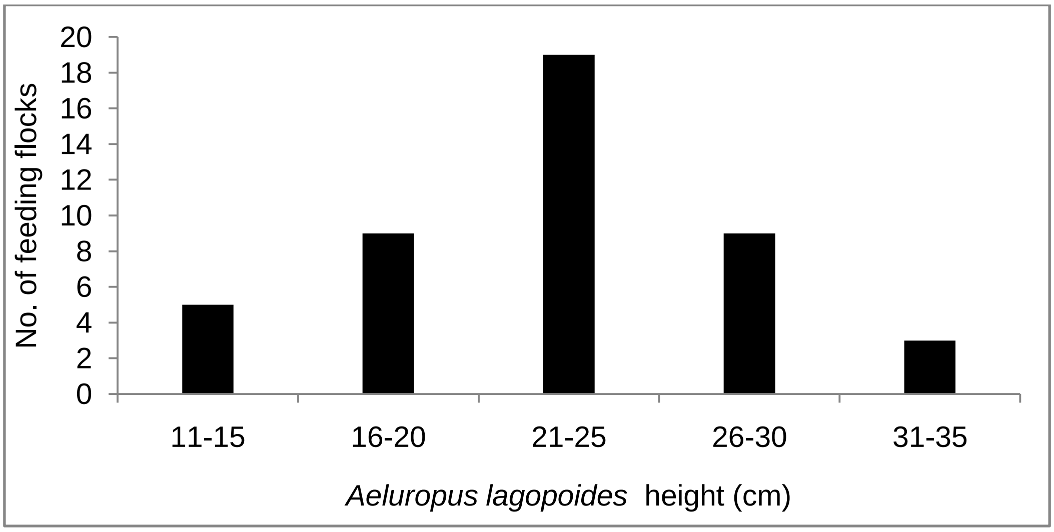

Fig:17: Height of *A. lagopoides* and Number of feeding flocks of Flamingo

Similarly, *Aeluropus lagopoides* in KWSP2 also affected the feeding activity of flamingos. Flamingos preferred areas with moderate grass height of 21-25 cm where, 19 feeding flocks were recorded. Similarly, 9 flocks were recorded at grass height of 16-20 cm (Fig. 16). Only 3 flocks were recorded feeding at grass height exceeding 30 cm. thus showing clear avoidance towards more grassy patches. The grass height was negatively affected the feeding flocks of flamingos ($r = -0.52$, $p=0.001$) (Plate 4B, 4C).

As the Newport site did not support any such vegetative outgrowths, no such correlation was calculated for Newport site.

One explanation for the difference in use of the short and long grass plots is that it is due to perceived predation risk. Flamingos are likely to rely on visual cues to detect predators, whether such detection is direct or, as in the case of individuals responding to flock departures signifying danger (Lima & Dill, 1990).

Water level

Water level plays a significant role in affecting the waterfowl population in areas where the water level flactuations are very frequent. Daily, seasonal and annual variations in water levels and flow drive important ecological processes that maintain a diversity of wetlands and associated biodiversity (Keough et al., 1999; Weller, 1999; Keddy, 2002).

In Kumbharawada area, water level depends on the i) rainfall received during the monsoon, ii) the industrial run-offs from the Chitra GIDC (Bhavnagar Industrial Area) and iii) partly from the excessive water released by salt manufacturing units in the surrounding area. During the initial study period, seasonal water level fluctuations were less variable due to constant supply of waste water from the industrial area (2009-2010), but during the later part of the study (February 2011- May 2012) due to the diversion of waste water from the industrial area to some other areas, there were significant alterations in the average water level at the Kumbharwada site (Plate 1A, 4A).

The water depth/water level in Kumbharwada ranged from 5 cm to 40 cm in all the different habitats from January to May. Though, highest water level was recorded in the monsoon (> 50 cm); flamingos were absent from the study area during this period as it was the breeding season of the species.

The water level fluctuations were more visible in abandoned saltpans and Sewage ponds as compared to used saltpans. The mean water level in sewage ponds 25.7 ± 3.1 cm (range 19 cm - 33 cm) and in abandoned saltpans during flamingo's extensive use of these habitats ranged from 6 cm to 22 cm (12.9 cm ± 4.2). The water level fluctuations were more prominent in Abandoned saltpan habitat showing wider range (6 cm - 22 cm). Used saltpans did not show much water level fluctuations as they were used for salt manufacturing throughout the study period. The mean water level in used saltpan habitat was 29.5 cm ± 3.4 (range 24-37 cm) (Fig.17).

Newport site

The water depth/water level in Newport site ranged from 9 cm to 35 cm in all the different habitats from January to May. Though, highest water level was recorded in the monsoon (> 45 cm); flamingos were absent from the study area during this period as it was the breeding season of the species (Plate 1 B).

The water level flux was more visible in abandoned saltpans. The mean water level in abandoned saltpans ranged from 10 cm to 24 cm (16.5 cm ± 3.6). In Mudflats it was 21.6 ± 2.4 cm (range 17 cm - 26 cm). Water level fluctuations were less in used saltpan habitat. The mean water level in used saltpan habitat at Newport site was 29.5 cm ± 2.2 (range 24 - 33 cm) (Fig.18).

Effect of Water Level on Flamingos

Flamingos preferred water level of about xx cm (stat value). However water level fluctuations did not have significant effect on its resting behavior.

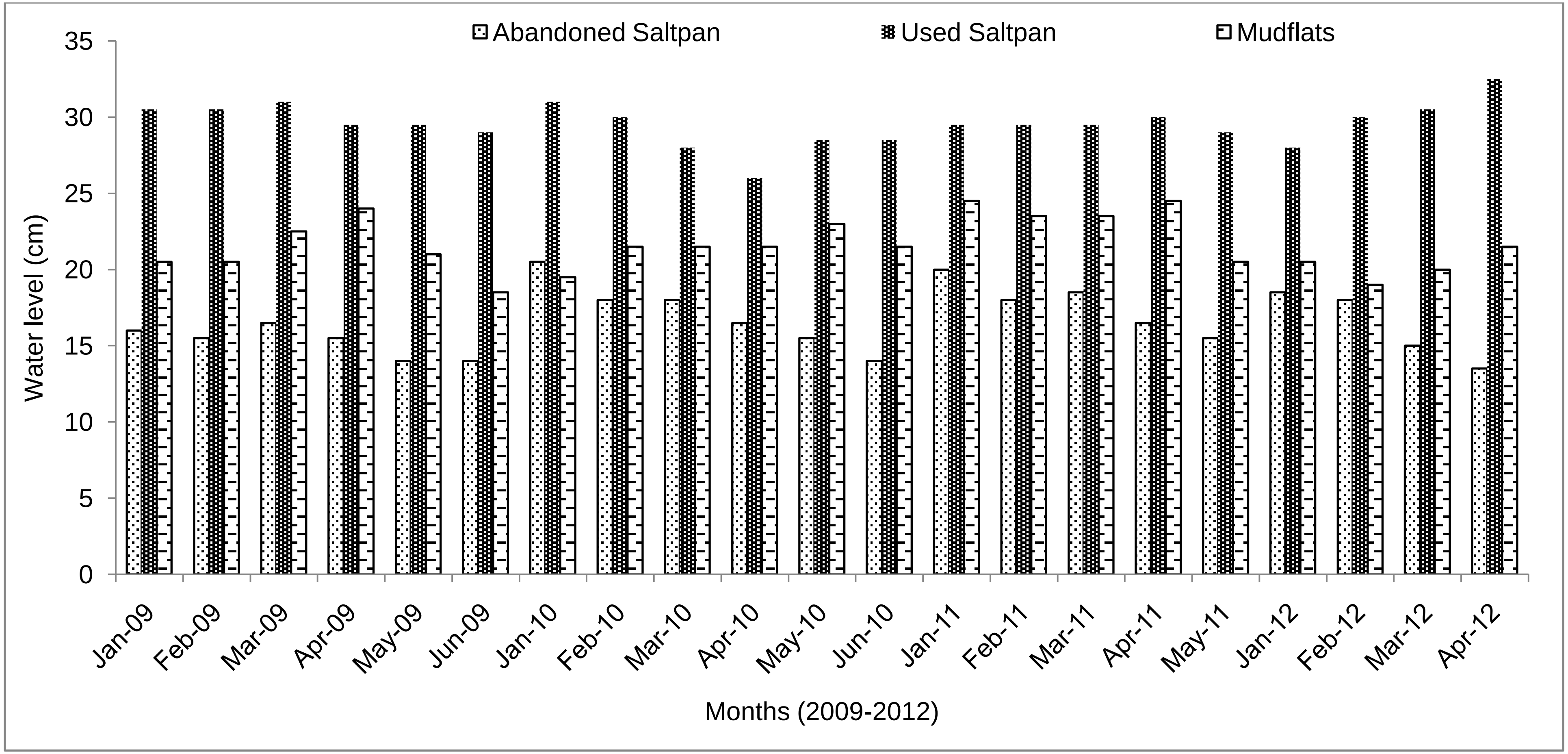

Fig.18: Water level at three sites in Newport site across the study period

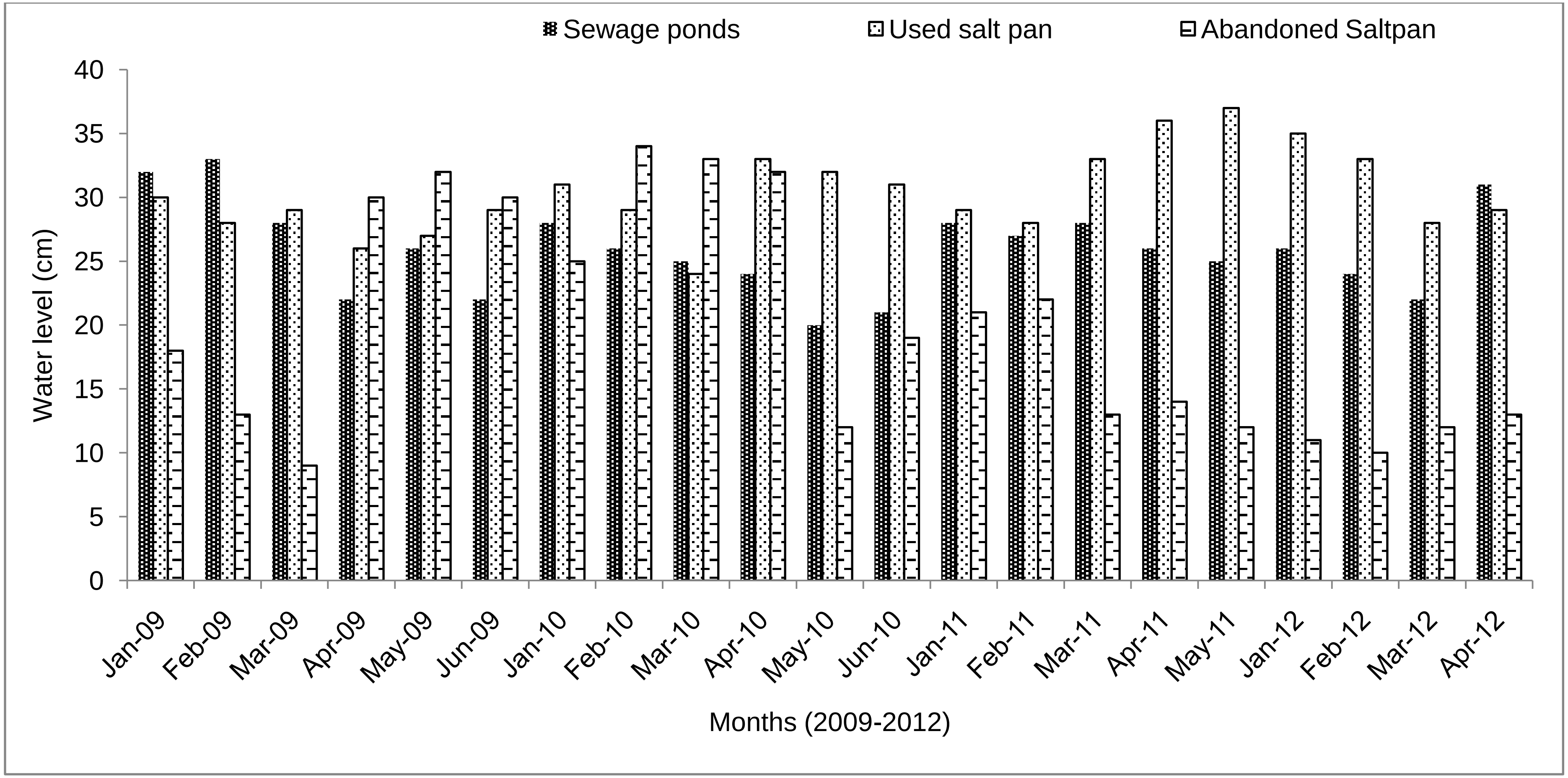

Fig.19: Water level at three sites in Kumbharwada site across the study period

In Kumbharwada site, water level fluctuations in Sewage Ponds showed a moderate positive correlation with flamingo numbers (R^2 = 0.56, p=0.05). Flamingos actively fed at water level between 20 cm – 30 cm (Fig 19).

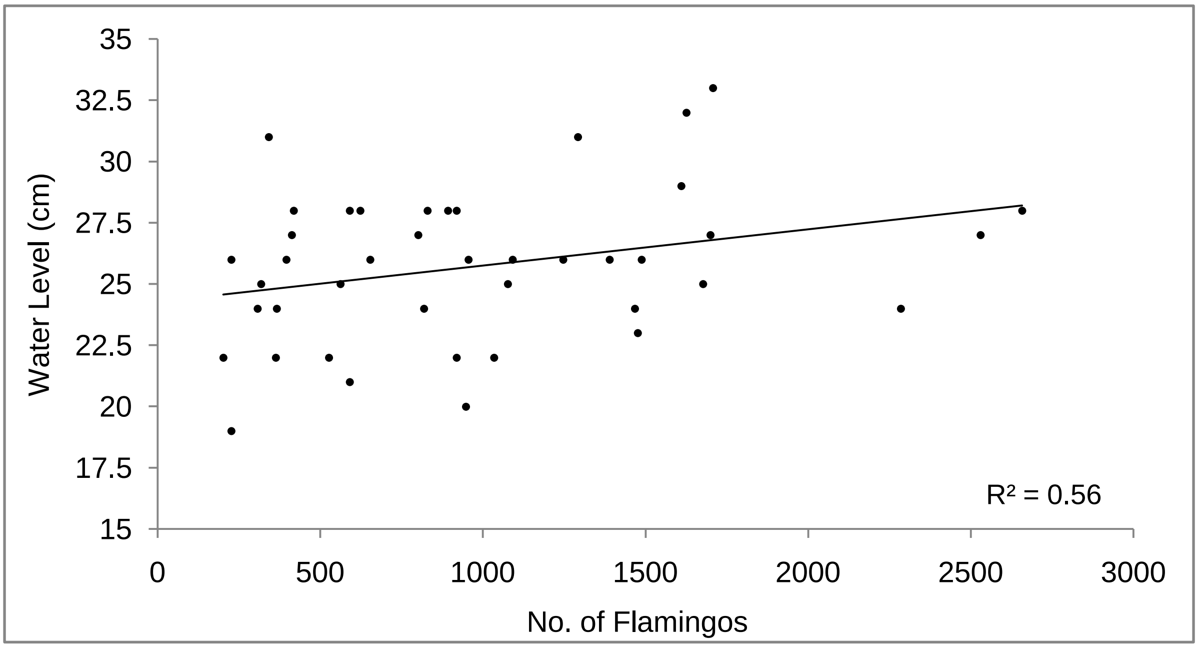

Fig. 20: Scatter plot diagram for water level vs flamingo numbers at Sewage pans habitat of Kumbharwada

In used saltpans and abandoned saltpans, flamingos showed moderate positive correlation with water level (r = 0.32, p=0.09) and (r = 0.48, p=0.01) respectively.

Flamingos at sewage ponds in Kumbharwada were observed more frequently in shallow water (51% of groups at water level 26-30 cm , 34% in water level 21-25 cm), whereas groups in used saltpans were distributed in water depths of about 26-30 cm (51% of birds). In Abandoned saltpans, 45% of flamingos were observed in water level 11-15 cm. Overall, at Kumbharwada site, flamingos fed at higher water levels in sewage ponds and low water levels in abandoned saltpans.

In Newport site, flamingos in abandoned saltpans preferred moderate water level and 50% of the flamingos were recorded at water level 16-20 cm. In used saltpans flamingos preferred 61% of flamingos were recorded in moderate water level of 26-30 cm. In Mudflats, flamingos were evenly distributed in respect of water level. 53% of flamingos were observed in moderate water level and 41% in low water level.

Water Temperature

Owing to the proximity to the sea and the prevalence of sea breeze in the coastal region the temperature fluctuations in the study area are not as intense as in other parts of the district. With the onset of the southwest monsoon by about the middle of the June the day temperatures decrease a little. After mid-September, day temperatures increases after mid-November both day and night temperature begin to decrease till January which is the coldest month. The period from March to May shows continuous rise in temperatures. May is the hottest month with temperature range of 40-43 ^{0}C is common.

The mean monthly water temperature at Kumbharwada site was 24.1 ^{0}C ± 2.3 (maximum 29.1^{o}C and minimum 21.3^{o}C). The water temperature at Kumbharwada site did not show much fluctuation during the study period. The mean monthly water temperature at Newport site was 25.7^{o}C ± 2.5 (maximum 29.9 ^{o}C and minimum 22.0^{o}C).

The effect of water temperature was negligible on the habitat selection of Lesser Flamingos at both Kumbharwada and New Port site. The visible effect was only noticed during the early morning hours of winters where flamingos spent comparatively longer time in resting and preening activities.

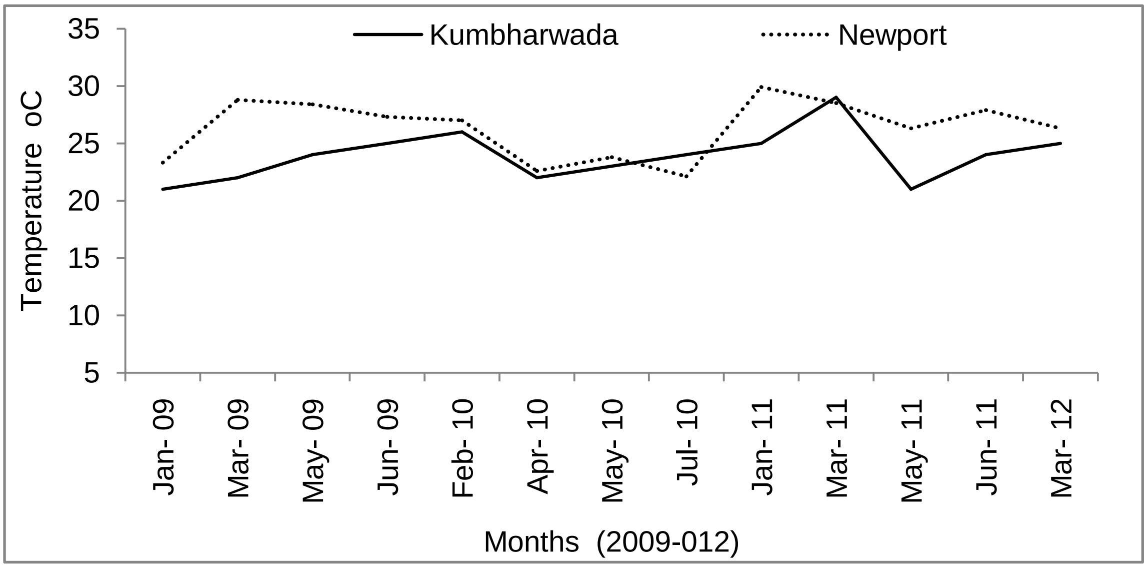

Fig. 21: Water temperature across the study period in Kumbharwada and Newport Saltpans area

Cluster Analysis for habitats

Different habitat characterstics viz. salinty, ph, DO were compared using cluster analysis of habitats to assess the level of similarity among different habitats of both Kumbharwada and Newport site.

Sr. No.	Habitat Types
1	Kumbharwada Sewage Pans
2	Kumbharwada Saltpans
3	Kumbharwada Abandoned Saltpans
4	Newport Saltpans
5	Newport Abandoned Saltpans
6	Newport Mudflats

Habitat types with serial numbers for Cluster Analysis

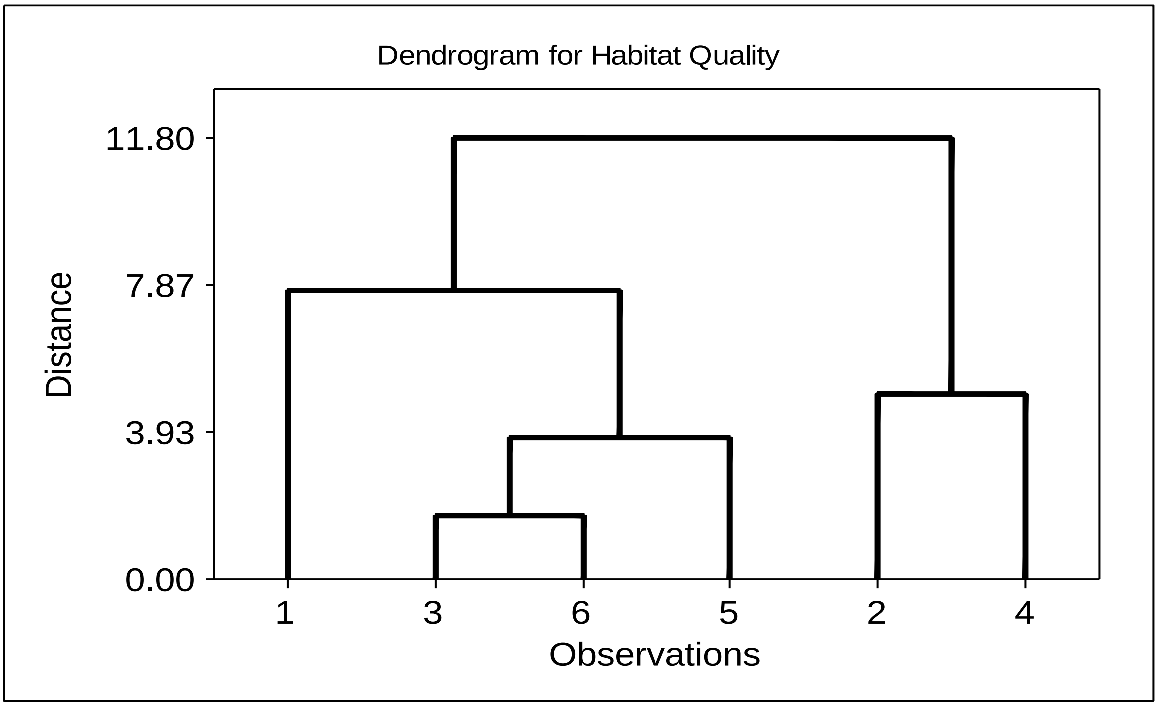

Fig 22: Results of Cluster Analysis of different habitat types in the study area.

Table: 5 Cluster Centroids

Variable	Cluster1	Cluster2
SALINITY	-0.548972	1.09794
pH	0.048346	-0.09669
DO --	0.481894	0.96379

It was observed that, based on the habit characterstics, Saltpans of Kumbharwada site and Saltpans of Newport site showed a high value of similarity, suggesting the similarity in salt production activities carried at both sites. Other similar habitats were Abandones salatpans of Kumbharwada site and Newport site which is interesting as Newport site being nearer to coast also has similar DO and pH values along with salinity (Fig. 21) (Table 5).

Habitat Preference study (Used and Available habitats)

Hall et al. (1997) defined "habitat use" as the way an animal uses (or consumes in a generic sense) a collection of physical and biological components (i.e., resources) in a habitat. Hall et al. (1997) defined "habitat availability "as how accessible and procurable physical and biological components of a habitat are to animals. This is in contrast to the abundance of these resources, which refers only to their quantity in the habitat, irrespective of the organisms present (Wiens, 1984).

It is often referred that, a species will select resources that maximize its fitness (i.e., survival, reproduction etc). Availability of various resources existing at a particular site to a species is not uniform in space or time and thus resources (habitat, food) are "selected" when they are used in higher proportion to their abundance. For Lesser flamingos in Kumbharwada and Newport site, attempt was made to study habitat availability and use by Lesser Flamingo during the study period.

Kumbharwada site

Habitat preference study was carried out at both the sites to know if the species shows preference towards particular habitat. The distribution pattern of flamingos was compared with the percentage of area available to the flamingos for its various diurnal activities.

Of the seven different types of habitat, Sewage pans (1, 2 and 3) covered about 64.8% of the total habitat available to the flamingos, abandoned saltpans (1 and 2) covered about 10.3% of the available habitat and used saltpans (1 and 2) covered 24.8% of the total habitat under study.

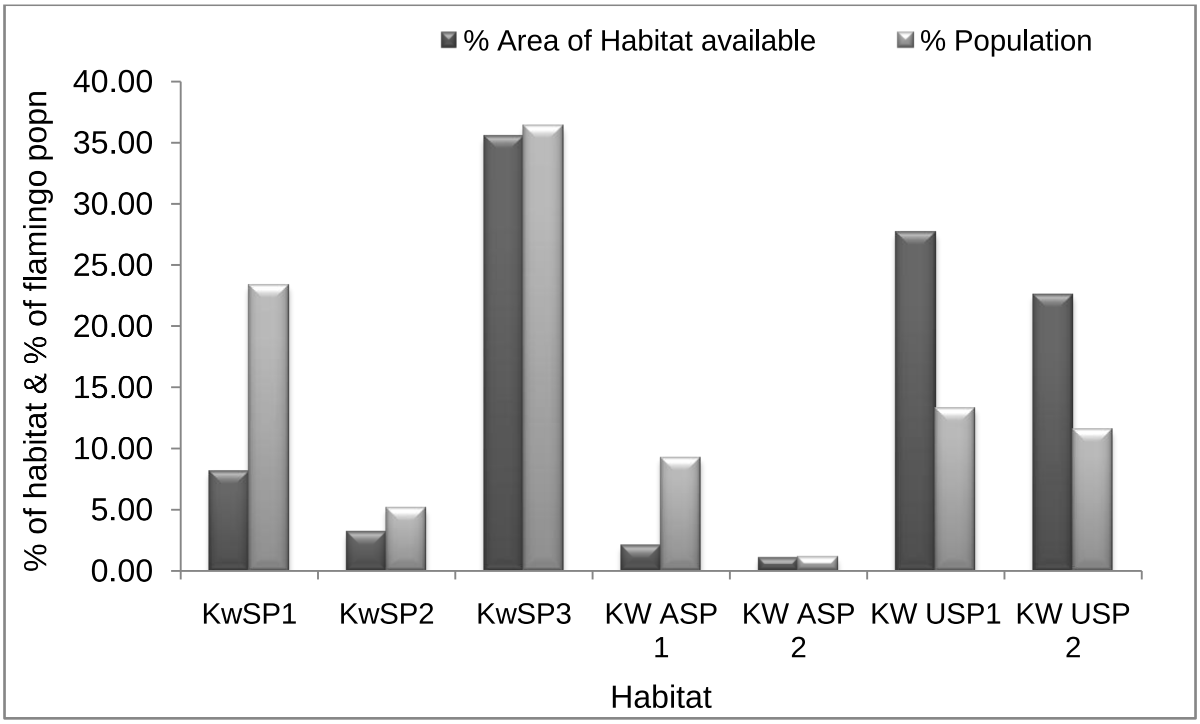

Fig 23: Proportion of available and used habitat by Lesser Flamingos in Kumbharwada

Flamingo population was evenly distributed with different habitat. It was observed that, Sewage pond 1 was used by 23.4% of the Lesser flamingos during the entire study period despite its spread of 8.1% of the total habitat. This showed preference for Sewage pond 1by Lesser Flamingos. This was followed by Sewage ponds 2 and 3 which were occupied by 5.1% and 36.4% of flamingo population respectively despite their spread of 3.1% and 35.5% respectively. Abandoned saltpan 1 was also used more irrespective of its extent, 9.2% of flamingos used this habitat despite its spread of only 2.03%, suggesting preference towards this habitat by the species. Used saltpans 1 and 2 were the least preferred habitat in Kumbharwada site as only 13.3% and 11.5% flamingos respectively used this habitat even with its spread of 27.6% and 22.5% of the total available habitat to the Lesser Flamingo (Fig 22).

Habitat selection was further analyzed by the use of the Savage selectivity Index, wi = Ui/pi (Tella and Forero, 2000). Ui is the proportion of observations in a given habitat and pi is the proportion of that habitat against the total available area. A Savage selectivity reading of 0 is the maximum negative selection; it has not been selected at all. An index value of 1 means there is no habitat selection (Table 5)

Table 5: Savage Index value (Wi) for each habitat type in the Kumbharwada site

Habitat Types	% Area of Habitat available	% Population	Savage Index (Wi)
KwSP1	8.13	23.36	**2.875**
KwSP2	3.15	5.11	1.624
KwSP3	35.49	36.37	1.025
KW ASP 1	2.03	9.22	**4.537**
KW ASP 2	1.02	1.09	1.071
KW USP1	27.63	13.31	0.482
KW USP 2	22.55	11.54	0.512

The value for Wi for Kumbharwada Sewage pans 1 (Wi= 2.875 > 1) and Abandoned saltpans 2 (Wi= 4.5 > 1) and these values are also greater than calculated Bi (0.14) thus, it can be inferred that, sewage pans and Abandoned saltpans are the habitats selected by the species. The Wi values (or Savage selectivity value) near 0 indicates maximum negative selection by the species and an index value of 1 means there is no habitat selection by the species (table 5).

Newport Saltpans

Of the six different types of habitat at Newport site, used saltpans (1 and 2) covered about 40.0% of the total habitat available to the flamingos, abandoned saltpans covered about 29.4% of the available habitat and mudflats covered 30.6% of the total habitat under study.

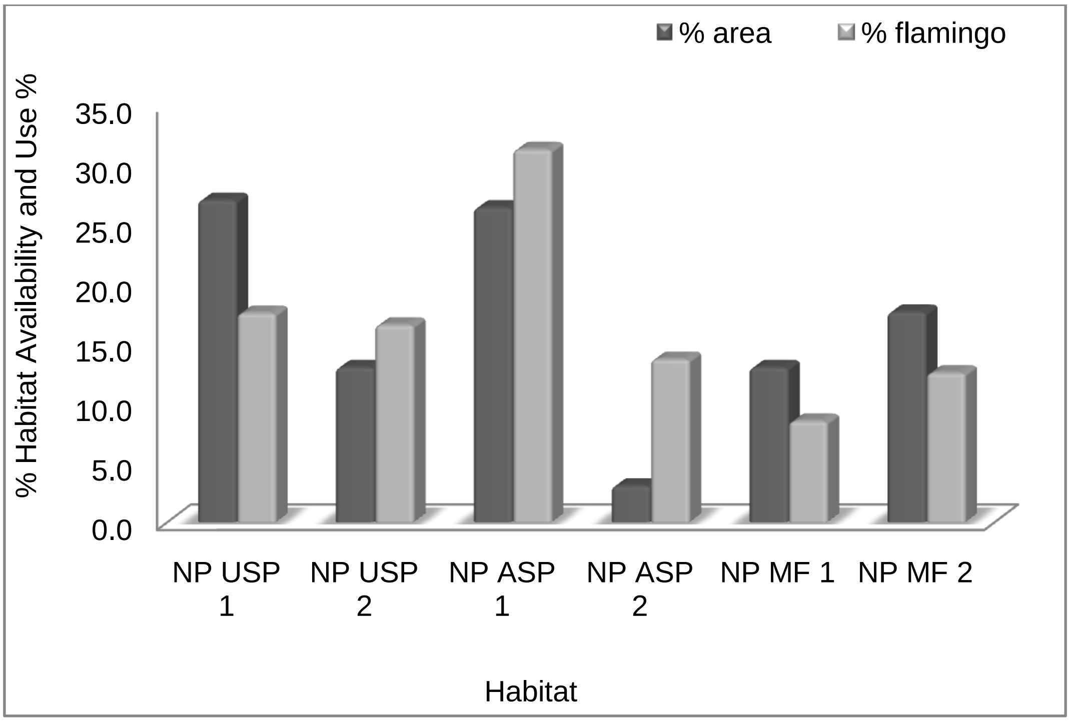

Fig 24: Proportion of Available and used habitat by Lesser Flamingos in Newport site

It was observed that, used saltpans 1 was used by 17.5% (range 9%-45%, SD=11.4) of the lesser flamingos during the entire study period despite its contribution to various habitat types was 27.0%. This showed avoidance for used saltpans 1 by Lesser Flamingos. This was followed by used saltpans 2 which were occupied by 16.5% of flamingo population despite its spread of 13.0% of the total available habitat in the area, showing moderate preference for this habitat. Abandoned saltpan 1 and 2 were also used more irrespective of its extent, 31.3% and 13.7% of flamingos used this habitats despite its spread of only 26.4% and 3.0% spread respectively, suggesting preference towards these habitat by the species. Mudflats 1 and 2 were the least preferred habitat in Newport site as only 8.5% and 12.5% flamingos respectively used this habitat even with its spread of 13.0% and 17.6% share of the total available habitat to the Lesser Flamingo (Fig. 23) (Table 6).

Table 6: Savage Index value (Wi) for each habitat type at the Newport site

Habitat Types	**% Area of Habitat available Pi**	**% Population ri**	**Savage Index (Wi)**
NP USP 1	27.01	17.53	0.649
NP USP 2	12.98	16.55	1.275
NP ASP 1	26.38	31.27	1.185
NP ASP 2	3.04	13.67	**4.498**
NP MF 1	12.98	8.47	0.653
NP MF 2	17.62	12.52	0.711

The value for Wi for various habitat types in Newport site shows that, Abandoned Salt pans 1 (Wi = 4.49 > 1) this value are also greater than calculated Bi (0.17) thus, it can be inferred that, Abandoned saltpans 1 are the habitats selected by the species. The Wi values (or Savage selectivity value) near 0 indicates maximum negative selection by the species and an index value of 1 means there is no habitat selection by the species (Table 6).

Discussion

Both abiotic and biotic conditions fluctuated markedly but very differently at two sites used by flamingos in the study area. Salinity increased in the dry season as fresh water input decreases and evaporation is intensified. However, shallow salt pans of Newport were more saline than Kumbharwada saltpans because the Kumbharwada lacked the mediating effects of ocean tides and on the other hand (i.e. at Newport saltpans) freshwater input was less, and as they were shallower, the evaporation rates were higher. Flamingos are adapted to high saline conditions and can tolerate salinities above 150 ppt (Allen, 1956). But salinity indirectly affects flamingos because it affects distribution and abundance of the food base (Britton and Johnson 1987; Hurlburt et al., 1986).

Feeding tactics also differed at the two sites, and these differences could be due to qualitative and distributional differences in the food base. However, basic behavioral attributes such as flock size and percent feeding overall did not differ between sites indicating that habitat differences did not result in unequal payoffs between sites or that these patterns are not influenced by food density or type (Jhonson, 1987).

Various physical parameters of habitat governing flamingo distribution in the study area were evaluated for its association with occurrence of the species in various habitat types in both Kumbharwada and Newport sites. The present study is first of its kind since earlier studies have only addressed the population pattern of the species in various coastal habitats of Gujarat (Tere, 2005). The utilization of these habitats by flamingos is a result of several interacting factors. These include limnological dynamics within the lakes, climatic conditions, inflow and hydrological characteristics, lake water levels, density and phytoplankton species composition.

Hydrological, climatic, phytoplankton density and species composition and Lesser Flamingo behavioral requirements are the most dominant factors affecting utilization patterns and movements. Phytoplankton density and species composition is a function of water chemistry, nutrient loads, climatic conditions and water level. Factors affecting the food base have been found to be the principal factors inducing and precipitating nomadic non-breeding movements (Vareschi, 1978). Food resources decline and distribution have similarly been found to cause dispersal and changes in utilization patterns of the lakes and sites within lakes (Brown, 1973). The food resource too affects Lesser Flamingo densities at particular sites and influence foraging strategies adopted, Lesser Flamingo behavior and flock dynamics (Githaiga, 2003). Periods with low-density food resources are associated with lesser flamingos' dispersal and heightened antagonistic interactions within flocks (Githaiga, 2003).

Flamingos in Kumbharwada Sewage ponds and abandoned saltpans preferred areas with low salinity. This may be because alterations in salinity level frequently result in increased respiratory activity to maintain osmotic balance (Qasim et al., 1972). A rise in NaCl levels in the medium has been shown to increase respiration rate and decrease photosynthetic O_2 for phytoplanktons (Mohamed and Shafea, 1992; Miller and Kamykowski, 1986). During the present study, flamingos were evenly distributed with salinity in different habitat types, however, the extreme saline saltpan habitats at both the sites were avoided by the flamingos and were only used for resting activity.

Dissolved Oxygen levels in water body correlates with amount of Chlorophyll-a which results from phytoplankton biomass, in a water body when amount of phytoplankton increases, the amount of chlorophyll-a increases as well (Hardy, 1973) and so does DO due to algal photosynthesis during daylight. Moreover, DO concentration also depends on temperature and salinity (Weiss, 1970). High temperature and salinity cause the oxygen to be relatively low (Ramberg, 1987). The DO values at sewage ponds habitat at Kumbharwada site, showed slightly positive correlation with flamingo numbers (r =0.48, p<0001). However, a weak correlation was observed between flamingo numbers and DO in abandoned saltpan habitats. Used saltpans were mainly used for resting and self maintenance activities only and also these habitats showed depleted levels of which did not show correlations with flamingo numbers.

Oxygen depletion may also occur in saline ponds when many plants die and decompose, or when wastewater with large amounts of organic material enters the estuary. In some saline ponds, large nutrient inputs, typically from wastewater, stimulate algal blooms. When the algae die, they begin to decompose. The process of decomposition depletes the surrounding water of oxygen and, in severe cases, leads to hypoxic (very low oxygen) conditions that kill aquatic animals. Kumbharwada site is also under the influence of vegetation, waste water and industrial wastes that might stimulate die offs for algae and ultimately lessen the DO. The DO level at Sewage pans at Kumbharwada was comparatively low.

The coastal water of Bhavnagar was similar to the other parts of the Gulf of Khambhat with the characteristics of seasonal variability in water temperature and pH, as expected for the buffered system of seawater (Jiyalal et al., 1990; Neelam et al., 1998). The reason for prolonged period of low salinity at Kumbharwada site could be due to i) fresh water influx by heavy monsoon, and ii) frequent release of waste water by industries surrounding Kumbharwada site. In spite of very high nutrients and DO in coastal waters of Bhavnagar, the phytoplankton production was markedly poor, which suggested the vulnerability of phytoplankton to SS due to hindrance in photosynthesis and poor irradiance in the region (Jiyalal et al., 2013).

Several researchers including Brown (1973), Vareschi (1978) and Githaiga (2003) have described the distribution of lesser flamingos within a lake. Most of the work has been carried out in Lake Nakuru where flamingos were observed and documented to utilize different microhabitats for different activities depending on the site characteristics. The hydrological regimes and limnological conditions of the alkaline lakes affect Lesser Flamingo ecology, their breeding cycles and success, and ultimately the Lesser Flamingo distribution and population structure.

Though, during the present study, data on the phytoplanktons (food of the flamingo) was not studied, it was observed that, pH, Salinity, DO and water depth played significant role in governing the distribution of the species in various habitat types. The study by Kihwele et al. (2014) suggests that water temperature; salinity and DO readings regulate the temporal and spatial abundance and diversity of phytoplankton, their blooms, and the abundance and distribution of the Lesser Flamingo. Other studies have shown that environmental conditions may take precedence over the nutritional composition and quality in regulating the abundance of Lesser Flamingos. There were fluctuation in flamingo numbers at Lake Brogoria even when there were adequate food resources (Kaggwa et al., 2012).

Considering the habitat preference of the species, the species used abandoned saltpans at both site more than its extent. Also sewage ponds at Kumbharwada sites were more preferred compared to other sites. This preference for a particular habitat suggests the water level, DO and salinity levels of the species. However, density and abundance of food may also be one of the regulating factors. The possible reasons for the differences in selecting habitats within the complex and rejecting others are (1) adequate water depth and quality (Allouche, 1988), (2) the type of food available that was found to influence the presence, in a given site, of specific species according to their needs (Del Hoyo et al., 1992). Moreover, the release of untreated waste water and effluents into the sewage pans might lead to some extent to water pollution that might cause the gradual decrease in the number of flamingos and other waterfowl observed at the site.

The present study demonstrates that, climatic conditions influence the hydrological balance and water chemistry which in turn determines site physical characteristics and Lesser Flamingo distribution and activities, foraging style and flock dynamics, hydrological balance and water chemistry also influences the courtship behaviour and breeding requirements and success of the species.

Plate 1

A. Lesser Flamingos in Abandoned saltpans (Kumbharwada site)

B. Flamingos in abandoned saltpans at Newport (Low water level)

C. Flamingos feeding in Low salinity ponds

Plate 2

A. *Aeluropus lagopoides* dominated sewage pans at Kumbharwada

B. *Porteresia coarctata* dominated sewage pan area

C. Associated avifauna at Kumbharwada site

Plate 3

A. *Porteresia coarctata*

B. *Aeluropus lagopoides*

Plate 4

A. Mudflats at Newport site

B. *Porteresia coarctata* height and Flamingos feeding

C. *Aeluropus lagopoides* height and L. Flamingo