Food and Feeding Ecology

CHAPTER 3
FOOD AND FEEDING ECOLOGY

The flamingos are filter feeders While feeding, the bill is down turned and the flamingo dips its bill upside down into the water. It feeds by sucking water through the bill and passing it through sieve-like plates to filter out the small shrimp and planktons of the diet. Although it is normal to see both Greater and Lesser Flamingos feeding together in the same lake, there are marked differences in their food and feeding methods. There are fundamental differences in the structure of their bills, *viz.*, (1) shallow keeled and (2) deep-keeled. The shallow keeled bill is found in Greater Flamingos, which is capable of straining comparatively larger objects from the water or mud. The deep-keeled bill is found in Lesser Flamingos, which is capable of straining the finer organisms such as small diatoms. The Greater Flamingos feed from deep layers of water while the Lesser feeds from the surface (Ogilvie and Ogilvie, 1986; Ridley, 1954).

The Greater Flamingos largely feed on zooplanktons, mollusks, crustaceans (e.g. *Artemia*), insect larvae, small fishes and to some extent on aquatic vegetation. The Lesser Flamingos are particularly herbivorous and feed on phytoplankton, algae (*Spirulina*), diatoms, and seeds of aquatic plants (*Ruppia, Scirpus etc.*). Both species are known to consume grit and organic mud (Ali and Ripley, 1983). *Spirulina*- a blue green algae is considered to be the major food of Lesser Flamingo in Africa; however, diatoms are also consumed to some extent (Tuite, 1979; Jenkin, 1957).

Food of the flamingos has been studied by several scientists in India and other parts of the world. McCann (1939) examined stomach of chicks of Greater Flamingos, in Great Rann of Kachchh and found a quantity of sand and large number of small black seeds-identified later as *Ruppia rostellata.* Examination of adult flamingo's stomach, showed the presence of seeds of *Ruppia rostellata* along with other brown seeds of *Scirpus maritima* and small portions of aquatic plants resembling *Najas* and *Chara.* McCann also referred to the fact that the flamingos inhabiting the Rhone Delta existed almost entirely on a tiny

Phyllopod, the brine-shrimp (*Artemia salina*), which was found there in marvelous abundance.

Ali (1945) found greenish brown vegetation matter and Chironomid larvae in the gut of Greater Flamingo collected from salt pans of Kandla, Kachchh.

Ridley (1954) analyzed gut contents of some fourty individual flamingos under microscope and found chiefly Chironomid larvae, a few sedge seeds, a few Copepods, Corixids, various insect larvae, higher plant remains, algae and diatoms in gut contents of the Greater Flamingos; and Corixids, some Chironomids, blue-green algae (Myxophycea), diatoms (Bacillariophycae) *etc* in gut content of Lesser Flamingo in East Africa.

Abdulali (1964) examined gut content of both the species at the Gulf of Kachchh. Blue green algae (*Oscillatoria sp*) was predominant with rare occurrence of diatoms in the gut content of Lesser Flamingo. Seeds of *Ruppia* and graminaceous plant, grit and Chironomid larvae were found in the gut of Greater Flamingo. He also suspected that in the Great Rann, they might be feeding on small fry of fishes, *Cyprinodon disper,* in early season.

3.1 Feeding Methods:

Many authors have described feeding methods used by flamingos (Rooth, 1965; Allen, 1956; Ogilvie and Ogilvie, 1986). These methods are described in more details with some photographic representations (Plates-3.1A and 3.1B).

Materials and Methods:

Flamingos feeding in different habitats were observed by using a spotting scope (20X80) and binoculars (10X50) and their feeding methods were noted. The depth of water in different habitats was recorded. The feeding groups were captured in camera. A few feeding methods were documented by videography and described in more detail.

Results:

The flamingos were observed feeding by following methods.

1. Walk-Feed:

This is the most common and widely known method used by the flamingos for capturing food from mud and shallow water. Both the species of flamingos were observed feeding by this method during the study period.

The flamingos walk at relatively constant pace, with the head, alternately up or extended forward, and down trailing the surface of the soft mud below or filter feeding in the water column, repeatedly probing water column with forceps movements of bill (Plates-3.1A –1,2).

Greater Flamingos were observed feeding by this method in shallow waters of salt pans, sewage ponds, fresh water ponds, sea-coasts, *etc.* Lesser Flamingos were also observed feeding by walk-feed method largely on mudflats and in shallow water wetlands.

At many sites, both the species of flamingos were seen standing for a long time (several minutes or more) and feeding constantly without moving. The Greater and Lesser Flamingos were observed feeding by this method at many salt pans and in shallow water channel, near Cherwari in Little Rann of Kachchh. This method used by flamingos can be called as "Stand Feed", as the flamingos stand at a single place for a long time and feed constantly. Probably, they do "stand feed" when food density is very high and there is constant flow of food where they are standing. In this method, the bird may change its standing position to some extent but do not rotate its body when the bill is submerged.

2. Stamp-Feed /Treading:

In this method, the birds stamp their toes while rotating their body clockwise or counter clockwise around their partially or fully submerged bill. This activity loosens the mud so that the larger objects such as molluscs and crustaceans float free and are sucked into the bill.

The Greater Flamingos were observed feeding by this method at Nirveri, in the Great Rann of Kachchh. The food available in the surrounding was a large number of Chironomous larvae. The Lesser Flamingos were not observed feeding by this method during the study period.

3. Tip-feed/ Swim while Feeding:

The flamingos swim in the water and feed just by dipping their bills in the superficial layers of the water (Plate 3.1A-3). This method is used when there is greater depth for wading (more than 60 cm).

The Lesser Flamingos were observed feeding by this method at the Chhaya Rann, a sewage pond located in Porbandar. The Greater Flamingos were seen swimming and feeding at Nirveri, in Great Rann. At Khambhat coast, the Lesser and Greater Flamingos, which were feeding by walk feed method in incoming tide water, started swimming when the water level rose and changed to tip feed.

4. Duck like Bobbing:

In this method, flamingos swim in deep water. For capturing the prey, they insert their entire head and neck in deep water in such a way that only the posterior part of the body remains above the water. The tail region is kept obliquely up and the body is balanced by paddling alternately with both the legs in the water. Flamingos retain their heads in the water comparatively for longer period and then bring the bills out of water. This method is very similar to that of ducks and used for feeding in deep water (60 cm-100 cm) (Plate 3.1A-4).

Both the species of flamingos were observed feeding by this method, in the salt pans of Charakala and Malia; and Greater Flamingos was observed feeding by this method in inundated water around Flamingo City.

5. Feeding in Heron Manner:

Flamingos feed in shallow water like a Heron, suddenly darting a few paces forward, and then dabbing down with its bill as if to catch the prey.

The Greater Flamingos were observed feeding by this method, at Nirveri in Great Rann of Kachchh during February 2004, where, few fresh water channels from the Kala Dungar and from a well were mixing with the inundated Rann. This shallow water had large number of small fishes, *Cyprinodon disper*. These fishes were highly mobile, forming swarms and flamingos were attempting to capture them in the same way as the herons capture their prey.

Heron like feeding method of the Greater Flamingos is shown in more details in Plate 3.1B. It can be divided into 3 steps:

a) Down Stroke: the bird dips its beak and head under water.
b) Capture/Attempt to capture: the bird attempts to capture food
c) Up Stroke: the bird takes the bill out of water and prepares for the next stroke.

Various feeding steps can be described with reference to the movement of following body parts (i) Head and beak (ii) Neck and (iii) the abdominal and tail region

In normal posture, the flamingos stand or walk by keeping their necks up in S-shape, with their heads no higher than the level of their beaks, their abdominal regions remain almost horizontal to the surface and the tail slightly downward. In this position the head remains above the level of the rest of the body (Plate 6.1A-1).

(A) Down Stroke:

During the down stroke, the head is taken down vertically at the same level of the body by bending the neck forming "U" shape. (Plate 3.1B-D1). Then, it moves its head forward horizontally by straightening the neck and bringing it slightly below the level of body, so that the neck is bent horizontally in "C" shape (Plate 3.1B-D2). The neck is extended further obliquely down thereby bringing the head near to the surface of water. The vent region is raised slightly up occasionally (Plate 3.1B-D3). The entire beak is then inserted into the water with a jerk. The vent region is further raised up so as to balance the body (Plate 3.1B-D4). The strike is made with slightly opened beak.

(B) Capture/Attempt to Capture Food:

The Greater Flamingo maintains its position (Plate 3.1B-D4) and makes attempts to capture the food. Then it takes out its beak. This process is done very fast. Normally a single strike is made at one place, however, some times, a few of them were seen making 2-3 attempts at the same place, without raising the head up.

(C) Up Stroke:

As it walks simultaneously, its body is brought forward, and hence, the shape of the neck changes to inverted "L" (Plate 3.1B-U1). This is followed by the inverted "S" shape formation of neck by bringing the body more close to the head (Plate 3.1B-U2). The flamingo then takes its head out of water, the head is raised up slightly and the neck is kept in horizontal "C" shape again. The vent is lowered down and the body is kept in horizontal position again (Plate 3.1B-U5). The flamingo then starts the next stroke by extending its head forward, and repeating the entire procedure (Plate 3.1B-U6).

Between the two repeated strikes, the head is raised and kept below the level of its body and never brought parallel to or above the body level. In this method, the strike rate varied considerably. In a group of 20 feeding birds, we counted the strike rate to the tune of 40-50/mın. However, the success rate seemed to be very low as we could not observe a single bırd handling a fish or attempting to swallow it lıke a heron The Greater Flamingo fed by this method, simultaneously walked for some distance, turned and then walked and fed in opposite or any other direction.

The entire action was very fast and jerky. The feeding attempts were rhythmic and it seemed that they were locating the food and striking immediately. Ogilvie and Ogilvie (1986) have suggested that the movement of tıny fish or fry attracts the attention of flamingo and ıt attempts to capture ıt.

Plate 3.1A : Feeding Methods of Flamingos

1. Walk Feed by Lesser Flamingos

2. Walk Feed by Greater Flamingos

3. Tip Feed by Lesser Flamingos

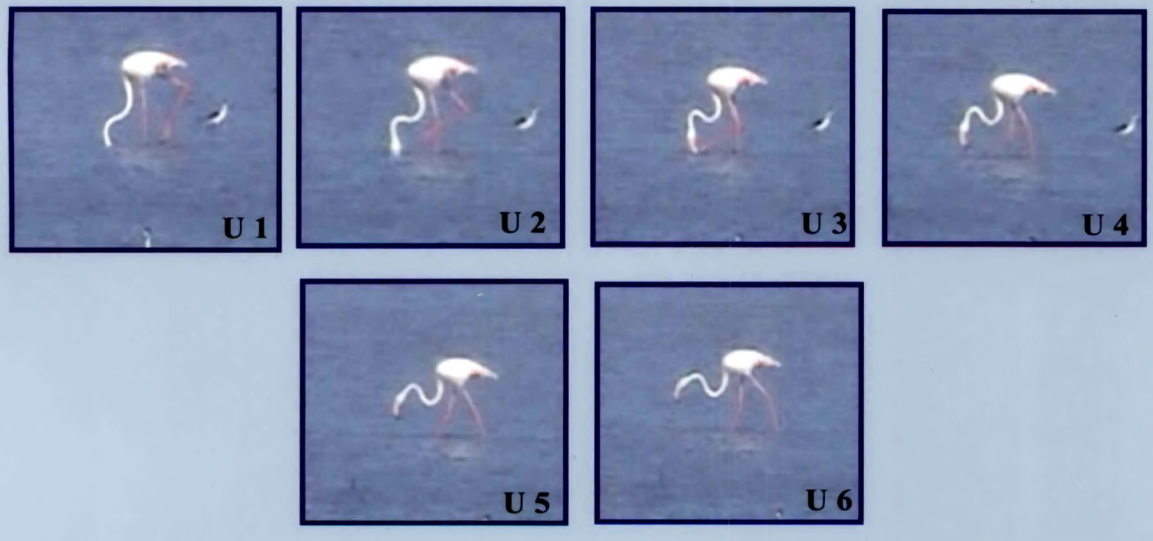
4. Duck like Bobbing by Greater Flamingos

Plate 3.1B : Greater Flamingo Feeding by Heron like Manner

(1) Down Stroke

(2) Capture/Attempt to Capture

(3) Up Stroke



3.2 Feeding Areas:

The flamingos were recorded feeding in different habitats of Gujarat state. The feeding areas are identified and described.

Materials and Methods:

Flamingos feeding in different habitats were observed by using a spotting scope (20X80) and binoculars (10X50) "Block Method" was used for counting their number. The feeding method used by the flamingos in different areas was also recorded.

The different habitats were classified broadly into 4 feeding areas: (I) Mudflats, with no or very shallow water (≤2 cm) (II) Wetlands with Shallow Water (2 to 45 cm) (III) Wetlands with Deep Water (≥60 cm) and (IV) Rice fields

The method described by Arengo and Baldassarre (1999) was used to measure the depth of water relative to the length of the legs of flamingos, in areas where it could not be measured directly. Accordingly, the depth was classified as (i) metatarso-tarsal joint level (≤ 2 cm) (ii) half way up the tarsus (approx. 15 cm), (iii) tarso-tibiotarsal joint (approx. 30 cm); (iv) half way up to the tibio tarsus (approx. 45 cm) and (v) on the tibiotarsus at the thigh muscle (approx. 60 cm) In some wetlands the water depth was measured by a calibrated rod.

Results:

The flamingos were recorded feeding in following areas (Table 3.2a and b):

1. Mudflats:

Wet mudflats were the most preferred feeding sites. During the study period, Lesser Flamingos were observed feeding in large numbers on coastal mudflats of Bhavnagar, Dholera, Khambhat and Dhuwaran, as well as in Little Rann of Kachchh. They were observed feeding on the wet surface of mudflat by walk feed method. At Cherwari, in Little Rann of Kachchh, large numbers of Lesser Flamingos were observed feeding from shallow

water channels, by constantly standing at one place for a long time. Most of the mudflats were wet with no water, however at some sites, water was present up to metatarso-tarsal joint of flamingos.

2. Wetlands with Shallow Water:

Both Greater and Lesser flamingos were observed feeding in wetlands with shallow water. This included salt pans, tidal regulators, sewage ponds and village ponds located in different districts of Gujarat as well as in inundated Great Rann and Little Rann areas (Plate 3.2-1). The water level varied from (i) up to the metatarso-tarsal joint (≤ 2 cm) to (iv) up to half way up the tibio-tarsus (approx. 45 cm). Both the species were sharing the same feeding areas at many sites, *viz.* salt pans, sewage ponds, *etc*

The Lesser Flamingos were observed feeding by "walk feed" method in all wetlands with shallow water. However, the Greater Flamingos were observed feeding by "stamp feed" and "heron like feeding" methods besides "walk feed".

3. Wetlands with Deep Water:

Both Greater and Lesser Flamingos were observed feeding in wetlands with deep water. This included salt pans, sewage ponds, inundated Rann areas, *etc*

Both Lesser and Greater Flamingos were observed feeding together in the deep water of salt pans at Charakala and Malia. The water was reaching up to the tibiotarsus at the thigh muscle (approx. 60 cm). Both the species were feeding by "Duck like Bobbing".

A total of 7,769 Lesser flamingos and 10 Greater flamingos were counted at the Chhaya Rann, a sewage pond located in Porbandar, in January 2003. All the flamingos were swimming in the pond, where water depth was more than 60 cm. All the Lesser Flamingos were observed feeding by tip-feed method.

In inundated Rann, where the water depth was more than 64 cm, various groups of Greater Flamingos were recorded feeding by "Duck like Bobbing".

4. Rice-field:

The Greater Flamingos were recorded inhabiting Rice-field at Sarkhej, Ahmedabad district, on June 28, 2003 (Plate 3.2-2). A total of 533 Greater Flamingos were recorded. The Rice field was adjacent to the road between Sarkhej and Juhapura, in Ahmedabad city and spread in about 1-2 km^2 in the area. The entire cropped area was divided into several square blocks by the bunds and was inundated by water. The water was up to metatarso-tarsal joint level (2 cm) or slightly more. Some paddy fields had freshly transplanted saplings while in other fields saplings were not yet transplanted. Most of the Greater Flamingos were found feeding in the fields while some were resting and walking.

During this study, the Greater Flamingos were recorded for the first time and only for once, in the Rice field. However, they are regularly recorded in Rice fields at Camargue, France (Tourenq *et al.*, 2001) and known to cause damage to the rice crop by trampling the grain into earth preventing germination, uprooting and consuming them (Del Hoyo *et al.*, 1992). Flamingos are reported visiting rice fields, soon after sowing and until the rice germination period.

The Paddy seeds are not drilled directly at the field, in most of the study areas of Gujarat state. Here seedlings are grown in the nursery and then transplanted into the fields, so there is no question of serious crop damage by the flamingos, even if they visit the rice fields regularly; however by their movements and attempts to capture food from this area, they may cause mechanical damage *i e.* trampling or uprooting. Regular monitoring of the Greater Flamingos should be done to check, whether they inhabit the rice fields regularly and the possibility of any damage.

Table 3.2a: Feeding Methods Used by Lesser Flamingos in Different Habitats

No.	Habitat	Sites	Water Level	Water Depth (cm)	Feeding Method	Frequency of method used %
1	Mudflats (n=4,700)	Cherwari, Bhavnagar, Khambhat, Dholera, Dhuwaran	Shallow Water	i	Walk Feed	100
2	Salt Pans (n=2,751)	Dholera, New Port	Shallow Water	i	Walk Feed	30 93
				ii	Walk Feed	40
				iii	Walk Feed	12.36
				iv	Walk Feed	15.07
		Charakala, Malia	Deep Water	v	Duck like Bobbing	1.64
3	Tidal Regulator (n=2,087)	Meedha Creek, Gosa Karli, Nikol Bundhara	Shallow Water	i	Walk Feed	8.49
				ii	Walk Feed	73 21
				iii	Walk Feed	18.3
4	Sewage Pond (n=12,738)	Jamnagar, Kumbharwada	Shallow Water	i	Walk Feed	20
				ii	Walk Feed	8.41
				iii	Walk Feed	3.3
				iv	Walk Feed	7.3
		Chhaya Rann	Deep Water	iv	Tip Feed	60 99
5	Great Rann (n-300)	Inundated Rann	Shallow Water	i	Walk Feed	100

(i) water up to metatarso-tarsal joint (≤ 2 cm); (ii) halfway up the tarsus (approx. 15 cm); (iii) tarso-tibiotarsal joint (approx. 30 cm) (iv) halfway up to tibio tarsus; and (v) on the tibiotarsus at the thigh muscles (approx. 60 cm) of flamingos

Table 3.2b: Feeding Methods Used by Greater Flamingos in Different Habitats

No.	Habitat	Sites	Water Level	Water Depth (cm)	Feeding Method	Frequency of method used %
1	Salt Pans (n=3,439)	New Port, Dholera	Shallow Water	i	Walk Feed	9.54
				ii	Walk Feed	21.52
				ii	Stamp Feed	13.01
				iii	Walk Feed	10.03
				iii	Stamp Feed	22.88
				iv	Walk Feed	8.26
				iv	Stamp Feed	10.22
		Charakala, Malia,	Deep Water	v	Duck like Bobbing	4 54
2	Tidal Regulator (n=1,280)	Meedha creek, Gosa Karli, Nikol Bundhara	Shallow Water	ii	Walk Feed	33 91
				ii	Stamp Feed	11.23
				iii	Walk Feed	18.14
				iv	Walk Feed	22.4
				iv	Stamp feed	14.32
3	Inundated Great Rann (n=531)	Near Nirweri	Shallow Water	i	Walk Feed	41.62
				ii	Heron like Feeding	5.65
				ii	Stamp Feed	3.77
				iii	Heron like Feeding	1.88
				iii	Walk Feed	37.77
				iv	Heron like Feeding	9.31
4	Village Ponds (n=2)	Pipri, Patvagam	Shallow Water	ii	Walk Feed	100
5	Sewage Pond (n=102)	Jamnagar ,Lambhvel	Shallow Water	i	Walk Feed	66.66
				ii	Walk Feed	33.34
6	Rice Field n=400)	Sarkhej, Ahmedabad	Shallow Water	i	Walk Feed	100

(i) water up to metatarso-tarsal joint (≤ 2 cm); (ii) halfway up the tarsus (approx. 15 cm); (iii) tarso-tibiotarsal joint (approx. 30 cm) (iv) halfway up to tibio tarsus; and (v) on the tibiotarsus at the thigh muscles (approx. 60 cm) of flamingos

Plate 3.2 : Feeding Areas

1. Flamingos Feeding in Salt Pan

2. Greater Flamingos Feeding in Rice Field

Conclusions:

In mudflat areas with wet soil and very little or no water, only Lesser Flamingos were recorded feeding by Walk-Feed method. In shallow and deep water wetlands, both the species were recorded feeding. In many such feeding areas, they were sharing the same feeding areas. In the rice fields, only Greater Flamingos were recorded feeding.

The Lesser Flamingos used "Walk Feed" method very commonly, for feeding in shallow water. They used "Tip Feed" and "Duck like Bobbing" for feeding in deep water.

The Greater Flamingo used "Walk Feed", "Stamp Feed" and "Heron like Feeding" methods for feeding in the shallow water, while in deep water "Duck like Bobbing" was used

3.3 Analysis of Gut Contents:

The analysis of gut contents can provide information about the food of an animal. Dead flamingos recorded at several places after collision with power lines during the study period, were collected for gut analysis.

Materials and Methods:

1. Collection of the specimens:

Flamingos were recorded dying after collision with power lines (either electric or telephone wires), at several places in the Great Rann of Kachchh. The gut (crop) content was collected from the dead flamingos for analysis. Freshly dead flamingos were identified by their fresh, un-rotten appearance and warm body.

Greater Flamingo:

The Greater Flamingos were found dead in the Rann areas near Bhirandiyara (23^0 32.038'N; 69^0 40.077'E), 50 km north to Bhuj, on Bhuj-Khavda road. Out of several carcasses, one fresh specimen was taken for the study, on February 24, 2004.

Lesser Flamingo:

The Lesser Flamingos were found dead at Rann of Shiranivandh (23^0 54' 29.632''N; 70^0 32' 32 624''E) in Great Rann of Kachchh, on October 23, 2003. The gut content was studied from one fresh carcass.

2. Collection and Identification of the gut contents:

The dead flamingos were dissected and their crop was taken out. The contents were collected in plastic vial, preserved in 70% alcohol and brought to the laboratory. The contents were examined under compound microscope and identified.

Results:

Gut contents of Greater Flamingos:

Total amount of crop contents was 67 ml. The entire content consisted of only one type of food, *i e* small, brown round particles identified as cysts of *Artemia salina* (Plate 3.4A -1).

Gut content of Lesser Flamingos:

Total amount of crop content was 45 ml. It was dark green in color. All the content consisted of diatoms identified as *Navicula sp* (Plate 3.4A-6).

Discussion:

The Greater Flamingos were recorded feeding on adult *Artemia* in past; however, the *Artemia* cysts have not been described before. The Greater Flamingo feeding exclusively on the *Artemia* cysts is reported for the first time in India.

The gut content analysis of Lesser Flamingo showed that it fed exclusively on one type of food only. No other food items were found beside the *Navicula sp* Abdulali (1964) found blue-green algae (*Oscillatoria sp.*) as predominant food with rare occurrence of diatoms, from the gut content of Lesser Flamingo in the Gulf of Kachchh. In present study, the flamingo seemed to have fed exclusively on diatoms (*Navicula* sp.) only.

Conclusions:

Greater Flamingo is recorded to feed exclusively on *Artemia* cysts in the present study. This is the first recording of its type from India. Lesser Flamingo on the other hand seemed to feed exclusively on *Navicula sp*

3.4 Analysis of Food of Greater Flamingos in the Environment:

Food abundance and availability are likely factors determining flamingo movements and distribution (Arengo and Baldassarre, 1995). Wetlands are characterized by seasonal rainfall and water level fluctuations; hence, knowledge about strategies used by waterbirds in response to such variability, particularly extreme in variation, is necessary for implementation of conservation strategies (Arengo and Baldassarre, 1999). Hence, study of food availability in the surrounding environment becomes important.

Study Area:

The Greater Flamingos were recorded in large numbers around the Flamingo City, in October 2003 (during breeding season). Hence this area was selected to study the food availability and abundance, as the food is an ultimate factor for reproduction.

The Flamingo City (24^0 03.749'N; 70^0 02.671'E), is about 25 km north to Nirveri, 10 km northeast to Nir (Nirwandh), located in Kala Dungar-hilly area in the Great Rann of Kachchh. Entire Rann area was inundated after southwest monsoon. Greater Flamingos used a small island, for nesting in this area. The nesting site (Flamingo City) was approached from Nirveri. The area between Nirveri and the Flamingo City was selected for the study of food resources.

3.4A: Analysis of Food by Ground Truth Studies:

Materials and Methods:

The sampling of food was done at four different points, *viz* (1) at the edge of Nirveri, (2) 10 km from Nest Site, (3) 5 km form Nest site and (4) near Nest site (Island).

The area was surveyed by assault boat. The depth of water was measured at different points by calibrated rod. Light penetration was measured by Sechchi Disc. Water samples

were collected and analyzed in the laboratory. Total salinity, pH and conductivity were measured. The ambient temperature and water temperatures were measured by thermometer at 11:30 and 13:00 hrs.

The potential food items, in the substrate were collected by removing 15 cm deep section of substrate/mud with 15X15 cm^2 Eckman dredge. The samples were strained with a $1mm^2$ mesh sieve, preserved in 70% alcohol and taken to the laboratory for identification and counting. The biomass of wet sample was measured.

The water column was sampled by dragging a plankton net, 24 cm in diameter, for 5m, below the water surface. The sampling was done from a boat, moving slowly to minimize disturbance to the site. The samples collected were preserved in 70% ethanol and brought to the laboratory. The food samples were identified to the smallest possible category. A total of three samples were collected at each point for sampling of water and mud.

As the fishes were very active, they could not be trapped by the above method, hence another sampling method was applied. The fishes were captured by using funnel shaped nylon net. Five attempts were made and the total number of fishes captured in the net was recorded. The sampling was done in the channels as well as in open water. The fishes were counted, weighted and preserved.

Total number of flamingos present at the nest sites and in the feeding areas were estimated.

Sampling Period:

The sampling in the Great Rann of Kachchh was done thrice at point 1 *i.e.* at the edge of Nirveri in October 2003-the beginning of the breeding season, February 28, 2004-during active breeding season, and April 29, 2004-at the end of breeding season. We could not reach up to the nest site in October 2003, hence, the sampling of other three points could not be done. However, sampling at remaining points was done twice, (i) during breeding season on February 28, 2004 and (ii) at the end of breeding season on April 29, 2004.

Results:

Totally, 5 food items, belonging to 3 taxa, were found from different points in the study area, during the study period (Table 3.4b, c).

At the beginning of breeding season:

In October 2003, the water was turbid, and light was penetrating up to 115 cm at a site where total depth of water was 170 cm. As the Rann area around the Flamingo City was having undulating land, the depth of water at different sites varied considerably. At Point 1, the depth of water was 46 cm. The maximum depth of water was 180 cm. The depth of water between points 2 and 3, was 160-180 cm. The salinity of water was 51.2 ppt at the beginning of the breeding season (Table 3.4a).

In the beginning of breeding season, 4 food items *viz.* very small sized fishes identified as *Cyprinodon disper,* cysts of *Artemia salina,* and *Chironomous* pupae were recorded from inundated water and *Chironomous* larvae from the substrate (Plate 3.4A). The adult of *Artemia salina* was absent during the breeding season. The *Chironomous* larvae were abundant in the soft mud at point 1 (45/sample). The fishes were very small in size and abundant (8 fishes/ five attempt) at Nirveri (Table 3.4b, c).

During the breeding season:

The water was greenish and light was penetrating up to the substrate level. The salinity of water was 66.5 ppt and pH 7.55 during the breeding season. Compared to October 2003, overall water depth had decreased considerably. At point 1, the depth of water was 40 cm. The depth was 50-64 cm between points 2 and 3. At the edge of Nest site, the water was about 10 m away from the nest site and the depth was 46 cm. At 50 m from the nest site, the depth of water was 64 cm (Table-3.4a).

In the breeding season, four food items *viz. Cyprinodon disper,* cysts of *Artemia salina,* and *Chironomous* pupae were recorded from water column and *Chironomous* larvae from the substrate. The adult of *Artemia salina* was absent during the breeding season (Table 3.4b, c).

The abundance of these food items varied at different points. The fish- *Cyprinodon disper* was abundant and recorded only at point 1 and absent at other points. At point 1, they were recorded swimming in big swarms in fresh water channels from Kala Dungar hills and adjoining inundated Rann. Totally, 5 fishes/five efforts could be captured. The wet biomass of an average sized (2-3cm) *Cyprinodon* was 0.67 gm. The *Chironomous* larvae present in loose mud were equally abundant at points 1 and 4, while very few in deep water. Wet biomass of *Chironomous* larvae was 0.005 gm/larva. *Chironomous* pupae and Artemia cysts were free floating in the water, and distributed at all the points, however their number was significantly higher in deep water at points 2 and 3 (Table-3.4b, c).

A total of 21,000 Greater Flamingos (7,000Adult + 14,000Juveniles) were counted in February 2004. Most of the adult birds were engaged in nesting on the bet, at Flamingos City, few were observed in feeding areas. Very young juveniles (1-20 days) were at the nest sites while comparatively older juveniles (2-3 months) were a little away in the water.

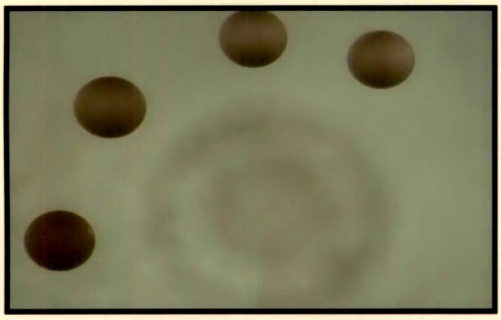
At the end of breeding season:

The water was transparent and clean totally. The salinity and pH of water were 80.6 ppt and 7.33 respectively. The water level had decreased drastically. At point-1, the depth was 12 cm and between points 2 and 3, it was 30-46 cm. The water had receded 500 m away from the nest site (Table 3.4a).

There was a 50% decrease in total food abundance, in April 2004 *i.e* at the end of breeding season, compared to the active breeding season (Fig. 3.4a, b and c). The *Chironomous* larvae and pupae were totally absent from all the points, during the post-breeding season. The *Cyprinodon* fishes were found dead, and floating in water. The number of *Artemia* cyst decreased by 44.49%. At the end of the breeding season, the adult *Artemia salina* were also found, however, many adults were dead and floating on the inundated water, while a few live adults were present at all the four spots (Table 3.4b, c).

Plate 3.4A : Food of Flamingos

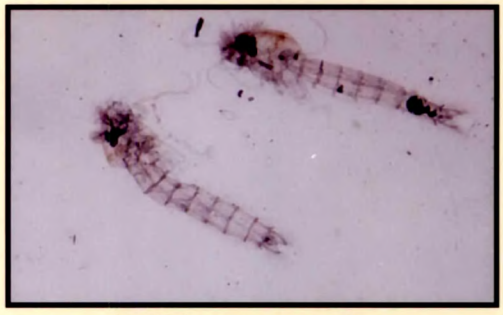
(A) Food of Greater Flamingos



1. Artemia salina Cysts

2. Artemia salina Adult

3. Chironomous Larva



4. Chironomous Pupae

5. Cyprinodon disper

(B) Food of Lesser Flamingos

6. Navicula

Table 3.4a: Physical Conditions of Flamingo City at the Beginning, during Active Breeding and at the End of Breeding

No.	Physical Conditions		Oct-03	Feb-04	April-04
1	Ambient Temperature	Day	28^0C	32^0C	43^0C
		Night	08^0C	11^0C	25.5^0C
2	Water Temperature	At 11.30hrs	19^0C	22^0C	36^0C
		At 13.00hrs	20^0C	24^0C	40^0C
3	Water Depth	Point 1	46 cm	40 cm	12 cm
		3 km from Nirveri	150 cm	116 cm	46 cm
		Between Point 2 and 3	160-180 cm	50-64 cm	30-46
		500 m from the Nest Site	110 cm	80 cm	5 cm
		50 m from the Nest Site	-	64 cm	0
		10 m from the Nest Site	-	46 cm	0
4	Salinity		51.2 ppt	66.5 ppt	80.6 ppt
5	pH		7.59	7.55	7.33
6	Light Penetration		115cm at depth of 170 cm	Substrate Level	Substrate Level

Table 3.4b: Food Items of Greater Flamingo in Water Column (No. /sample)

Period	Food	Point-1	Point-2	Point-3	Point-4	Total
Oct 2003	*Artemia* Cyst	200	-	-	-	>200
	Artemia Adult	0	-	-	-	0
	Chironomous Pupae	11	-	-	-	>11
	Total	**211**	-	-	-	**>211**
Feb 2004	*Artemia* Cyst	190	250	230	200	870
	Artemia Adult	0	0	0	0	0
	Chironomous Pupae	8	11	2	7	28
	Total	**198**	**261**	**232**	**207**	**898**
April 2004	*Artemia* Cyst	110	145	120	108	483
	Artemia Adult	2	3	4	2	11
	Chironomous Pupae	0	0	0	0	0
	Total	**112**	**148**	**124**	**110**	**494**

Table 3.4c: Food Items of Greater Flamingo in Mud (No./Sample)

Period	Food	Point-1	Point-2	Point-3	Point-4	Total
Oct 2003	*Chironomous* Larvae	45	-	-	-	45
Feb 2004	*Chironomous* Larvae	38	1	2	40	81
April 2004	*Chironomous* Larvae	0	0	0	0	0

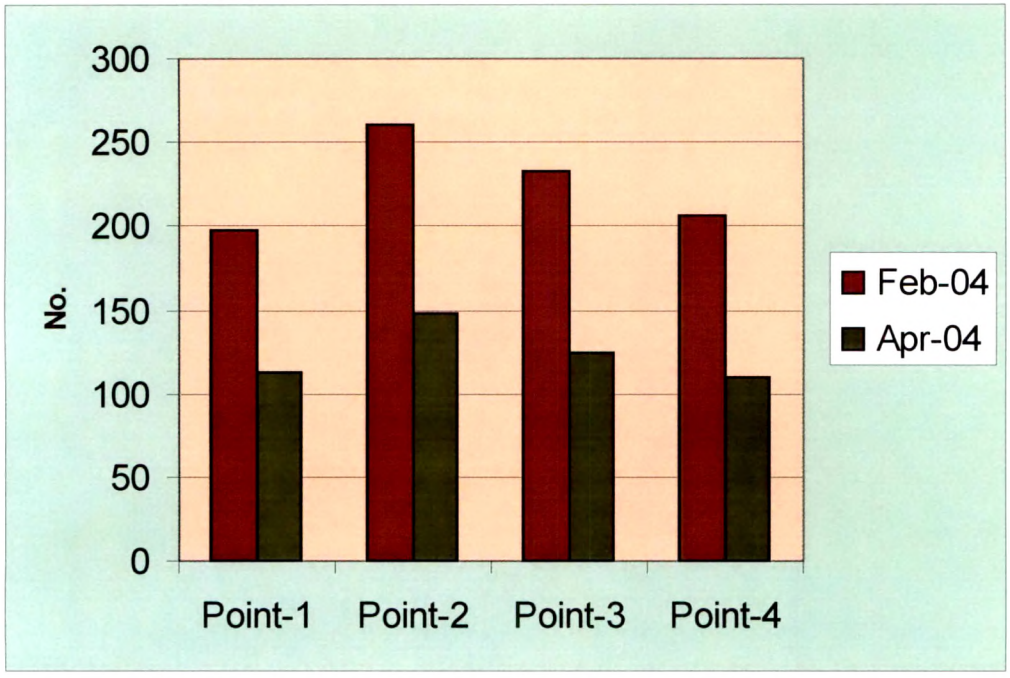


Fig 3.4a: Food Items in Water Column during Active and at the End of Breeding Season.

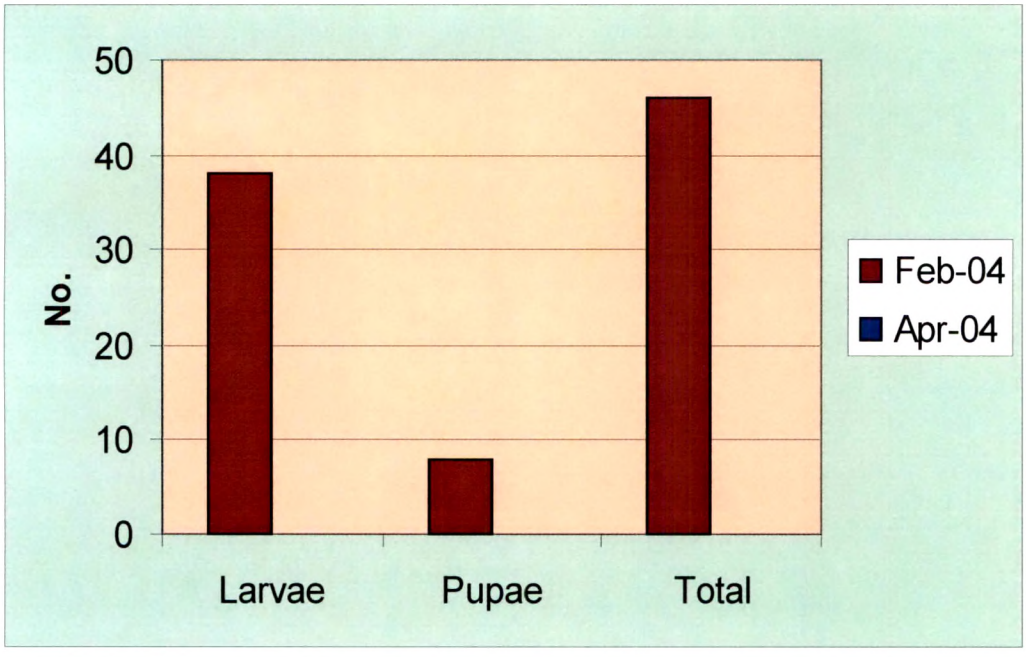


Fig. 3.4b: *Chironomous* (larvae and pupae) in Mud during Active and at the End of Breeding Season.

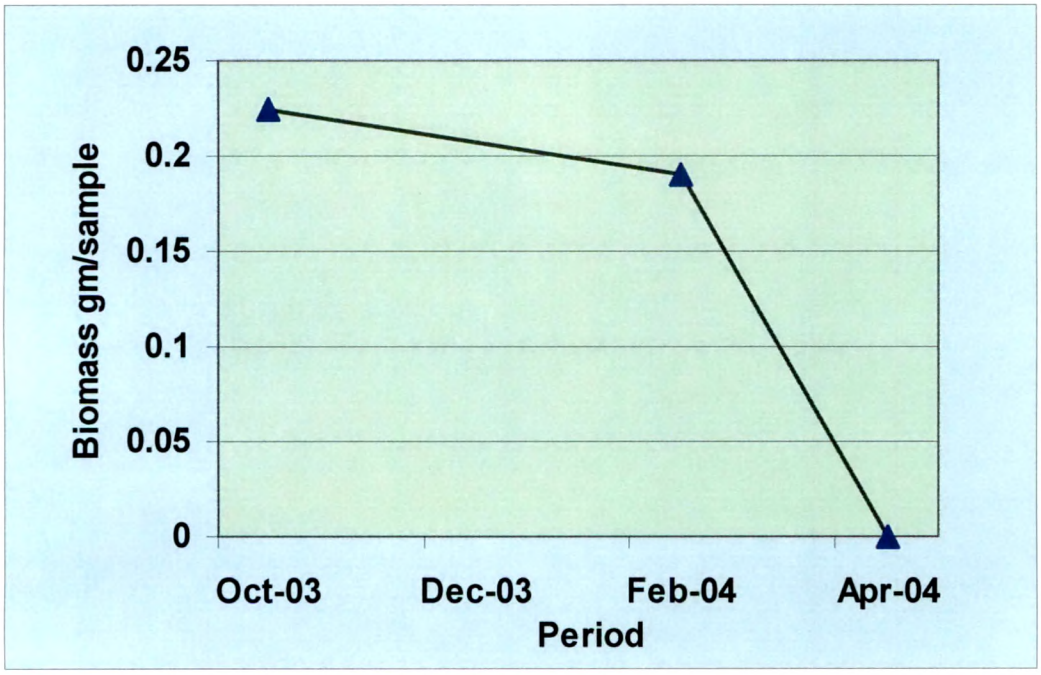


Fig. 3.4c: Changes in the Biomass of *Chironomous* Larvae at Point 1

At the end of the breeding season, only 259 adult Greater Flamingos were present along with 9.655 live juveniles at the nest site. Both adults and juveniles were in water, away from the nest site. Flamingos were absent at points 1, 2 and 3.

Conclusions:

The correlation of salinity (Table 3.4a) and abundance of food (Table 3.4 b, c) in the Great Rann of Kachchh, during different periods of breeding season, suggested that food abundance was greatly affected by two factors (i) Salinity and (2) depth of water.

As the season changed, water started receding, which resulted in decrease in water depth and its spread. This resulted in tremendous increase in salinity of water. The food organisms could not survive in high salinity water and hence the total food decreased.

The availability of food affected the number of flamingos inhabiting the City in the Great Rann. At the beginning of breeding season, and during active breeding season, the food was abundant and the number of Greater Flamingos was also very high. At the end of breeding season, the number of flamingos decreased as food availability decreased. Very high salinity depleted the food, which compelled the flamingos to desert the colony.

3.4B: Analysis of Food and Habitat Evaluation by Remote Sensing:

The synoptic view of the earth's surface provided by space borne remote sensing has enabled man to perceive and monitor habitats of living organisms from an entirely new perspective. Census of flamingoes has been done using aerial imagery (Grzimck and Grizmek, 1960). Quite a few studies have been carried out using satellite imagery for habitat mapping, estimating food availability and understanding the nesting behavior of different migratory birds (Henry and Reeves,1978; Richard, 1978).

The study of wildlife habitat in India using remotely sensed data, began at Space Applications Centre (SAC) with the use of Bhaskara–II TV data for mapping the breeding ground of flamingoes. The mapping of inundation pattern of the Rann of Kachchh using multi temporal data gave clue to the possible reason for shifting of breeding ground of flamingoes (Thakker, 1982).

Materials and Methods:

The availability of food and variations in its abundance in different periods was analyzed through ground truth studies (Chapter 3.4A). The Remote Sensing Technique was also used to determine food availability and evaluate the habitat conditions of surrounding areas. The ground truth analysis (Chapter 3.4A) was compared with the interpretation of Remote Sensing images of the different periods.

The IRS WiFS, IRS P4-OCM, IRS P6 data and MODIS data of Great Rann, from September 2003 to April 2004 were used to generate detailed information regarding the habitat conditions of nesting ground after inundation by southwest monsoon. MODIS data were obtained from the website http://rapidfire.sci.gsfc.nasa.gov. Interpretations of OCM and IRS P6 data of period (i) before initiation of breeding (September 2003) (ii) at the beginning of nesting (October 2003) and (iii) active nesting period (January-February 204) were done and it was compared with OCM data of period of termination of breeding *i e* Aril 2004,

when the nesting was terminated, to study the habitat conditions at the time of start and termination of nesting.

Chlorophyll Map of October 2003 of the Great Rann was utilized to analyze the primary food present in water surrounding the nesting ground during the breeding season. The MODIS data were also used to study the primary food in the area. The interpretation of factors like food availability, water spread area, water depth *etc.* was done from the false color composite image using bands 3,6 and 8 of available OCM data.

Results:

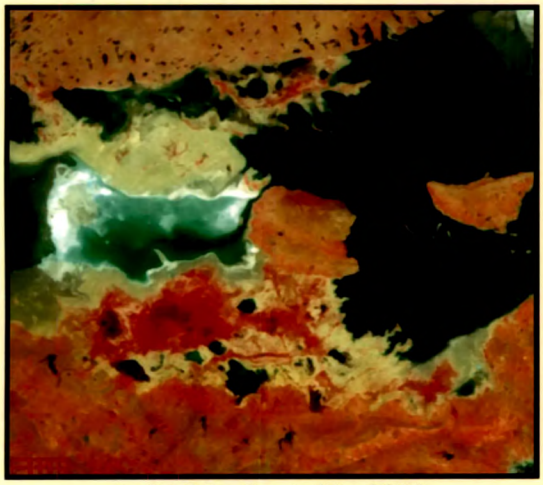
The OCM, MODIS and IRS P6 data of the Great Rann of Kachchh from September 2003 to April 2004 showed the period and patterns of inundation around Flamingo city in the Great Rann of Kachchh.

The OCM data of September 29, 2003 (Plate-3.4B-1), of Great Rann area, showed black and deep blue colors suggesting the inundation of the area by deep water. The entire Khadir Island was surrounded by deep water.

OCM data of October 15, 2003 (Plate-3.4B-2) showed deep blue and light greenish blue colors, suggesting that the area was still inundated with deep water, however compared to September 2003, the depth of water had decreased slightly. Shading of blue and black in OCM data of October, suggested the variation in depth in different parts in the sanctuary area and also the effect of wind on water. In October 2003, the Khadir island was still surrounded by water. The water was up to the edge of Rann around Kuda and Bela and also beyond that.

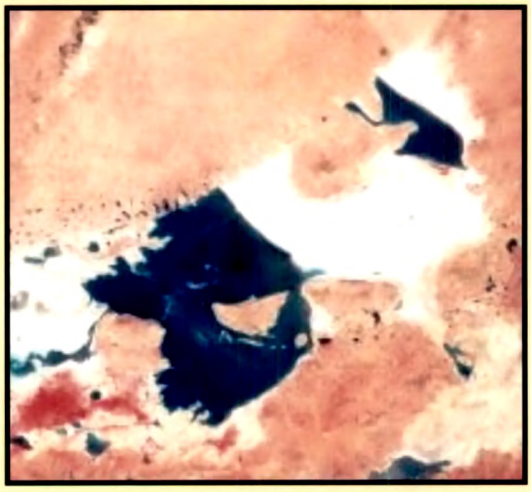
The IRS P6 data of November 22, 2003 (Plate-3.4B-3) showed drying of the Rann areas around Bela, Kuda and beyond. White color around the Rann of Kuda and Bela showed the salt encrusted areas. The areas around Khadir and Flamingo City were still inundated with deep water. However certain high elevated areas were exposed, which were seen as white dots in black/blue background.

Plate 3.4B : Remote Sensing Images of Great Rann of Kachchh

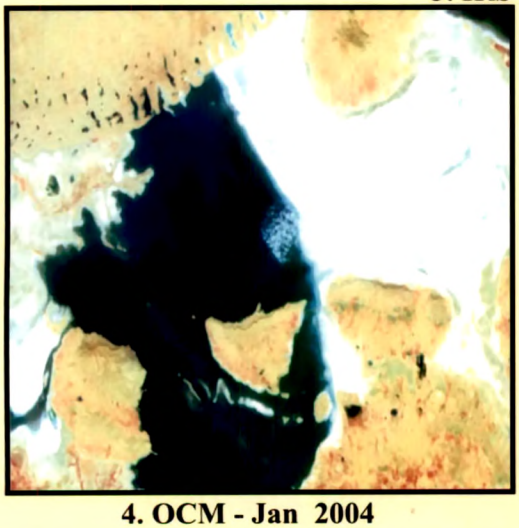


1. OCM - Sept. 29, 2003

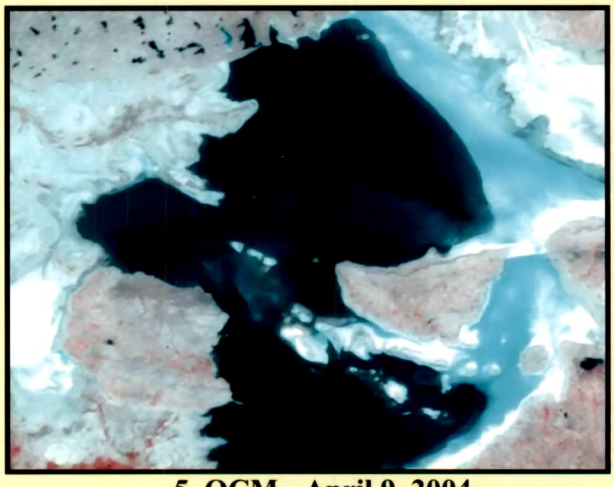
2. OCM - Oct. 15, 2003



3. IRS- P6 Nov. 22, 2003

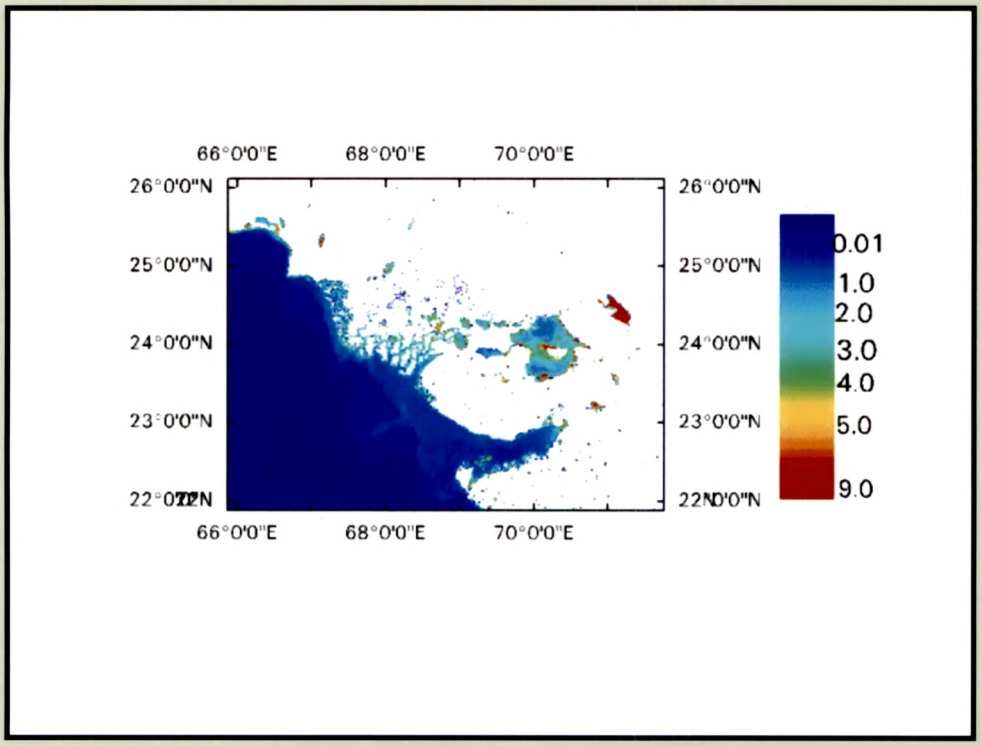


4. OCM - Jan 2004

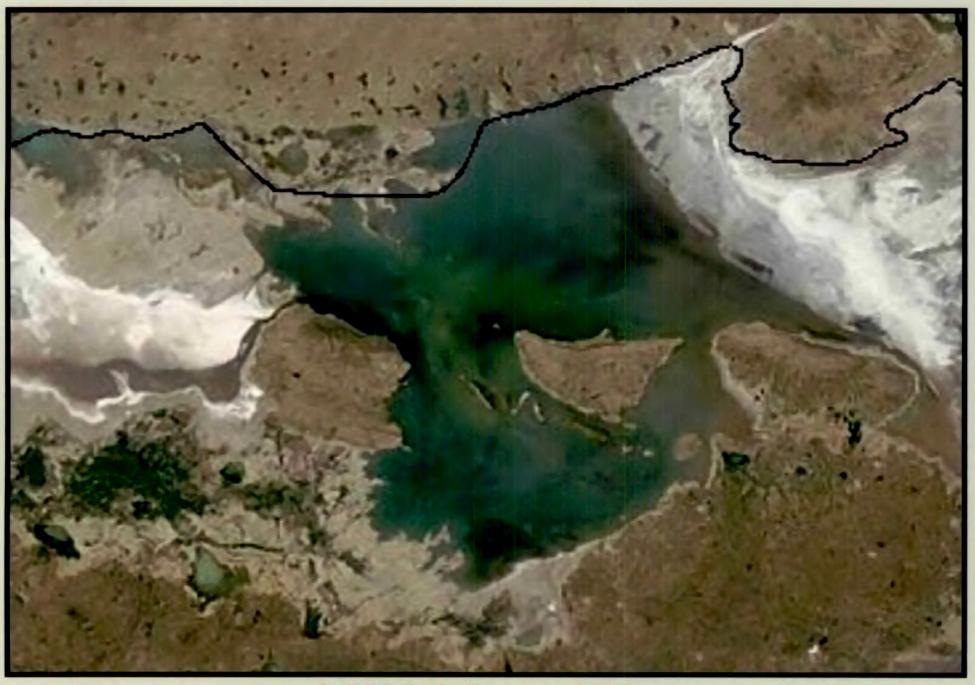


5. OCM - April 9, 2004

Plate 3.4C : Primary Food in Surrounding Water of Great Rann



1. Chlorophyll Image October 2003



2. MODIS October 2003

The OCM data of January 2004 (Plate-3.4B-4) showed, further receding of water on the eastern side of the Khadir island. The Rann around Bela and Kuda, was totally dry, with salt encrusted areas. Deep blackish blue color around the Flamingo City suggested deep water. Several white, salt encrusted, high elevated areas were exposed.

In the OCM data of April 9, 2004 (Plate-3.4B-5), the light blue color suggested wet soil between Khadir and Kuda. White color showed the exposed, dry salt encrusted areas. The Flamingo City was exposed out clearly seen as a dot. Large number of salt encrusted high elevated areas were seen in the water between Khadir and Pachchhm islands. Light blue color with white shading suggested that the depth of water had decreased around the Flamingo City.

Comparison of the Remote Sensing data from September 2003 to April 2004 revealed that the water spread area and water depth had decreased in April 2004, and the total dry, salt encrusted areas had increased. The comparison also revealed that the Great Rann started drying up from its eastern side.

The Chlorophyll Map (Plate-3.4C-1) of the Great Rann in October 2003 showed that the amount of Chlorophyll varied between 0.001 to 0.3 mg/lt. The green color in water, in MODIS data of October 2003 (Plate-3.4C-2) suggested the presence of primary food in water around the nesting ground.

Discussion:

Remote sensing data became very useful to study habitat condition of the nesting ground of flamingos, which is otherwise very difficult to monitor on ground due to hard terrain. The RS data provided information about the factors affecting the breeding of flamingos, like water depth, water spread area, inundation pattern, inundation period and availability of food.

The interpretations of Remote Sensing data supported the ground truth analysis. As the salt remains in the same environment in the Great Rann of Kachchh, sufficient inundation

of this area by southwest monsoon, diluted the salts, making the area inundated with brackish water, resulting in deep blue or black color in OCM data of September and October 2003, during which the salinity became comparatively low. The chlorophyll data and MODIS data also shows primary food around the nesting ground during the breeding season. Food is found abundantly during the active nesting season as seen by the ground truth studies.

The increase in temperature caused evaporation of inundated water and hence, decrease in water level, which was detected by ground truth studies also (Table 3.4a). The decrease in water spread area and depth are apparent by the white salt encrusted areas around the Flamingo City and the light blue color of water.

Conclusions:

1. Salinity is the major factor affecting food abundance in the Great Rann of Kachchh. Salinity varies with total inundation, *i.e.* total water spread and water level. A decrease in total inundation, increased salinity, which ultimately decreased the food. Hence, the flamingos terminated their nesting, when the salinity of water around the nest site increased.

2. As the nesting grounds are inaccessible during the monsoon and post-monsoon seasons, the Remote Sensing data can give information regarding the available factors supporting nesting, such as water spread, water depth, availability of primary food in the surrounding water *etc.* Hence, the possibility of nesting by flamingos in a particular area can be determined by reading the Remote sensing data of that area.