CRAB ECOLOGY AS POTENTIAL BIOMONITORING TOOL: STUDIES ON POPULATION AND BEHAVIOUR ECOLOGY OF *ILYOPLAX SAYAJIRAOI* (CRUSTACEA: BRACHYURA: DOTILLIDAE)

A SYNOPSIS OF THE THESIS SUBMITTED TO

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Summary

Word ecology dates from about 1900, but only in the past few decades has the word became part of general science. Ecology was and will remain the discipline that addresses highest and most complex levels of biological organisation. Ecology isn't just about species-rich forests, pristine wilderness, or scenic vistas. One core goal of ecology is to understand the distribution and abundance of living things in the physical environment. The literal meaning of of ecology is study of "life at home" with emphasis on the pattern of relationship between organisms and their environment. These patterns in nature are driven by interactions among organisms as well as between organisms and their physical environment. Untill there is crisis, humans tend to take natural goods and services for granted. During the 1970s, almost everyone became concerned about pollution, natural area, population growth, food and energy consumption, and biotic diversity, as indicated by the wide coverage of environmental concern.

Oceanic muddy beaches are one of the major habitat types present on Gujarat coastline. Gulf of Khambhat is one such region in which the estuarine mudflats of Kamboi holds a centre for attraction to tourists having mythological importance and also for very rapid high tides due to its unsual inverted funnel like geomorphological structure. The numerically dominant fauna on this beach are crabs from genus *Dotilla, Ilyoplax* and *Uca*, of which *Ilyoplax sayajiraoi* is a newly discovered species by Trivedi et al (2015). Fiddler crabs are significant link to higher trophic level in intertidal and shallow water food web, as they convert intertidal organic matter into smaller sized particles for many predators, both terrestrial (shore birds) and aquatic (marine crustaceans and fishes). The direct conversion of detritus to biomass may be the sole source of energy transfer to carnivore population (Nicholas and Moshiri, 1974). Yet no ecological or physiological studies are carried out for this species. This study employes a range of methods to increase our knowledge for *Ilyoplax* species. Mud flat coastline are very dynamic with faunal zonation patterns hypothesised to be worked upon by physical factors. *Ilyoplax sayajiraoi* occupy a very well defined zone on the muddy beach of Kavi-Kamboi. Ecological studies on these crabs will offer an opportunity to investigate what physical factors structured ditribution of crabs on mudflats of Kamboi. Crabs play significant role in maintenance of ecosystem and different methods have been suggested to assess the

effect of pollution on brachyuran crabs. Studies carried out have shown that these crabs can be established as a bioindicator species.

Population ecology is the study of ecological parameters that affect the population of specific species. Populations are groups of organisms of the same species living in the same area at the same time. Study plays major role in understanding conservation biology, involving population dynamics. It explains many questions like, which factors affect the rate of individual growth in present and future scenario. The study of population ecology includes understanding, explaining and predicting species distributions. Population ecology has its deepest historic roots and its richest development, in the study of population growth, regulation and dynamics or demography. It also includes major events relating to growth, development, reproduction and survival. It again may vary tremendously from one species to the next. Population ecology is the study of how populations of plants, animals and other organisms change over time and space and interact with their environment.

Introduction:

Ng *et al.* in 2008 gave annotated checklist of brachyuran crabs consisting of 6,793 species; 1271 genera and subgenera, 93 families and 38 superfamilies worldwide. Total 28 well established species are described under the genus *Ilyoplax* all over the World (Davie and Naruse 2010; Ng *et al.* 2008). Serene and Lundoer (1974) have provided the identification keys for the species of genus *Ilyoplax*. *Ilyoplax sayajiraoi* is very close to *Ilyoplax stevensi* and *Ilyoplax frater* described by Kemp (1919), as it falls under the group-III. Group-III species include *Ilyoplax stevensi* and *Ilyoplax frater*, but still showed significant morphological differences.

The total 808 brachyuran crab species belonging to 62 families have been reported from Indian waters out of which 226 species are reported from west coast of India while 461 species are reported from east coast of India (Dev Roy, 2013). In 2015 Trivedi *et al* compiled a checklist of 157 species of crustaceans belonging to 87 genera and 41 families of Gujarat. The highest diversity was recorded in Gulf Of Kachchh (138 species) followed by Saurashtra (76 species) and (GOKh) (37 species).

Work was carried out on population ecology of *Ilyoplax frater* (Kemp, 1919) at Korangi creek, Pakistan, showed highest population from December to May and densities decreased during August to October. Though juvenile recruitment was seen throughout the year. Cheliped length and gonopod of male crab showed a positive relationship for mating and other antagonistic behavioural adaptations (Qureshi, 2011).

Waving behaviour is most important character of genus *Ilyoplax,* it may show courtship or agonistic way of expression. It shows three ways of waving behaviour; 1. Circular 2. Vertical 3. Asymmetric. Species covered in genus *Ilyoplax* shows asymmetric behaviour (Kituara and Wada, 2006). Droving behaviour is seen after the breeding period in this genus observed in *Ilyoplax dechampsi* for first time (Rathbun, 1913). Kitaura *et al* in 1998 reported that *Ilyoplax deschampsi* performs neighbour burrow plugging behaviour, but does not build barricades which are interpreted as the more highly developed territorial behaviour. Among crabs of the family Ocypodidae, *Ilyoplax* has been known to exhibit unique mud-using territorial behaviour against neighbours, including neighbour burrow plugging, barricade building, and fence building (Kitaura et al., 2006). Pollution studies on *Ilyoplax gangetica* (Kemp, 1919), shows that sewage waste decreases the rate of feeding activity and bioturbulation. Behavioural change in crab thus can be used as bioindicator (Bartolini *et al.* 2009).

Aim and Objectives:

1. To study the population ecology of *Ilyoplax sayajiraoi*

(I) Population size and sex ratio

(II) Distribution pattern

(III) Zonation with respect to changes in sediment characteristics

2. Burrow morphology of *Ilyoplax sayajiraoi* and sediment analysis

(I) Seasonal variations in burrow morphology

(II) Distribution of burrows in different tidal zones

(III) Sediment characterisation

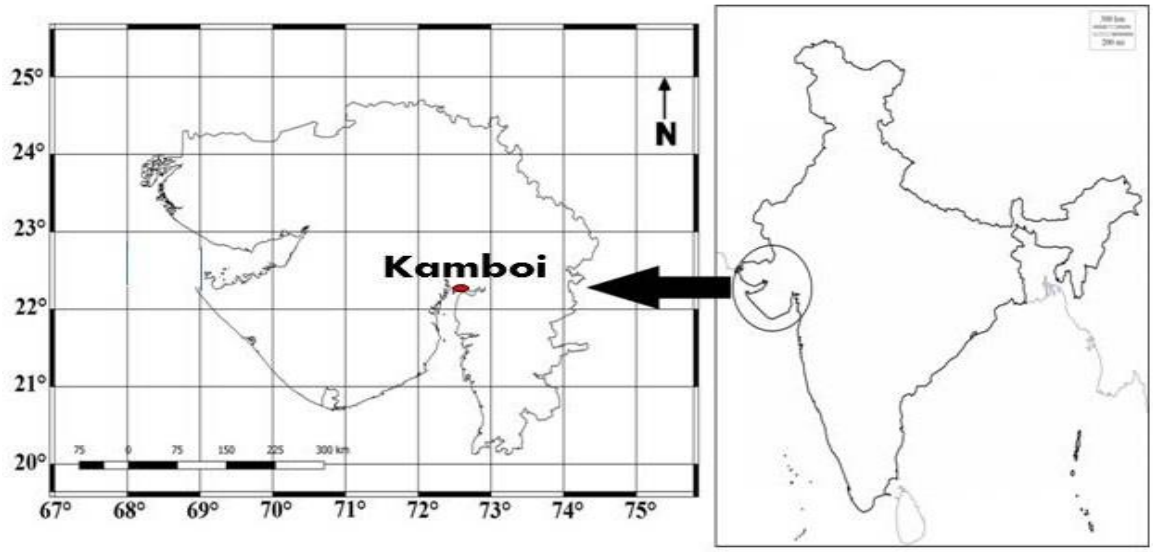
3. Insitu effect of chemical pollutants on behavioural ecology of *Ilyoplax sayajiraoi.*

(I) Normal behavioural analysis (Foraging, Feeding, Popping, Droving, Cheliped waving, Territorial)

(II) Comparative study of above objective (I) and in-situ chemically driven behavioural studies

(III) Establishing *Ilyoplax sayajiraoi* as a bio-indicator

Area of study:



Arabian Sea is known for its high-shore currents which rise due to strong winds. The average speed of the wind is 3 to 4 knots that dominate the flow which is directly proportional to the ebb and flow tides. The maximum velocities of 6 knots associated with high wave energy occur during mid-tide (Unnikrishnan *et al.* 1999). With transition in seasons the flow also adjusts accordingly. The turnover residence times are quite short because of its shallow depth, large tidal amplitude and strong tidal current. With a physical funnel shaped structure of Gulf and partially enclosed nature at the head, the tidal height increases tremendously in the upstream. After Bay of Fundy in Newfoundland coast of Canada (17 m) 2nd highest tide recorded is at Bhavnagar reaching up to height of 12.5 m.

Gulf is known for its extreme tides and variations in heights of the tides. It is 70Km wide and 131 km long. It lies between Saurashtra peninsula and the mainland Gujarat. Gulf is inverted funnel shaped and occupies 3120 km^2 of area. The Gulf merges into the shallow estuaries of the Mahisagar and Sabarmati rivers through Khambhat Channel. Apart from Sabarmati Mahisagar, the other major rivers joining the eastern shore of the Gulf

include Dhadhar, Narmada and Tapi. Westward cover to gulf is of minor seasonal rivers such as Utavali, Malesari, Shetrunji River and Dhantarvadi that join the Gulf.

Kamboi is the place where Mahi River connects the Gulf at northern end forming a broad estuarine stretch of 50km ranging from Kamboi to Fajalpur. River Mahi is major one that flows through Gujarat state. Estuary is very shallow with brackish water having large quantities of lagoons and swamps with high species richness. Mahi estuary is a tropical estuary with a chain of shallow brackish water lagoons and swamps, is rich in aquatic life.

Methodology:

1. Basically it is divided into two main parts: A. Abiotic component B. Biotic component

A. Abiotic component

- Water and sediments were collected from site and following APHA procedure various physical and chemical analysis were carried out.
- Methodology for burrow analysis is described further in detail.

B. Biotic component

- Distribution pattern of *Ilyoplax sayajiraoi* is studied by population ecology, its detailed methodology is given further.
- Behavioural ecology was carried out to establish *Ilyoplax sayajiraoi* as a bioindicator species. It consist of in-situ video recording of normal behaviour and chemically treated behaviour at particular time interval and folowing the format. Detailed understanding is given further.

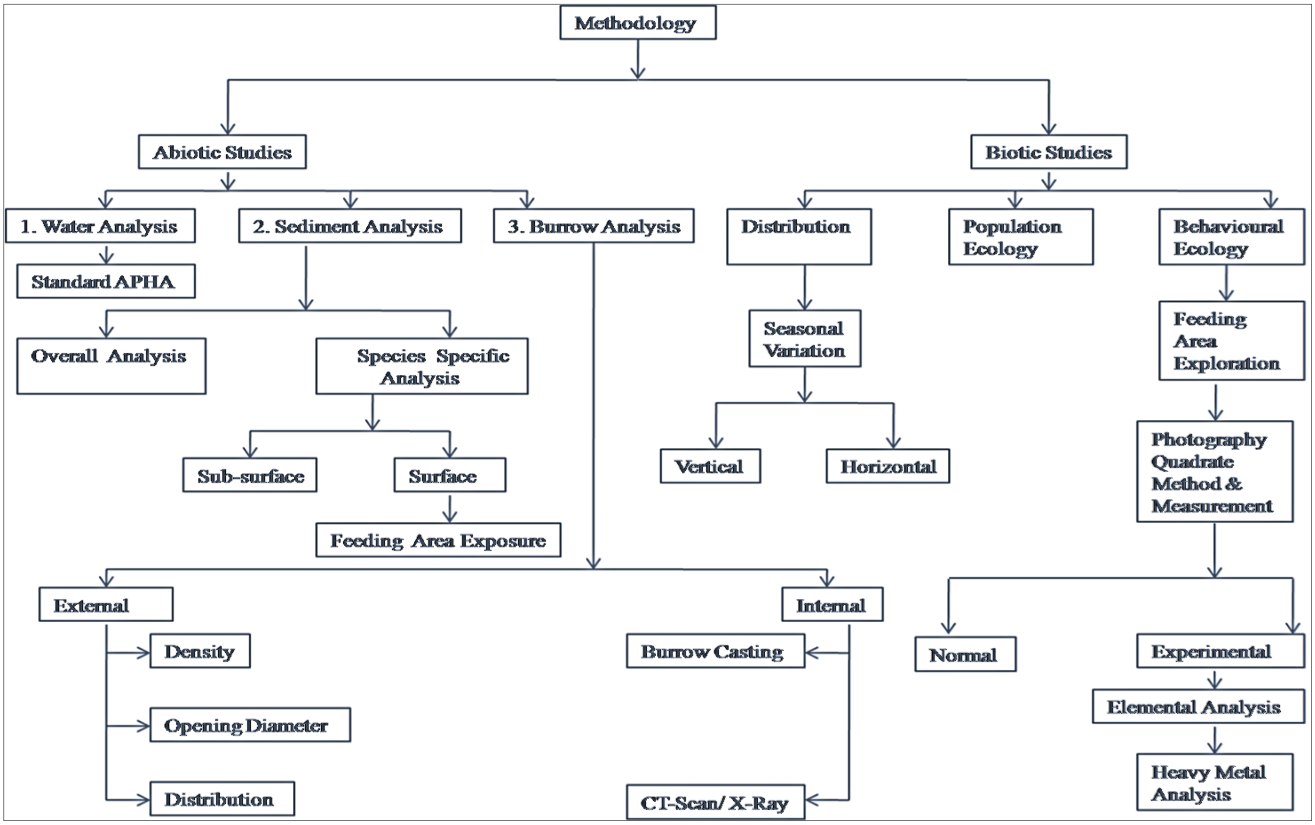


Figure: 1

A. Methodology for population ecology

1. As shown in figure:2, entire area of *Ilyoplax syajiraoi* is divided into 5 segments each at a distance of 200 meter, thus covering 1000 meter of the area horizontally and vertically at a distance of 10 meter. Per segment one quadrat is placed.

2. Random sampling was carried out with the help of quadrat sampling technique at predetermined time period every month for one year.

3. Specimens were collected and stored in 10% formalin and brought back to laboratory to carry out various morphological analysis like, sex determination (male/female/ovigerous female/ juvenile), size determination (by measuring carapace width and length) and chela length.

4. Statistical analysis were carried out to get various relationship curves between parameters and seasonal changes in population.

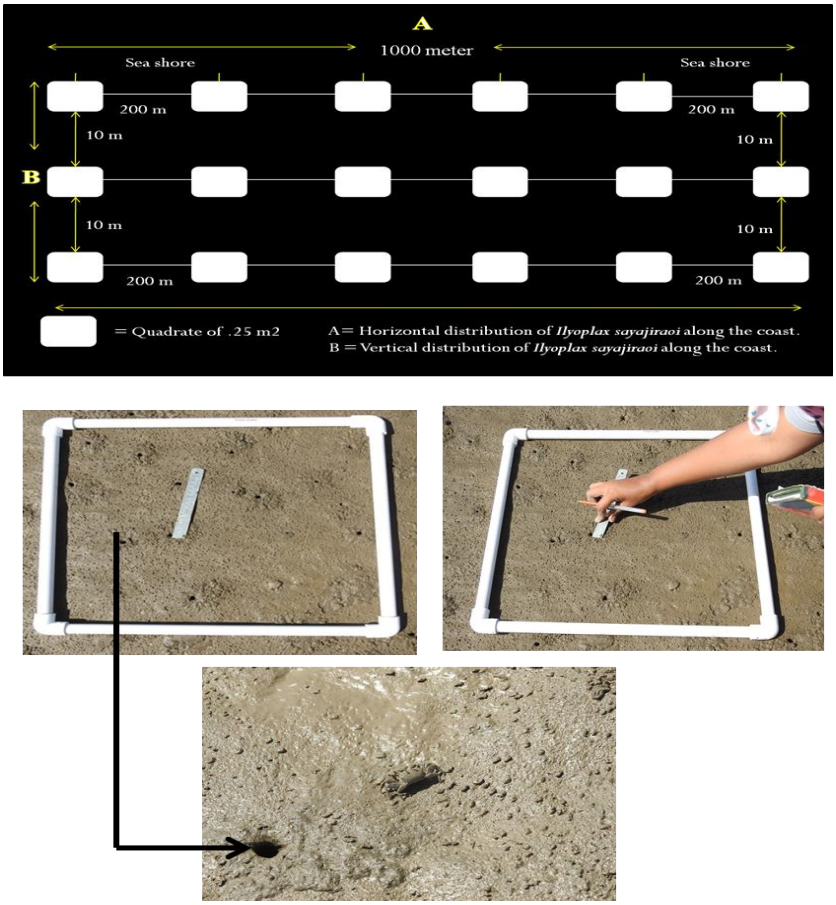


Figure: 2

B. Methodology for burrow analysis

1. Burrows of *Ilyoplax sayajiraoi* was identified and burrow diameter was measured along the transect.

2. Resin mixed with cobalt and catalyst (1:2) was poured to burrows till it gets completely filled. If Crabs emerged from the burrows were collected, sexed and the carapace width and length measured using vernier callipers (± 0.1mm).

3. Burrow cast gets solidified after two hours and were dug up for subsequent measurement of burrow dimensions. The volume of the burrows was determined by weighing the burrow cast (± 0.1g).

4. Seasonal burrow analysis was carried out and relationships between various parameters were interpreted.

C. Eco-behavioural studies

Methodology for eco-behavioural analysis:

- DSLR camera attached to tripod stand was set, focused on crabs of *Ilyoplax sayajiraoi*.
- Two different types of treatments were applied to analyse the behavioural difference in crabs of *Ilyoplax sayajiraoi*.
- Each treatment was divided into three seasons, summer, monsoon and winter. Each video was divided into initial, medial and final according to the specific time interval.
- Quadrats were marked (Chemically treated, fertilizer treated and normal behaviour)
- According to the type of quadrates, 1. Chemically treated- 10% solution of $CoCO_3$ was sprayed evenly covering all burrows of *Ilyoplax sayajiraoi.* 2. Fertilizer was evenly sprayed on quadrate.
- Video recording of their behaviour was carried out and noted in particular format sheet after comparing all the behavioural videos in the laboratory.

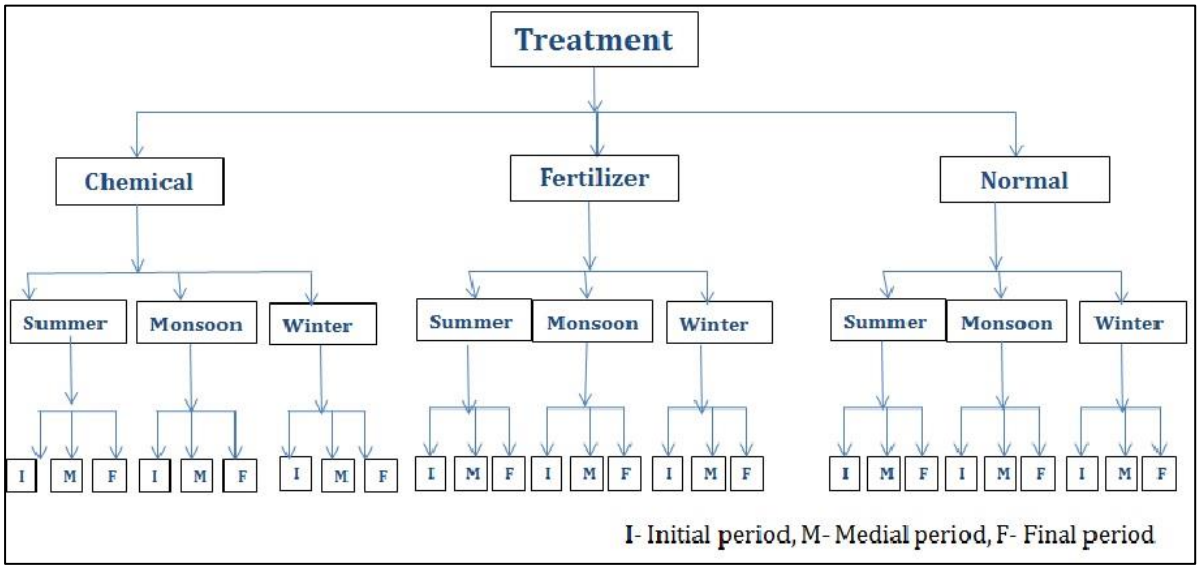
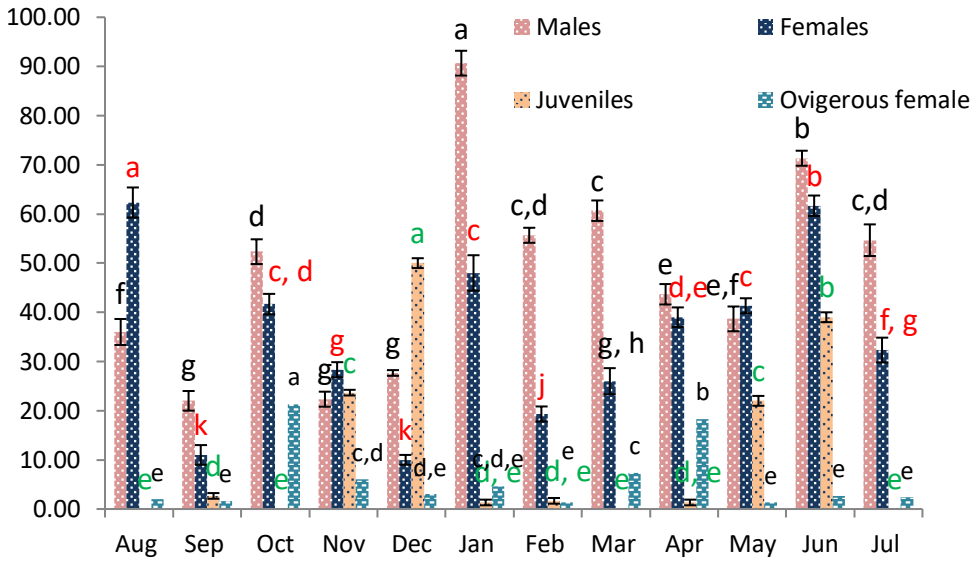
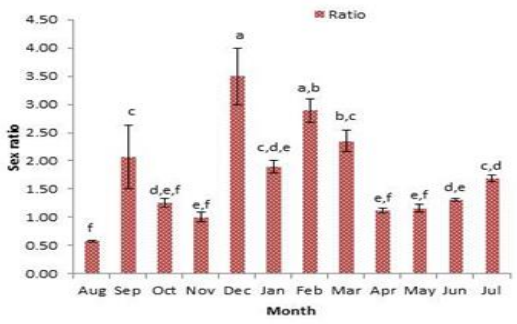


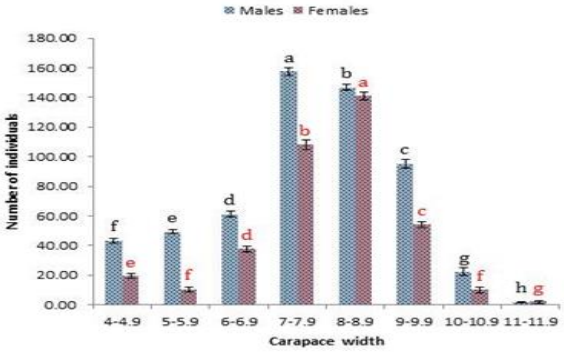
Figure: 3

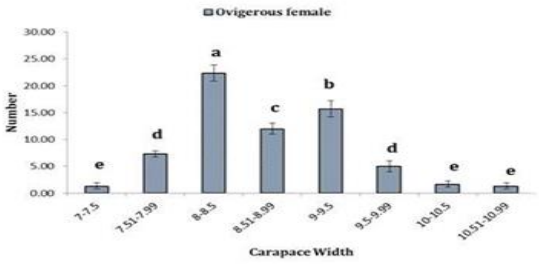
Analysis:

A. Population ecology









	LTZ		MTZ		UTZ	
	Regression equation	**R2**	**Regression equation**	**R2**	**Regression equation**	**R2**
Sediment temperature						
Ilyoplax sayajiraoi	y = 2.2447x - 53.054	0.8734	y = 3.8783x - 89.518	0.8695	y = 0.5748x - 11.483	0.6803
Dotilla blanfordi	y = 2.1071x - 42.511	0.4437	y = 0.0375x + 1.5159	0.0178	y = -0.1067x + 3.4142	0.5257
Uca annuplies	y = 0.9781x - 23.941	0.9243	y = 2.2256x - 54.387	0.8785	y = 2.6073x - 64.079	0.8376
Sediment pH						
Ilyoplax sayajiraoi	y = 2.2143x - 2.4286	0.8705	y = 0.0444x + 6.5278	0.8127	y = -x + 13	1
Dotilla blanfordi	y = -13x + 93.5	0.6036	y = -x + 13	1	y = -0.2x + 7.75	0.9143
Uca annuplies	y = 10x - 62.286	0.5738	y = 0.75x - 0.2857	0.9037	y = 0.1147x + 6.8824	0.8521
Salinity						
Ilyoplax sayajiraoi	y = -0.25x + 11.083	0.1875	y = 0.1136x + 38.451	0.1703	y = 0.7143x + 2.3333	0.169
Dotilla blanfordi	y = -0.6667x + 40	0.1667	y = 0.3529x + 38.588	0.0882	y = -0.2857x + 39.143	0.0714
Uca annuplies	y = 0.3529x + 38.353	0.0882	y = 0.1491x + 38.677	0.1491	y = 0.2051x + 38.282	0.2051
Moisture content						
Ilyoplax sayajiraoi	y = 3.9423x + 48.904	0.9247	y = 0.2096x + 1.8357	0.9125	y = 3x + 18	0.6857
Dotilla blanfordi	y = 0.1854x - 2.3227	0.8832	y = 3.5385x + 23.231	0.9222	y = 0.2286x - 4.7143	0.9143
Uca annuplies	y = 0.2346x - 7.2231	0.9247	y = 0.3371x - 4.7507	0.9551	y = 2.5x - 35	1

Table-1 Sediment/Physical characteristics with respect to species.

B. Burrow morphometric analysis

Summer

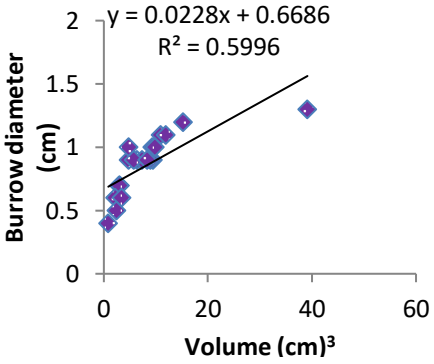


Figure 4(a)

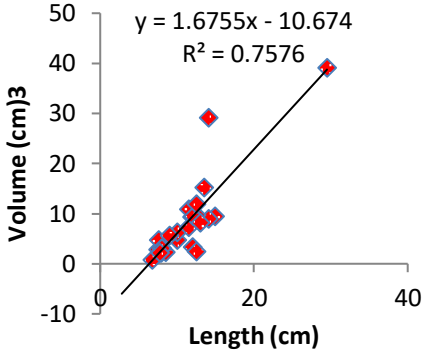


Figure 4(b)

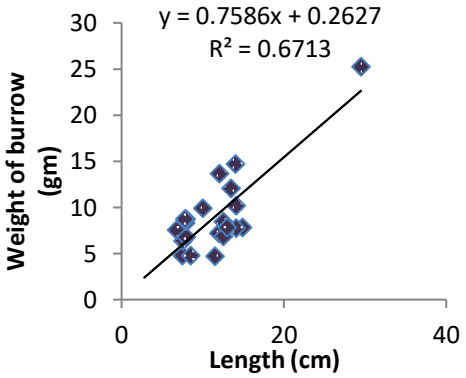


Figure 4(c)

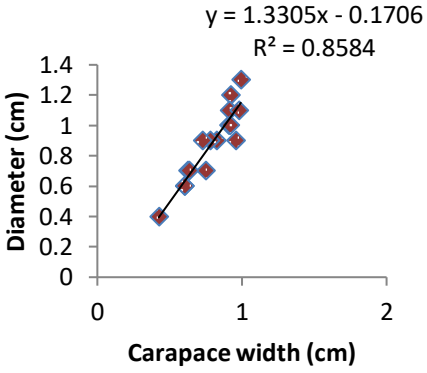


Figure 4(d)

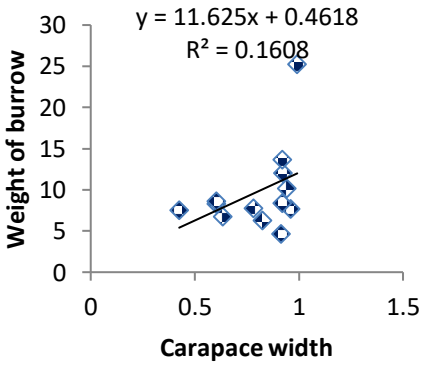


Figure 4(e)

Monsoon

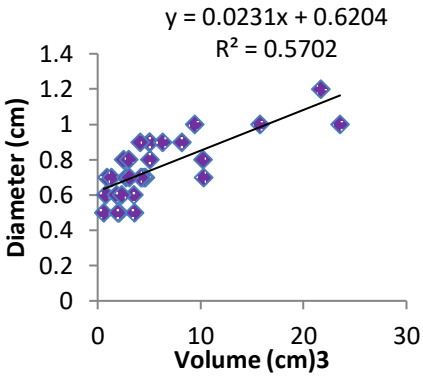
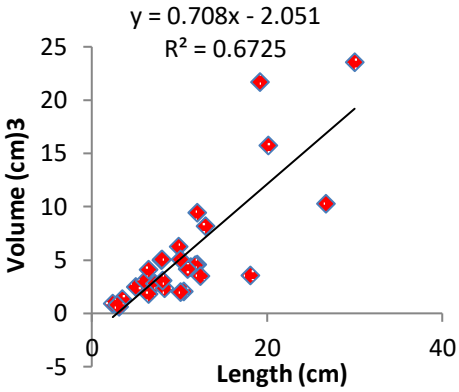


Figure 5(a)



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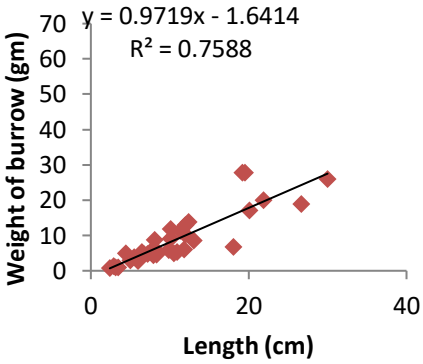


Figure 5(c)

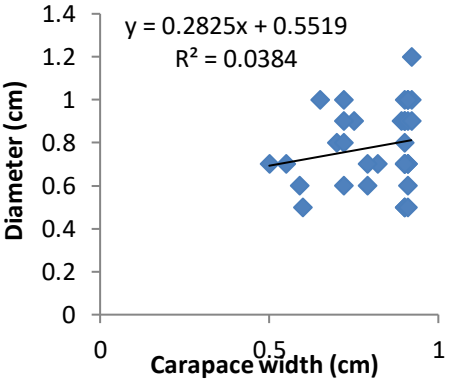


Figure 5(d)

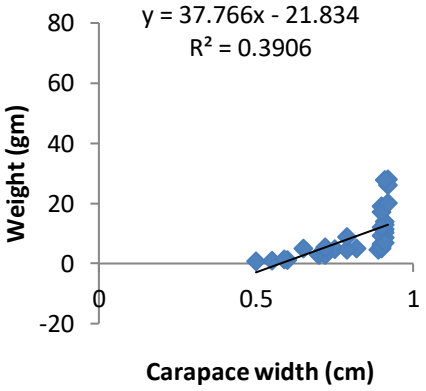


Figure 5(e)

Winter

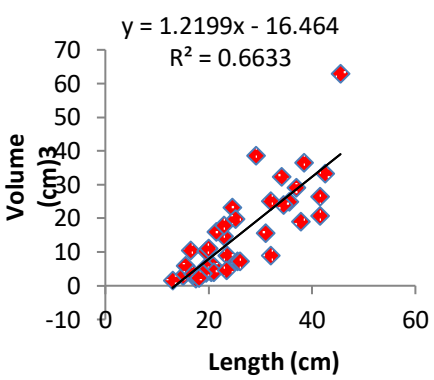


Figure 6(a)

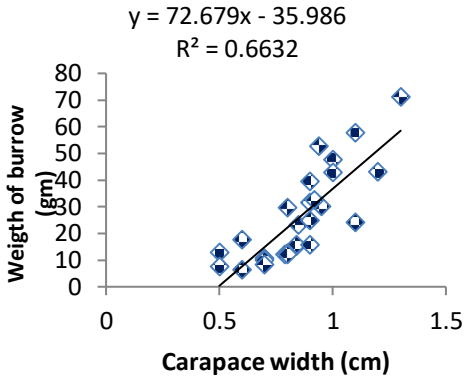
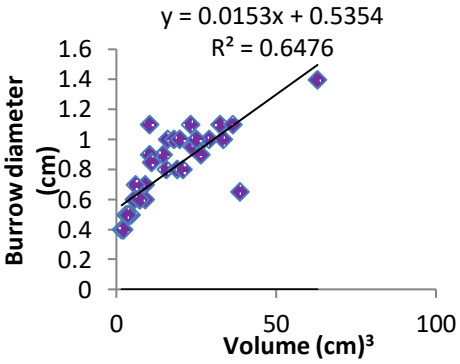


Figure 6(b)



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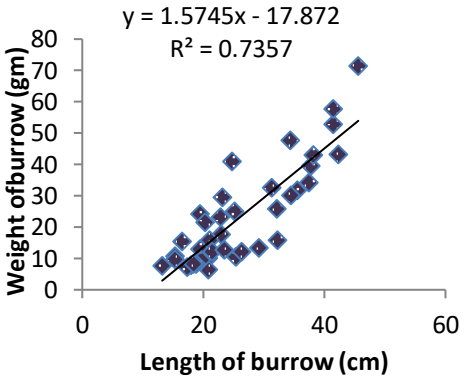

Figure 6(d)

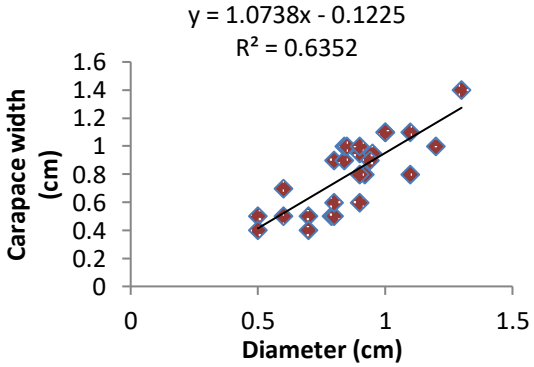

Figure 6(e)

C. Eco-behavioural analysis:

Date	18-05-2019	Type of study: Chemically Treated Burrow						
Season	Summer							
Time	Poonam/9:42							
Video	1							
Sr.No.	Total time	Observation						
		Foraging	Feeding	Popping	Time Spent In Burrow	Chelipad waving	Fighting & Territorial	Remarks
Crab:1	03:24	Not observed	Not observed	0'52" to 1'01"=9" 1'51" to 3'05"=74" T= 83"	3'24" to 1'23"=2'01" T= 121"	Not observed	Not observed	Maximum time spent clinging to the burrow
Crab:2	03:24	Not observed	Not observed	0'4" to 0'53"= 49" 1'48" to 2'45"= 57" T= 108"	3'24" to 1'10"= 2'14" T=134"	Not observed	Not observed	Mostly come out at similar time
Crab:3	03:24	Not observed	2:20 to 2:27=7" 2:59 to 3:00=1" T= 8"	0'31" to 0'32"=1" 0'53" to 1'01"= 8" 1'35" to 3'17"= 102" T=111"	3'24" to 2'25"=1'05" T=65"	Not observed	Not observed	Time for spending out increases in asceding order
Crab:4	03:24	2'28" to 2'39" 11"	1'47" to 2'1" =14" 2'39" to 3'05"= 26" T=40"	0'49" to 0'57"= 08" 1'34" to 3'22"=108" T= 116"	3'24" to 2'28"= 64" T= 64"	Not observed	Not observed	-

Table-2 Four different crabs were focused and their behavioural activity treated with chemical, was video recorded.

Result:

The major outcomes of present research work are as follows:

- Population structure was observed for one year (Aug_2016 to July_2017) that showed 1139 specimens of *Ilyoplax sayajiraoi* (576 males, 421 females and 142 juveniles).
- The average population of *Ilyoplax sayajiraoi* at Kamboi is 10 individuals/0.25m^2. Highest population in month of December and January and lowest in month of September.
- The sex ratio of male: female was 1:1.3, giving variability in expected ratio of 1:1. There is significant difference between number of male and females following Pearson correlation of 0.189 and showing notable biased towards male.
- Ovigerous female and juveniles give bimodal graphs for population growth and months are October, April for ovigerous and November, May for juveniles.
- It shows 4 major shaped burrows J (single curve), I (linear), S (two curved) and Spiral of which 'J' is predominantly present. Proper burrow formation takes place in winter season and least in summer.
- Species is burrowing in nature and density ranges from 15 burrows/ m^2 to 25 burrows /m^2. Burrow diameter is from 5-11mm and burrow depth is from 15-40cm.
- In summer optimum correlation was obtained between volume and diameter of burrow (R^2=0.599) Fig 4(a); length vs. volume of burrow and weight also showed positive correlation (R^2=0.757) Fig 4(b) and (R^2=0.671) Fig 4(c) respectively; carapace width of crab and burrow diameter and weight (R^2=0.85) Fig 4(d); (R^2=0.16) Fig 4(e) respectively determining negligible correlation. In monsoon optimum correlation was obtained between volume and diameter of burrow (R^2=0.57) Fig 5(a); length vs. volume of burrow and weight also showed positive correlation (R^2=0.672) Fig 5(b) and (R^2=0.758) Fig 5(c) respectively; carapace width of crab and burrow diameter and weight (R^2=0.038) Fig 5(d); (R^2=0.390) Fig 5(e) respectively determining negligible correlation. In winter strong positive correlation was seen w.r.t. burrow between its length of burrow and volume (correlation coefficient R^2=0.6633) Fig 6(a); carapace width of crab and weight of burrow (R^2=0.66) Fig 6(b); volume and diameter of burrow

(R^2=0.64) Fig 6(c); burrow diameter and carapace width of crab (R^2=0.635) Fig 6(d); length and weight of burrow (R^2=0.735) Fig 6(e).

- Table-2 shows activities of four crabs which are chemically treated by 10% solution of $CoCO_3$. Foraging behaviour was observed only in crab-4. Feeding behaviour was observed in crab-3 and 4. Popping out behaviour was seen in all the four crabs. Chelipad waving and territorial behaviour was seen in none of the four crabs.

Discussion:

- The unbalanced sex-ratio in the population was reported as reflection of different foraging behaviour between males and females with males as more active grazers looking for food away from shelter whereas females tend to graze near their shelter. This could make males more exposed to sampling (Arab *et al.* 2015; Abele *et al.* 1986).
- A low population was seen in April and May; a significant increase in temperature gives rise to harsh environmental conditions for crabs to survive. The maximum surface temperature observed during that period was 40^{o}C, and burrow temperature was 34^{o}C. Juvenile recruitment was outrageous in winter and monsoon as overall temperatures were low and prohibitive in the summer season. Several such studies have been carried out on genus Scopimera (Silas and Sankarankutty 1967; Fielder 1971; Wada 1976; Wada 1983a, b). Population structure has been evaluated by several methods that include size-frequency distributions, sex ratio, juvenile recruitment and reproductive season (Thurman 1985; Diaz and Conde 1989; de Arruda Leme and Negreiros-Fransozo 1998; Yamaguchi 2001).
- Population of *Ilyoplax sayajiraoi* is more concentrated to mid tidal zone as grain size, moisture content and organic content is suitable for its individuals to grow and develop.
- Analysis showed that burrow diameter is significantly smaller at foreshore compared to that of backshore, suggesting that larger individuals reside along the backshore where they excavate deeper and larger diameter burrows to minimize chances of desiccation.

- The species' population is restricted to a particular area and requires specific habitat to perish, making species *Ilyoplax sayajiraoi* highly habitat-specific, limiting its distribution. In the present scenario, the Gulf of Khambhat is bordered by many industries. A slight change in *I. sayajiraoi's* habitat by pollutant influx from industries will affect its population and distribution. Thus population structure of this species will act as baseline data for such researches establishing it as a bioindicator.
- Positive Pearson coefficient was obtained for crab's carapace width and burrow diameter. This analysis implies that crab fit tightly in the respective chamber, which may prevent them from being displaced from larger crabs.
- In analysis carried out till date, territorial (intraspecies and interspecies), feeding, popping, waving and foraging behaviour can easily be observed in this species, plugging behaviour just before arrival of high tide is also observed. Overall frequency of popping, feeding and foraging decreases.
- Crabs of the burrows around which chemical was sprayed had reduced popping out activity and foraging activity as compared to untreated in-situ crabs. If sudden rush can affect the present behavioural activity then layover of huge chemical (heavy metals) contamination can have caused or causing a great impact on present and previous species.