

**“STUDIES ON BIOLOGICAL ASPECTS OF RAINBOW SARDINE,
DUSSUMIERIA ACUTA, VALENCIENNES, 1847, WITH A NOTE ON
SARDINE FISHERY OFF MANGALURU COAST”**

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JULY, 2016

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Thesis submitted to the
Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar in
partial fulfillment of the requirements for the award of the degree of

MASTER OF FISHERIES SCIENCE

In

FISHERIES RESOURCES AND MANAGEMENT

By

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JULY, 2016

DEDICATED
TO
MY BELOVED PARENTS
AND MY
SISTER

**KARNATAKA VETERINARY, ANIMAL AND FISHERIES SCIENCES
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DEPARTMENT OF FISHERIES RESOURCES AND MANAGEMENT

COLLEGE OF FISHERIES, MANGALURU

Certificate

This is certified that the thesis entitled “*Studies on biological aspects of rainbow sardine, Dussumieria acuta, Valenciennes,1847, with a note on sardine fishery off Mangaluru coast.*” submitted by **Mr. Halesha, K., I.D.No.MFK 1414** in partial fulfillment of the requirements for the award of Master of Fisheries Science in Fisheries Resources and Management of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar is a record of bonafied research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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ACKNOWLEDGEMENT

I wish to record my deep sense of appreciation and gratitude to my major advisor **Dr. H. N. Anjanayappa**, Professor and Head, Department of Fisheries Resources and Management, for his pragmatic support, constant encouragement and inspiration during my study period. His guidance and keen interest have helped me a great deal in the execution of the research work as well as course work. It is solely because of his motivation that this thesis is in the present form.

I express my heartfelt gratitude to members of advisory committee, **Dr. S. Benakappa**, Professor, Department of Fisheries Resources and Management, **Dr. K. S. Ramesh**, Professor, Department of Aquaculture, **Dr. Shivakumar Magada**, Professor, Aquatic Environment and Management, **Dr. S. Varadaraju**, Professor, Department of Fisheries Engineering Technology, for their regular counsel and support during study and helpful comments for the improvement of the thesis

I express my sincere gratitude to **Dr. S. R. Somashekara**, Professor, Department of Fisheries Resources and Management, **Dr. Mansing Naik**, Associate Professor, Department of Fisheries Resources and Management, **Shri. Kumar Naik A. S.** Assistant Professor, Department of Fisheries Resources and Management, for their moral support which has helped me to execute my P.G.studies smoothly.

I am thankful to **Smt. Geetha** and **Sudheer** for their help in the department. My thanks are also due to the **academic unit** who rendered a helping hand whenever I approached them and **library staff** for their help to locate the literature scattered over diverse source in the library during the study period.

I would also thank my seniors **Mr. Jithendra**, **Mr. Rajesh D.P**, **Miss. Nayana P**, **Miss. Chitra Soman**, **Mr. Devanand T.N** and **Mr. Kishor C** for their moral support during my

studies. I must thank my friends **Venugopal, Shoba Rawat, Suma, Ashwini, Manjushree, Sahana, Manjunath** and others who helped during my study period.

I am thankful to **Puneeth, Shreeharsha, Madhushree, Srinivasa, Gayathri Pandey, Pema**, for their sweet memories. I am thankful to **Manoj Kumar, Mahesh Sonwal , Sneha Darshan, Pramod Suvarna, Adarsh** and others who have directly or indirectly helped in my research endeavour.

My words will not be enough for the affection, care and moral support of my father **Mr. Krishnappa R.C** and my mother **Mrs. Sukanya** whose prayers made me reach whatever I am in my life. The prayers and encouragement of my lovely sister **Roopini. K** helped me to work hard and paved the way for success in my life.

Finally, I am deeply indebted to the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar.

Mangaluru

July 2016

(Halesha.K)

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I. INTRODUCTION

Fish is consumed by a large percentage of population in the world due to its high quality protein. It contains the most important nutritional components and serves as a source of energy for human beings. Majority of the nutrition experts have recommended that the human beings should consume fish every day as it can reduce the risk of cancer, including colon, breast and prostate, lower the risk of Dementia, and Alzheimer's diseases and prevent the cardiovascular diseases (Palani kumar *et al.*, 2014)

The lesser sardines belong to the families Clupeidae and Dussumieridae. The lesser sardines rank much lower than the oil sardines. They are shoaling fishes, the longer shoals striking the coastal waters seasonally resulting in quite good catches. They occur commonly in the inshore waters along both the east and west coasts of India. The lesser sardines comprising several species of genus *Sardinella*, other than *S. longiceps* showed wide distribution in the tropics and one of the major pelagic fishery resources of India. They occur in the landings of all the maritime states. However, they particularly contribute to a lucrative fishery along the southeast and southwest coasts. Of the 15 species of lesser sardines in the Indo-Pacific region, 12 species occurred in the Indian waters namely *Sardinella jussieu* (Tembang), *S. gibbosa*, *S. fimbriata* (Fringe-scale sardine), *S. albello* (Short-bodied sardine), *Amblygaster sirm* (Spotted sardine /Trenched sardine), *S. dayi*, *S. clupeoides*, (Bleeker smooth belly sardine) *S. melanura* (Black-tipped sardine), *S. sindensis*, *Escualosa thoracata* (White sardine), *Dussumieria acuta* (common sprat/ rainbow sardine) and *D. hasseltii*

Dussumieria acuta belonging to family Dussumieridae are small pelagic fishes widely distributed in tropical and temperate regions of the Indo-pacific. The Gulf of Mannar and

the Palk bay, around Mandapam area on the south-east coast of India where rainbow sardine form major fisheries.

The various investigations mentioned that the rainbow sardine is only short account limited due to one or other aspects of biology, such as food and feeding habits, spawning season, description on larvae and early development. Moreover, the identification of this species also been confusing to most of the earlier workers on biology and systematic (Radakrishna Nair, 1982).

The lesser sardines do not grow to a big size, 0 and 1-year size classes mainly sustain the lesser sardine fishery. Total length of the different species forming the fishery ranges from 4 to 24 cm. Fishing season of lesser sardines form a year round fishery in different regions of the country, but the fishing season, species composition and catch rates vary between and within regions. On the east coast along West Bengal, Odisha and Andhra Pradesh coast it extends from November to April-May and on the southeast coast of Tamil Nadu and Pondicherry, it is done throughout the year. On the west coast, it is from August to January/February in Kerala; In Karnataka September to November, In Goa September, February, In Maharashtra December and April. Traditional, motorized and mechanized boats are used for catching lesser sardines. Canoes and plank built boats with outboard engines are also operated. Seines (shore seines, boat seines, ring seines and purse seines), gillnets, bag nets and trawl nets are the gears commonly used for catching lesser sardines. (Anon, 2014).

The lesser sardines exhibit fast growth, have short life span (2-3 years) and high natural mortality. Most of the species attain 70% of their maximum length in the first year itself. They are consumed in the fresh/frozen/dried/salted-dried form, smaller sized fishes are used for fish meal, preparation of poultry and fish feed. Exploitation of small pelagic fish

from the coastal waters is sustainable and they are easily vulnerable to the traditional sector. As no single species is harvested continuously, there is no excess fishing pressure at present on the lesser sardines.

Although rainbow sardines have been landed in local marine fish fauna of Mangaluru region, and forms a valuable fish species of the total catch, there is paucity of information on the biology of fish species. Hence the present study was undertaken to investigate, fishery, food and feeding habits, length-weight relationship, condition factor and reproductive biology of fish species from Mangaluru region, with following objectives-

Objectives

1. To study the length-weight relationship.
2. To study the food and feeding habits and reproductive biology.
3. To ascertain sardine fishery off Mangaluru coast.

II. RIEVIEW OF LITERATURE

2.1. Taxonomic Studies:

According to Bleeker (1872) the characteristics of *Dussumieria acuta* mentioned as follows. Small silvery fishes, elongate, cylindrical; belly rounded, without keel of scutes. Snout distinctly pointed, mouth small, premaxillae rectangular; branchiostegal rays usually 13-15. Dorsal fin origin a little behind midpoint of body; anal fin short, far behind dorsal fin base. Scales thin and deciduous.

Maxillary not reaching below front margin of eye. Origin of anal fin far behind dorsal, pectorals pointed, caudal fin deeply incised. Distinct teeth on jaws, Palatines, pterygoids and tounge, gill racker about 20, with very fine spines along the inner side. Scale thin, deciduous, longitudinally (Radakrishna Nair, 1982).

2.2. Length - weight relationship

The length weight relationship were originally used for estimating the weight corresponding to a given length and to provide information on the condition of fish (Tesch, 1968).

Fish size is more biologically relevant than age mainly because several ecological and physiological factors are more size dependent than age dependent , variability in size has an important implications for diverse aspect of fisheries science and population dynamics (Erzini, 1994).

In the field of fish biology, physiology, ecology and fisheries management, the length-weight relationship having more important applications. In biological studies, it enables seasonal variation in growth to be followed and the calculation of condition indices (Richter, 2000).

Length-weight relationships of oil sardine give primary importance on setting up yield equation, in estimating the fish landings and in comparing population in space and time. Value of regression coefficient obtained from the length-weight relationship for small fishes (20- 39 mm) were 3.6 and for larger fishes (77-124 mm) were 3.0 (Antony Raja, 1971).

Mbaru *et al* (2010) studied length weight relationship of *Dussumeria acuta*. The maximum length and weight achieved at 19.5cm and 120 grams with a and b values -4.093 and 3.228 respectively.

Sekharan (1968) reported that the length-weight relationships in *S. albella* and *S. gibbosa* were estimated. In *S. albella*, the regression coefficients of the 20-39 mm size group the larger indeterminate of the 40-95 mm group and the sexes were found to be significantly different from one another and b value from 3. In *S. gibbosa*, the regression coefficients of the 20-39 mm group and the larger fish (indeterminate of the 40-95 mm group) were significantly different from one another and from b value 3.

Al-Jufaili Saud (2011) studied the overall length-weight relationships of *Sardinella longiceps* from sultanate of Oman. He found that for male $W = (8.13 \times 10^{-6}) \times L^3$ and for female $W = (9.07 \times 10^{-6}) \times L^3$, The pooled value of male and female was $W = (8.43 \times 10^{-6}) \times L^3$

The length-weight relationship and condition factor was studied using 1000 specimens of *Sardinella sindensis* caught along the Gwadar waters, Balochistan, Pakistan for 3 years from January 2003 to December 2006. The fish size ranged from 15 to 25 cm (mean \pm SD=17.8 \pm 1.50) and the body weight (W) of *S. sindensis* ranged from 40 to 75 g (mean \pm SD=50.3 \pm 11.28). The regression co-efficient value of 0.6991 was obtained (Naeema Elahi, 2015).

The length-weight relationship of *S.longiceps* was determined by Kumar and Balasubrahmanyam (1987), from Parangipettai. The logarithmic representation of equation obtained for male $\log W = -2.3645 + 3.1516 \log L$ and for female: $\log W = -3.0024 + 3.4436 \log L$.

Length-weight relationship was estimated for 31 fish species caught by bottom trawl surveys in Jiaozhou Bay on the west coast of the South Yellow sea. Specimens were collected from September 2008 to August 2009. The b value fell within the expected range of 2.5–3.5. The mean value of b was 3.094 ± 0.064 (95% CL), which was significantly higher than 3.0, indicating significant tendency towards positive allometric growth in most of the fishes. (Xue, 2011)

The length - weight relationship of *Sardina pilchardus*, collected by beach seine using artificial lights (luring) in the Boka Kotorska Bay from June 2004 to July 2005. The value of power of the length - weight equation was $b = 3.1671$. The comparison of regression lines showed that the difference existed was significant for the very low level of probability $P > 0.25$. (Ana Pesic *et al.*, 2006).

Estimates of length-weight relationship for twenty-four species caught in association with the Brazilian sardine, *Sardinella brasiliensis*, the value of the coefficient of determination r^2 and residual analysis were employed to verify the appropriateness of fit. The coefficient b values were tested with respect to isometry. The values of coefficient b ranged from 2.377 to 3.538. (Andre Martins, 2013).

Bosiljka Mustac and Gorenka Sinovcic (2010) studied a total of 1,219 specimens of sardine, *Sardina pilchardus* (Walbaum, 1792) from the Middle Eastern Adriatic Sea during the period from March, 2004 to February, 2005. The total length ranged from 13.0 to 19.0

cm, and weights ranged between 16.72 and 51.45 g. Negative allometry was established $b = 2.5538$.

Length -weight regression was presented for 33 fish species of pelagic fishes caught during 1992–1993 in the South Euboikos Gulf, Aegean sea. Samples were collected with beach seine and trammel gill nets. The value of the exponent b in the length- weight relationship $W = aL^b$ ranged from 2.320 to 3.521 and the median value was 2.987, where 50% of the values ranged between 2.840 and 3.140. (Petrakis and Stergiou, 1995)

Regression analysis ranged from 1.79 to 4.50 for a wide length range of fishes. Covariance analysis between fecundity-weight indicated that there was no significant difference among the slopes which ranged from 0.053 to 1.209 (Antony Raja, 1972)

2.3. Food and feeding habits

A distinct variation in the feeding intensity was noticed in *Dussumieria acuta* between the day and night. This was due to the diurnal variation in the feeding habits of this fish, feeding actively during day time and starvation during the night. The study over a period of two years in 1969-70 and 1970-71 showed that in day samples 6.05% fish during the first year and 2.57% fish during the second year were with empty stomachs, whereas in the night samples 98.33% during the first year and 98.16% during the second year were either with empty or with 'little' stomachs. (Radhakrishnan Nair, 1982)

The feeding study was based on a total of 901 captured larvae. Gut content analysis of the sardine larvae showed a diurnal pattern of food intake. Copepod nauplii dominated the diet of the preflexion and flexion larvae, but they were the second in abundance for the post flexion larvae which fed preferentially on copepodites and adults of *Oncaea* spp. Average feeding incidence of the 901 larvae was 37.6%, but it increased to 58.5% for day-

caught larvae. 70% of the food particles were found in the mid-gut and food eaten showed a natural increase in digestion from fore-gut to hind-gut, but higher densities of copepodite and adult of *Oncaea*, *Oithona* and *Paracalamis* were found within and beneath the thermocline. These results show that Brazilian sardine larvae can successfully adapt their diet, feeding on the most abundant food particles in the upper mixed layer of the survey area. (Frederico *et al.*, 2001)

Oil Sardine feeds mostly on planktons. Phytoplankton forms the chief food of the juvenile and adult forms. Diatom *Fragilaria oceanica* has been reported as their favorable food. The abundance of oil sardines during certain years may be related to the blooming of the diatoms. Preliminary observations on food and feeding habits of other sardine like *S. fimbriata* (Bennet, 1967) suggested that larger size groups have empty stomach.

The diet of *S. aurita* consisted predominantly of zooplankton (50.1%) followed by phytoplankton (34%) and relatively small quantities of detritus (15.9%). The major prey items were copepods supplemented by diatoms followed by Protozoa and Chlorophyceae. The type and abundance of ingested prey were related to the plankton composition in the environment in order to determine prey-type selectivity. Diet composition of stomach proved that *Sardinella aurita* has a flexible adaptive strategy appeared obviously from adjusting its feeding habits to its specific requirements. (Fedekar Madkour, 2012)

The food of oil sardine ranged from 40-79 mm in length consisted of diatoms, dinoflagellates and copepods. It seems to be no consistency in regard with various food items in different size groups. Studies have also showed that absence of selective feeding in small oil sardine (Dhulkhed, 1962)

Ara *et al.* (2011) studied the feeding habits and seasonal variation of diet of fish larvae of family Clupeidae from October 2007 to September 2008 in the estuary of Sg. Pendas,

Gelang Patah, Johor, Malaysia. The diet composition were grouped into seven major categories consisted of phytoplankton, zooplankton, plant-like matter, debris, fragments of copepod, algae and unidentified food items. The most predominant food items in the gut of clupeids was phytoplankton (82.53%), followed by plant-like matter (7.34%), debris (4.86%), fragment of copepods (2.69%), algae (0.92%), unidentified items (0.77%) and zooplankton (0.54%)

The food and feeding habits of round sardine, *Sardinella aurita*, was investigated by Bahar Bayhan *et al.* (2015) in the Izmir Bay, central Aegean sea of Turkey, during October 2010 - September 2011. They examined 434 stomach contents, 39 (9.0%) had empty. Most empty stomach encountered during autumn (19.1%), followed by (8.0%) summer, winter (2.2%) and spring (2.0%). A total number of 14266 prey items and forty eight species were identified, belonging to six major groups, Polychaeta, Crustacea, Mollusca, Chaetognatha, Tunicate and Teleostei.

The feeding strategies and diet composition of oil sardine, *Sardinella longiceps* caught during January to December 2010 by trawl net off the Parangipettai southeast coast of India was studied in detail. Diatoms (66.5%) and zooplankton (18.5%) were the major components of the food items. Dinoflagellates (15%) formed a major part of the stomach content throughout the year. The preferences for diatoms were found to be higher in male fish (40.04%) than female (38.46%). Copepods were more abundant in male (11.08%) than in female (10.35%). But dinoflagellates were less abundant in male (9.44%) than in female (10.35%). The semi - digested matter (41.46%) was higher in male than female (43.32%). The monthly gastro somatic index ranged from 0.85 to 2.40 in male and 0.89 to 2.42 in female and values were generally higher prior to pre monsoon months (Purusothaman *et al.*, 2014).

The gut content of oil sardine studied by Dhulkhed (1962) from Mangalore region considered mainly on diatoms and dinoflagellates. *Noctiluca sp.*, polychaete larvae, decapod zoea and *Sagitta sp.* were not observed in the stomach though they were recorded in large numbers on certain occasions in the plankton samples. Phytoplankton were present almost throughout the year in the plankton samples collected at Ullal.

2.4. Reproduction

The reproductive aspects of oil sardine were examined by Antony Raja (1972). The study showed that its relationship with length was curvilinear and with weight it was rectilinear. The regression coefficient of fecundity-length, size at maturity varied from 16 to 20 cm, with occurrence of well developed mature gonads in the months of August-September and spent ones in the months of November to February. Number of mature eggs in the ovaries of the gravid females with the total weight of fish ranging from 50-60 g varied from 45,000-75,000 eggs. Oil Sardine undergoes nine stages of maturity with distinct biological features in each stage. The stages were Immature (I), Developing virgin (IIa), Spent resting (IIb), Maturing (III & IV), Mature (V), Running (VI), partially spent (VIIa) and Spent (VIIb). The size at first maturity was estimated at 158 mm. Average GSI values of females were 1.4998 with maximum GSI value 5.4962 in the month of September and minimum in the month of October (0.4299). In case of males the maximum GSI value of 4.4962 was observed in the month of September and minimum of 0.2992 was observed in the month of October.

Al-Jufaili (2011) studied the spawning season of omani sardine, the length at 50% maturity for combined sex, female and male sardines was 16.35-16.46 and 16.28 cm respectively. He also noticed that the spawning season in October, June, and July, September, June, and January and September during the years 2004, 2005, 2006, 2007, and

2008, respectively. An overall mean sex - ratio of 0.68 ± 0.02 proved to be significantly different from the χ expected theoretical sex ratio of 0.5 ($2 : 0.05$) ≤ 200 ; $df = 1$; $P < 0.05$

Batch fecundity was related to fish size and mean batch size was $69\,894 \pm 4361$ oocytes per batch and 134 oocytes per gram of weight. The timing and duration of the spawning season, size at maturity, spawning frequency and batch fecundity of *S. australasicus* off southern Australia were consistent with those of *S. japonicus* in the northern Pacific ocean (Rogers *et al.*, 2007)

The number of eggs which were found in *S. fimbriata* ranged from 14513 to 25490 and estimated fecundity varied from 14508 to 25485. On an average the estimated fecundity was 19671. Study on the reproductive aspects such as fecundity and ova diameter studies can help in the fisheries forecast for its successful management (Kudale *et al.*, 2016)

The reproductive biology of round sardine, *Sardinella aurita* was studied for the first time in the north-eastern Mediterranean Sea. The overall female to male ratio was not statistically different ($P=0.34$) from unity, although it varied monthly and with the length of the fish. The seasonal changes in the gonado-somatic index and the macroscopic characteristics of gonads showed that the round sardine in the northern Aegean spawns between May and July. Male round sardine reach first sexual maturity at (155mm) a smaller length than females (168.3mm). Mean absolute fecundity increased exponentially with body length (Athanasios Tsikliras *et al.*, 2006)

Bhat *et al* (1989) reported that *S. fimbriata* spawned only once a year during December to March. Majority of the specimens observed were indeterminates (77.7%), followed by females (13.3%) and males (9.7%). Most of the fishes below 100 mm were indeterminates and those above 100 mm showed various degrees of sexual maturity. Spent fishes were in 138-155 mm size group. The rate of egg production in relation to standard length of the

fish was double to that of its total weight, the fecundity varied from 4958-43642. The diameter of ova in advanced stages of maturity was found to range from 0.23-0.43 mm, whereas in the immature and maturing stages, the corresponding values were 0.12 and 0.22 mm respectively

Al-Jufaili Saud (2011) studied the sex-ratio and gonado somatic index of *S.longiceps*. The sex- ratio of female: male was 1:0.6. The monthly variation in the Gonado-somatic index indicated that the fish had two spawning periods, one during March and April other during August-February.

Okera (2006) studied breeding biology of *S.gibbosa* and *S.albella*. *S. gibbosa* attained first maturity at about 10.5 cm and they spawn only once a season, the spawning period extended from August to November. *S. albella* attained size at first maturity was at 10.1cm. The fish had a prolonged season, which extended from august to February.

Sex-ratio of *S.auriata* in Majidun creek was investigated by Lawson and Doseku (2013). They found that the sex ratio between male and female was found to be 1:1.83 The fish abundance was greatly influenced by water temperature, rainfall and salinity.

2.5. Fishery

Sardines form an important resource off Mangalore-Malpe coast and the success or failure of their fishery in a way determined the status of marine fishery landings of this region. They contributed to an annual average (1997-98 to 2001-02) catch of 9,060 t. Since a number of gears are employed, the sardines are landed throughout the year along the coast. The fishery has registered a steep increase with the highest catch observed in 2001-

02. Several species of sardines supported the fishery, however the oil sardine, *Sardinella longiceps* comprised more than 90% of the catch. (Prathibha Rohit and Uma Bhat , 2003)

Oil sardine fishery starts during the southwest monsoon in the month of August and continued up to March, September to December the peak period of occurrence on the southwest coast of India. The oil sardine shoals first appear in the Calicut region and gradually observed in succession towards the north, disappearing towards the end of season in the reverse order (Deshmukh *et al.*,2010)

Mohanty *et al* (2013) studied fourteen species of sardines are in the Indian waters, of which *Sardinella longiceps* is the major single species fishery which contributed about 15% of the total marine fish production in the country. Other 13 species are termed as Lesser Sardines and contributed about 3-7% to the total marine fish catch

Though extensive studies on oil sardines have been carried out from time to time, very little attention is paid on lesser sardines and their fishery. Among the commercial food fishes of the world, clupeids ranks second. In India clupeid fish contributes about a one-third of the marine fish production and are represented by the sardines, anchovies and white baits. Sardines form a major fishery resource among the marine pelagic fin fishes of the Indian seas, of which lesser sardines contributes to lucrative fisheries along the Indian coast and has considerable employment potential. Two species of lesser sardines, *Sardinella fimbriata* and *Sardinella gibbosa* dominated in the commercial catches landed in and around Karwar. (Kudale and Rathod 2014)

Gosh *et al* (2013) made observation on fishery of *Sardinella gibbosa* and *Sardinella fimbriata* landed by gill netters from north west Bay of Bengal was studied during 2005 – 2010. Average annual catch was 21080 t, in which the contribution of *S.gibbosa* was

12790 t and the contribution of *S. fimbriata* was 8290 t. Rainfall and chlorophyll a were found to affect the annual catch of lesser sardines.

II. MATERIALS AND METHODS

3.1. Materials

The present study is based on the observation of a total of 724 *D. acuta* individuals ranging in size from 12 to 24 cm total length (TL) comprising 417 males and 307 females. Fortnightly samples were collected from Mangaluru main fish landing center and fish market from August 2015 to April 2016.

Laboratory observations

Samples of *D. acuta* were brought to the laboratory for recording morphometric measurements and for studying the food and feeding habits, reproduction and other related aspects. The total length from the tip of the snout to the tip of the caudal fin was measured to the nearest 1 millimeter using graduated measuring board. The fish was then cut open and sex and the stages of maturity were noted. Gonad was then weighed using an electrical balance the nearest of 0.01 g. Stomach and ovaries were preserved in 5% formalin for further analysis.

3.1.1. Length- weight relationship

The data on the length weight relationship was analyzed separately for each category as suggested by (Le cren ,1951) .The linear equation was fitted separately for males and females.

The length-weight relationship can be expressed by the parabolic equation

$$W=axL^b$$

linearized to the form of

$$Y= A+Bx$$

Where, $Y = \log W$, $B = b$ and $X = \log L$

Based on this equation, constants A and b were estimated for each month using least square method. The data for the sexes were treated separately in order to examine differences between sexes. Analysis of co- variance was used to test the significant difference in the estimates of b between sexes.

3.1.2. Relative condition factor

The relative condition factor for individual fish was calculated using the formula $K_n = W_0/W_c$ (Le Cren, 1951) where, W_0 =observed weight; W_c = calculated weight.

Monthly mean K_n values were calculated for both sexes separately to find out the relation, if any between spawning season and relative condition factor. To study the fluctuations in the relative condition of factor with the length of fish either sex, mean K_n values were calculated for each size group in order to ascertain the breeding season and feeding Pattern.

3.1.3. Food and feeding habits

Both qualitative and quantitative analysis was carried out to study the feeding habits of *D acuta*.

3.1.3.1. Qualitative analysis

Qualitative analysis consisted of identification of all organisms encountered in the stomach. The identification was done using compound microscope up to the generic level and whenever possible up to the species level depending upon the state of digestion. Identification of individual item was not always possible due to the semi digested condition of food inside the stomach and the advanced stage of digestion. Food items in the advanced stage of digestion were treated as semi-digested matter.

3.1.3.2. Quantitative analysis

Quantitative analysis was carried out by the eye estimation method. This method was found suitable for determining large quantities of decayed organic matter which was mixed with diatoms and sand particles that could not be easily separated. The stomach contents were washed in to a Petridish and analyzed by points volumetric methods (Hynes 1950; Pillay, 1952) taking into a consideration the extent of fullness of the stomach. Points were allotted for each food items based on its relative volume. From the volume obtained for individual fish, monthly averages and percentages were worked out. The percentage of each food item was calculated from the total points of all the item over the study period.

3.1.3.3. Feeding intensity

Feeding intensity of various months was studied by the degree of fullness of the stomach in relation to the size of the fish. The fullness of stomach was classified as (i) full (ii) $\frac{3}{4}$ full (iii) $\frac{1}{2}$ full; (iv) $\frac{1}{4}$ full ; (v) little (containing traces of food) and (vi) empty when practical in the stomach did not contain any food. Fishes with full stomach and $\frac{3}{4}$ full was considered to have been feeding actively. Similarly, stomach with $\frac{1}{2}$ full, $\frac{1}{4}$ full and little were considered to denote poor feeding. The percentage occurrence of stomach in different conditions of feeding over the whole period was also calculated. Food in relation to size of the fish was studied by tabulating percentage occurrence of each food items against the size of the fish.

3.2.1. Reproduction:

3.2.1.1. Gross examination of gonads

The length, weight, sex and stage of maturity of individual fish in each sample were noted. The ovaries were removed and preserved in 5% formalin for further studies.

3.2.1.2. Maturity stages

Maturity stages of female were classified based on macroscopic appearance of the ovary and microscopic characteristics of ova. In the male, stages were classified based on the macroscopic appearance of testis. The macroscopic observation were based on fresh material, whereas, microscopic observation were 5% formalin preserved material.

3.2.1.3. Growth of ova

For ova diameter studies of intra ovarian eggs, small pieces of ovaries from the anterior, middle and posterior region were cut and ova teased out on to a glass slide. Diameter of intra- ovarian eggs was measured by means of an ocular micrometer with a magnification of 0.01mm to each ocular micrometer division (O.M.D.) using compound microscope for the purpose of studying the process of growth of ova from the one stage of maturity to another. For ova diameter measurements a total of 300 to 400 ova were measured from each individual. These were grouped in to four ocular micrometer division and frequency polygons were drawn of all stages of maturity.

3.2.1.4. Spawning frequency

Based on the pattern of ova diameter distributions in advanced stages of ovaries, the frequency of spawning was estimated using the methods of Hickling and Rutenberg (1936) and De Jong (1940).

3.2.1.5. Spawning seasons

The spawning season was determined on the basis of availability of mature gonads in commercial catches. The Gonado Somatic Index (GSI) and relative condition factor (K_n) were also considered for assessing the spawning seasons.

3.2.1.6. Sizes at first maturity

The size at first maturity was determined (a) using mean relative condition factor with respect to size of fish (b) using length weight relationship for male and female fishes

(c) Plotting cumulative percentage of mature fish III, IV, V and VI, stages in case of male and female against size.

3.2.1.7. Gonado -somatic index (GSI)

For calculating the Gonado -somatic index, the weight of the individual fish was noted and the gonads were removed carefully and weighed in an electronic balance after removing the excess moisture using blotting paper. Gonado-somatic index was calculated using the formula, gonad weight x 100/fish weight (James, 1967; Baragi, 1997) the average GSI value plotted against months.

3.2.1.8. Fecundity

Fecundity was estimated gravimetrically using formalin preserved ovaries. The excess moisture was drained out and their ovaries were weighed to the nearest milligram. Ovaries of the IV and V stages were used for fecundity estimation. Sample from each ovary was removed and weighed. The number of mature ova in the weighed sample was counted. From the number of mature ova for each individual, fecundity was calculated by using following formula

$$\text{Fecundity} = \frac{\text{Number of mature ova in the sample} \times \text{Total weight of ovary (g)}}{\text{Weight of sub sample (g)}}$$

3.2.1.9. Fecundity: length/ weight/ gonad weight -relationship

The relationship between fecundity and length of fish/ weight of fish/ ovary weight were calculated using appropriate statistical method. In addition gonad index of body weight, relative fecundity on body weight and ovary weight are also calculated

3.2.2.1. Sex- ratio

Sex -ratio was studied with respect to months and size groups of fish. Data on sex ratio were analyzed by χ^2 (Chi-square) test to find out whether there was any dominance of either sex.

3.2.2.2. Fishery

Observations were made fortnightly in Mangaluru fish landing center (Bunder jetty) during August, 2015 to May, 2016. The main gears used for the capture were trawlers and Purse-seiners. On each day observation, about 10-20 % of units were observed at random to record the catch of oil sardine and lesser sardine in weight, from which total catch and effort data for different days observation were pooled and raised for monthly estimates. The monthly fishing effort is expressed in terms of number of boat units and catch per unit effort (CPUE) accordingly.

IV. RESULTS

4.1. Length weight relationship

The main objectives of studying the length weight relationship of fishes are (1) to determine mathematical relationship between the two variables, so that if one is known the other could be estimated (2) to calculate the relative condition factor. In order to study the above two aspects, the length and weight data were computed from the monthly sample of *D.acuta* (Table1).

The relationships obtained were as follows:

For male, $\text{Log } W = -2.1527 + 3.0723 \text{Log } L$

Or

$$W = 0.007036L^{3.0723}$$

For female, $\text{Log } W = -2.1248 + 3.0172 \text{Log } L$

Or

$$W = 0.0075021L^{3.0172}$$

Table 2 shows results of analysis of co-variance of length - weight relationship of male and female. From the F- ratio, it is evident that there was no significant difference among the regression coefficient between male and female.

Hence, the combined regression equation for male and female could be written as follows

$\text{Log } W = -2.1387 + 3.04775 \text{Log } L$

The corresponding non –linear equation is represented by

$$W = 0.0072661L^{3.04775}$$

The observed pooled values of length and weight of fishes were plotted and the curve drawn (Fig 1a and 1b).

4.2. Relative condition factor:

The relative condition factor $K_n = W_0/W_c$ for both male and female fish using respective length - weight relationship. Table 3 represents the monthly average relative condition factor for male and female separately.

4.2.1. Seasonal variation in relative condition factor:

Seasonal variation in relative condition factor was estimated using average monthly values presented Table 3 and Fig.2

In case of male, the K_n values varied from 0.7129 to 1.2094. The highest K_n values were observed in the month of April 2016(1.2094) followed by March (1.1874) and August (1.1542) .The lowest value was found during December 2015 (0.7129).

In case of female, K_n values varied from 0.8044 to 1.4601.The highest K_n value was observed in the month of August (1.4601) followed by April (1.3141) and March (1.2368) .The lowest value was observed during December (0.8044).

4.2.2. Size dependent fluctuations in the relative condition factor:

The mean K_n values of each size of male and female are the presented separately in the Table 4 and Fig. 3.

The K_n values for male showed that the condition remained the low in the size groups of 12-14 cm and 14-16 cm. Then gradually increased in the size range from 16-18 cm, 18-20 cm and 20-22 cm. The highest K_n values was observed in the size group 22-24 cm.

In the case of female, the K_n low in the size groups of 12-14 cm and 14-16 cm. Then gradually increased in the size range from 16-18 cm, 18-20 cm and the highest K_n value was observed in the size group 20-22 cm.

4.2.3. Monthly catch trend

The monthly catch trend of the Indian oil sardine and lesser sardine for the months, August 2015 to May 2016 presented in Table 5 and Fig. 4

During August 2015- May 2016, the monthly Indian oil sardine landings ranged between 38 to 2482 mt with annual total catch of 9182 mt. The percentage of total catch varied from 0.413 % in the month of August and 27.031 % in the month of January. The total effort varied from 3243 to 5680 in the months of December and September respectively. Units with total annual effort 43,358 units. The CPUE varied from 2.11mt in August to 4.68mt in October.

During August 2015 - May 2016, the monthly minimum and maximum catches of lesser sardine landings varied from 24 mt to 560 mt in the month of May 2016 and November 2015 respectively with annual catch of 2167 mt. The monthly percentage contribution of Indian Lesser sardine catch to the total catch varied from 1.107% in May to 25.842% in the month of November. The total effort varied from 3243 in the month of December and 5680 in the month of September, units with total annual effort 43,358 units. The CPUE varied from 2.11mt to 4.68 mt in the months of August and October respectively.

4.3. Food and feeding habits

4.3.1. Qualitative and quantitative analysis

The details of qualitative and quantitative analyses of gut contents of *D. acuta* are presented in Table 6 and Fig. 5. The gut content analysis showed that approximately consisted of shrimp appendages 13.58%, fishes 15.09%, crab larvae 2.14%, copepods

0.59%, semi digested matter 64.68%, diatoms 0.41%, dinoflagellates 0.83%, sand grain 1.00% and fish scale 1.84% .Represent the monthly diet composition of *D. acuta* in Table 6 and Fig.6

Semi-digested matter

The greater abundance of semi digested matter found in the month of January 2016 (74.07%) and February 2016 (73.66%). The lowest quantity of this item was found during September 2015 (51.03%).

Fishes

Fishes formed as a major constituent (15.09%) of the stomach content throughout the study period. Higher quantity appeared in the months of August (26.72%) and September (22.20%).Whereas, lower quantity were noticed in the month of January (4.82%) and March (8.37%).

Shrimp appendages

Shrimp appendages (13.58%) formed an important food item. Higher quantity found in the month of September (18.89%) and April (18.48%).The minimum quantity observed in the month of February (8.88%) and December (11.18). Crab larvae (2.14%) formed an important food items. The maximum quantity observed in the month of September (3.41%) and November (3.69%) and the lowest quantity was observed during February (0.55%) and March (1.18%).

Fish scale

Fish scale (1.848%) were found major food item after crab larvae. The highest quantity were found in the months of February (3.48%) and September (2.96%). The lowest quantity was observed during April (0.321) followed by March (0.37%).Other than these food items Diatoms (0.416%),copepod(0.59%), Dinoflagellates (0.83%) and sand grains (1.00%) constitute minor food items in *D.acuta*.

4.3.2. Food in relation to size

The details of percentage occurrence of various food items in the stomach contents of *D. acuta* belonging to various size groups are given in Table 7 and Fig. 6.

The size group starting from 12cm to 24cm, food items such as shrimp appendages, fish larvae, crab larvae, copepods, semi digested matter, diatoms, dinoflagellates, sand grain, and fish scale found in different proportions. The semi digested matter has found more in size group 18 cm to 20 cm (72.38%), while, it decreased as size of fish increased. Lowest semi digested matter found in the size range of 16cm-18cm (23.25%).

Fishes

Fishes constituted more abundance after semi digested matter. The highest proportion of fishes found in the size group of 16 cm to 18 cm (52.65%), and the lowest percentage found in the size group of 18-20 cm (5.00%).

Shrimp appendages

Shrimp appendages were the most dominant in all the size groups although they occurred in different proportions. The highest percentage found in 12cm to 14cm (6.67%) and the lowest percentage was found in the size group of 14cm to 16cm (3.00%).

Crab larvae

Crab larvae found an important food item the highest percentage occurred observed in the size group of 18cm-20 cm (3.85 %) and lowest percentage found in the size group between 12cm to 14 cm (2.15%).

Fish scales

Fish scales constituted major food items in different size groups. Highest food item was present in the size group 12cm to 14 cm (10.4%) and the lowest food item was found in the

size range between 16 cm to 18 cm (1.75%). Other than these food items copepods (2.50%), diatoms (3.16 %) and dinoflagellates (4.38%), constituted an important food items in stomach.

4.3.3. Feeding Intensity

The percentage occurrence of stomach in various degree of fullness during August 2015 to April 2016 is presented in Table 8 and Fig 7.

It can be seen from the table greater percentage of fishes had stomach with considerable food, indicating active feeding in the month of December and March. Moderate feeding was noticed in the month of October and poor feeding was recorded in the month of November and March. The percentage of empty stomachs increased in the month of November and February.

4.3.4. Feeding Intensity in different size group

The percentage occurrence of stomach in various degree of fullness in different size groups are presented in Table 9 and Fig. 8.

The table revealed that the size group of 12-14, 16-18 and 22-24 cm size of fishes showed highest percentage of active feeding except 14-16 cm and 20-22 cm respectively.

4.4. Reproduction

The result of the studies on maturity, spawning, size at first maturity, fecundity and sex-ratio are presented below.

4.4.1. Maturity

The gonads are bilobed structures located in the body cavity either side of the intestine. The ovaries are long and slender in the early stages, but increase in breadth and thickness with the advancement of maturity. As the ovaries mature, they get distended due to the changes in intra ovarian eggs and attain yellow colour as a result of yolk formation in the

eggs. a distinct asymmetry could be noticed in the structure of the ovary. The two lobes of the ovary are not alike in shape as in the relative position they occupy in the body cavity. In early stages of maturity the right lobe occupy in the full length of the body cavity, the anterior tips lying on the right side of the mass of the intestine, as the maturity advances the lobe become long and pear shaped, filling the right side of the body cavity, and contains the greater number of ova. The left lobe of the ovary is posteriorly placed and reaches early $3/4$ of the length of the right ovary in early stages spindle shaped and as the maturity advances the shape is retain through there is increase of bread and thickness it contains comparatively smaller number of ova.

The testis are small, thin, Pink- whitish structure with long and slender vasa differentia in the earlier stages but with advancement of maturity, they get enlarged and attain whitish colour. Fully developed testes are flat, thick and alike-white in colour with long, slender but conspicuous vasa differentia.

4.4.1.1. Classification of maturity stages – Female

The maturity stages of *D. acuta* have been classified based on the macroscopic appearance and microscopic structure of ova in the ovary and the following maturity stages were recognized.

Stage I-Immature:

Ovaries long, slender and rounded, tapering posteriorly and occupying the full length of the body cavity. The left lobe very small and spindle-shaped being placed posteriorly. The ovary slightly translucent. ova was not visible to naked eye, under microscope small and transparent ova each with a transparent nucleus visible. Majority of the ova range size between 0.047 and 0.12mm with a mode at 0.19mm the maximum size of the ova was observed at 0.19mm.

Stage II-Developing immature

The ovaries slightly enlarged, translucent and amber colour, ova visible to the naked eye as small granule, ova small, and transparent with large transparent nucleus. Yolk formation has started in few ova of the larger size group which were mostly semi-opaque. Majority of the ova ranged in size between 0.05mm and 0.16mm. Some eggs have grown still bigger with mode at 0.31mm maximum size reached up to 0.50 mm.

Stage III-Maturing

The ovaries greatly enlarged and occupy $\frac{3}{4}$ of the body cavity. The right ovary long and pear shaped, while the left ovary short and spindle- shaped. The ovaries were turgid, opaque and yellow in colour. The ovarian membrane was transparent and the eggs were visible externally through the cyst. The advanced group of ova has a mode at 0.56mm. The maximum size observed was 0.66mm. A second mode of maturing ova was noticed at 0.41mm, Both these ova are opaque, thickly yoked and yellowish in colour.

Stage IV-Mature

The ovaries are further enlarged, compact and peared-shaped, almost occupied the body cavity, orange –yellow in colour. The ovarian cyst thin and transparent. The largest ova measured about 0.78 mm. These groups of maturing yolked eggs noticed in the ova diameter frequency polygon. The most advanced group had the mode at 0.72 mm .The other two modes were 0.56mm and 0.31mm. The yolked ova were completely opaque with a thick transparent egg membrane.

Stage V-Advanced mature

The ovaries completely occupied the body cavity and mask the alimentary tract when viewed from the ventral side. Light reddish in colour, the ovarian cyst very thin,

transparent and the individual eggs visible externally, a few fully mature transparent ova noticed externally through the cyst in fresh condition, as colorless dots. The maximum diameter of ova observed was 1.03mm, the advanced group of ova had a mode at 0.82mm in addition to this two more groups of yolked ova was noticed. Among the mature ova some were completely opaque, some with transparent and a few fully transparent. The partly transparent ova are light yellow in colour. The completely transparent ova had a frothy appearance and had single oil globule or in some cases two or three small droplets present.

Stage VI-Ripe

The ovaries were turgid and light reddish in colour. With an increased number of colourless dots. In fresh condition, slight pressure was exerted on either side of the abdomen, a gelatinous mass of transparent ova were exuded. The largest ova were transparent and jelly-like reaching a maximum diameter of 1.12mm and minimum 0.78 mm diameter, the transparent ova has a single oil globule.

Stage VII-Spent

The ovaries were shrunken and elongated, Flabby with wrinkles on surface due to collapsed condition. In preserved condition it grayish in colour. A group of yolked eggs observed along same remnants of mature ova up to 0.81mm the minimum ova diameter observed was 0.69 mm.

4.4.1.2. Classification of maturity stages –Male

Stage I-Immature

The testes were small, translucent, pink white, thin slightly elongated and oval shaped structure with a long and slender vasa differentia. The right lobe placed anterior region of the body cavity, whereas the left lobe was posteriorly placed elongated and spindle-shaped. The asymmetry in shape and position exists in all stages.

Stage II-Developing immature

The testes of this stage have increased in size and were opaque and whitish in colour. The vasa differentia was long and thread- like.

Stage III-Maturing

Testes increased in size, the right lobe was wider and reaches $\frac{3}{4}$ towards the ventral side of the body cavity, with the long and slender vasa deferentia and appeared as shape of the letter P. the left lobe was spindele-shaped.the lobes were thicker and whitish in colour. The vas differentia were white and thread like.

Stage IV-Mature

The testis were greatly enlarged in width and fully reached the ventral side of the body cavity. Milky -white in colour.

Stage V-Advance Mature

The width of testes were greatly enlarged and the lobes occupy the entire depth of the body cavity, or even more,with the result their outer margins fold round to the opposite side through ventral side of the body cavity. When viewed from the ventral side the alimentary canal was completely marked by the testes which were milky -white in colour.

Stage VI-Ripe

The testes were milky-white in colour and greatly enlarged.

Stage VII-Spent

The testes were shrunken loose and white in colour and greatly reduced, with translucent patchy regions.

4.4.1.3. Development of ova to maturity

The ovaries of *D.acuta* belonging to seven stages of maturity described above were selected and the ova diameter frequency polygons of these ovaries were drawn. The data are presented in Table 10 and Fig 9.

In stage I, the size of ova ranged from 0.12mm to 0.19mm majority of them ranging in size from 0.12 mm to 0.16 mm. In stage II, a batch of mature in eggs withdrawn from the general egg stock, the maturing group has mode value at 0.16mm while the largest ova measure at 0.50mm. In stage III, this progress to 0.41mm to 0.66mm, Advance group of ova have a mode at 0.56mm. In IV stage the maximum size of ova observed 0.78mm and the lowest group of 0.56mm, most advance group present 0.72mm in size.

In stage V the maximum diameter observed 1.03mm, and the lowest size range starts from 0.82mm, in stage VI the maximum size observed in 1.12 and minimum in the range of 0.94mm in size. In stage VII the maximum size range is 0.81 and minimum size range of 0.69mm.

4.4.2. Spawning habits

The spawning season was determined on the basis of occurrence of individuals in mature, advance mature, ripe and spent stages of maturity in each month. A total of 417 males and 307 females of *D. acuta* were examined for this purpose. The data are presented in Table 11 and Fig. 11

The result of gonadal maturity of female during August to September showed only, I II, III, IV and V stages. II and V were predominant. In the month of October, stage I and II were dominant. In the month November II stage was dominant, in December stage II and

III were predominant. In January stage II and IV were dominant and lowest percentage occurred in stage V. In the month of February and March III and IV were present in the highest percentage was found in III stage. In the month of April stage V was dominant and the lowest percentage was found in VI and VII stages.

In case of male (Fig 11), stage I, II, III and IV were recorded in the month of August and III stage was dominant, in the month of September I, II, and III were present and I stage was dominant. In October, November and December months Stage I, II and III were present stage II was dominant. In January stage IV was dominant. In February and March stage I to stage IV were seen and stage IV was recorded dominant, in the month of April stage I to stage VII were recorded except II stage, highest percentages were found in stage V.

4.4.3. Size at first maturity

4.4.3.1. Relation between the size of fish and maturity

Fishes were grouped sex-wise in to 2 cm size groups and the details of percentage occurrence of fish in various stages of maturity were calculated. Fish from the stage IV onwards considered as mature. The data presented in Table 12 and Fig 12 and 13.

In case of male, the data revealed that all the fish were immature up to 12-14 cm (stage I,II, and III). In the size group of 14-16 cm, about 10.41% of mature fish were observed. From the size group of 16-18 cm the size group of fish gradually increased and crossed 50%. From the above data size at first maturity for male appears to lie size group between 16-18 cm.

From the Table 12, it evident that up to 12-14 cm, all the females were in immature stage. From the size group 14-16 cm, the mature group appeared and the percentage occurrence increased with increase in size. Where, 50% occurrence of mature fish crossed

in the size range group of 16-18 cm. From the above data indicated that the size at first maturity for female was found to be 16-18 cm.

The size at first maturity was also estimated using distribution of cumulative percentage of IV, V and VI stages. For this purpose, cumulative percentage frequencies of fishes plotted against size group. The size at 50% cumulative percentage frequency was considered to indicate the overall reproductive maturity of the population as a whole Fig14. The size at first maturity of male and female mature at 16.3cm.

4.4.3.2. Size at first maturity as determined from relative condition factor

The mean relative condition factor with respect to size was made use of to find out the size at first maturity. Mean K values for each mid class length plotted against respective size. From the Figure 14 it can be seen that the size at first maturity of the *D. acuta* was at 16-18 cm TL

4.4.4. Gonado Somatic index

In this study, both male and female were taken in to consideration separately. The Gonado somatic index was calculated for individual fish and was averaged for each month. The results were given in Table 14 and Fig 15.

The GSI value ranged between 1.966 to 2.876 in male during August 2015 to April 2016. The lowest GSI value was recorded in December (1.966), while, the highest was in the month of April (2.875).

In case of female, the GSI value fluctuated between 2.676 and 4.530. The GSI value decreased in the month of December and gradually increased from March to April. Maximum value of GSI was in 3.995 and 4.530 Indicated the appearance of maximum number of mature fish.

4.4.5. Fecundity

Only the mature ova were considered for the estimation of fecundity, a clear demarcation of mature and in mature ova were noticed from stage IV onwards. Hence, for fecundity studies, fishes of stage IV, V and VI were taken into consideration (Table15). The fecundity of *D.acuta* ranged from 12642 to 34782 with an average of 21796 eggs. The minimum weight of the mature fish was 32.3 g and the maximum weight was 77.56g with length varied between 14.6 cm to 20.9 cm TL. The number of ova increased generally with increase in length and weight of fish.

4.4.5.1. Relation between fecundity and length of fish

The logarithm values of fecundity Y were plotted again logarithmic values of length X, it showed a linear relationship between the two variables (Fig.16a). The relationship of fecundity was found to be

$$Y = -3.881 + 0.364 X$$

Where Y=Log. Fecundity and X=Log. Length of fish.

The correlation co-efficient r value of two variables was found to be 0.501 .

4.4.5.2. Relationship between fecundity and weight of fish

The relationship between the weight (W) and the fecundity (F) Fig.16b. The linear form of regression between weight of fish and fecundity was calculated as

$$Y = 3.778 + 0.330 X$$

Where Y=Log. F and X=log W

The correlation coefficient r between fecundity and weight of fish was found to be 0.226.

4.4.5.3. Relationship between fecundity and gonad weight

The logarithmic values of fecundity (Y) when plotted against logarithmic gonad weight (X) of the fish (Fig.16c) indicated a linear regression equation of the form $Y=A+BX$. The calculated regression equation was

$$Y= 4.179 + 0.385 X$$

Where $Y=\text{Log.F}$ and $X=\text{Log.G}$

The correlation coefficient r between fecundity and weight of ovary 0.371.

4.4.6. Sex-ratio

For the study of sex ratio a total of 724 specimen were examined (Table15), similarly, the male and female sampled in different size groups are presented in Table 16 represents data on sex ratio of *D. acuta* predominance of male were noticed throughout period except in the months of August, September, November, January and March. At 0.05 probability level, Chi-square value indicated no significance difference in the number of male and female in most of the months except August, September, November, January and March.

The data were also analyzed by chi-square test to test the number of male and female in various size groups. It is clear from Table 16 that size group 12-14, 14-16, 18-20 cm. TL indicated significant difference in Chi-square value in the number of male and female.

V. DISCUSSION

The results obtained from the studies on the various aspects of the biology of *D. acuta* are discussed below.

5.1. Length weight relationship

Length weight relationship gives an idea about the mathematical relationship between length and weight of the fish. It also depicts variation in the observed weight of individual fish from the expected. This variation indicates the fatness, general well being or can be described by the hypothetical cube law representing a condition in an ideal fish where in the fish maintain a constant shape $n=3$ (Allen, 1938). If there is change in density and form as a result of growth, there will be significant departure from the isometric growth pattern. Hence the formulae $W=a \times L^b$ will be more useful in describing the length – weight relationship.

In the present study, the length-weight relationship of *D. acuta* showed that the weight of the fish increased almost as the cube of length of regression co-efficient found to be 3.0723 and 3.0172 for males and females respectively. The regression co-efficient of female was found to be lower than males. It can be inferred that the length weight relationship of same size individual can vary species to species of the same genus besides, the quality and quantity of food consumed may also influence the body weight, along with the other unknown factor. The regression co-efficient found to be lower than the male. From the F-ratio it is evident that there is no significant difference between male and female.

In the length- weight relationship of *Dussumeria acuta* maximum length achieved at 19.5cm and maximum weight 120 grams with a and b values are 4.093 and 3.228 respectively (Mbaru *et al.*, 2010).

The length- weight relationship of *sardine pilchard* .The total length ranged from 13.0 to 19.0 cm, and weight ranged between 16.72 and 51.45 g. Negative allometry was established ($b=2.5538$) in the length-weight relationship (Bosiljka Mustac and Gorenka Sinovcic, 2010).

Estimates of length-weight relationships were presented for twenty-four species caught in association with the Brazilian sardine, *Sardinella brasiliensis*, the value of the coefficient of determination (r^2) and residual analysis were employed to verify the appropriateness of fit. The coefficient b values were tested with respect to isometry ($b=3$) using a $p<0.05$ test. The values of coefficient b ranged from 2.377 to 3.538. (Andre Martins, 2013).

The length - weight relationship of *Sardina pilchardus*, the value of power of the length - weight equation was $b = 3.1671$. The comparison of regression lines showed that the difference, although it obviously existed, was significant for the very low level of probability ($P > 0.25$). (Ana Pesic *et al.*, 2006).

The length-weight relationship of *S. longiceps* was determined by Kumar and Balasubrahmanyam (1987), from parangipettai. The logarithmic representation of equation obtained for male $\log W = -2.3645 + 3.1516 \log L$ and for female: $\log W = -3.0024 + 3.4436 \log L$.

5.2. Relative condition factor

The coefficient of condition or “condition factor” given by formula $K=100*W/L$ (Hile,1936), Where W =weight of fish; L =Ponderal index has been used to indicate the condition, fatness or general wellbeing of fish. The value of K is directly affected if fish does not obey the cube law. Le Cren (1951) suggested calculation of relative condition factor (K_n) based on length-weight relationship in order to eliminate the effect of length

and other such as age, sex, maturity, feeding intensity and selection in sampling on condition factor.

In the present study, seasonal variation in the relative condition factor of both male and female showed that the K_n values were more or less similar in both sexes, Thus indicate almost identical metabolic activity in male and female. The high condition exhibited by both sexes during April (1.2094 for male and 1.3141 for female) may due to gonadal development and active feeding. There was a fall in condition during December but value started increasing from February to April.

Above, (2009) reported from Nkro river of *Sardinella madernensis*. The highest condition factor value (0.95) was recorded in March and November the lowest (0.8) in June. In a stable environment and was more abundant in the dry season months of November, December and February

Fulton's condition factor showed greater values ($K_n=0.8205$) in sardine samples from the inshore waters (Virsko more,) than those from the offshore waters, Dugi Otok, $K_n=0.7317$ (Bosiljka Musta and Gorenka Sinov, 2010).

5.3. Food and feeding Habits

The details of qualitative and quantitative analysis of gut content of *D acuta* revealed that this species feed mainly on shrimp appendages 13.58%, fish larvae 15.09%, crablarvae 2.14%, copepods 0.59%, semi digested matter 64.68% diatoms 0.41%, dinoflagillates 0.83%, sand grain 1.008% and fish scale 1.84%.

Oil Sardine feeds mostly on planktons. Phytoplankton forms the chief food of the juvenile and adult forms. Diatom *Fragilaria oceanica* has been suggested as their favorable food. The abundance of Oil Sardines during certain years may be related to the blooming of this diatom. Preliminary observations on food and feeding habits of other

sardine like *S. fimbriata* (Bennet, 1967) suggest that larger size groups have empty stomach.

The diet of *S. aurita* consisted predominantly of zooplankton (50.1%) followed by phytoplankton (34%) and relatively small quantities of detritus (15.9%). The major prey items were copepods supplemented by diatoms followed by Protozoa and Chlorophyceae. The type and abundance of ingested prey were related to the plankton composition in the environment in order to determine prey-type selectivity. Diet composition of stomach proved that *Sardinella aurita* has a flexible adaptive strategy appeared obviously from adjusting its diet feeding habits to its specific requirements. (Fedekar Madkour, 2012).

A total of 1231 stomachs were examined from research cruises off the WCVI from 1997 to 2002. Of these, 362 stomachs were collected during summer months (June to August), examined using standardized laboratory procedures, and contained prey items (i.e. volume was not 100% digested material or scales) while the largest volume of prey items was recorded in 2002 (average 1.7 cc per stomach). The mean percent of digested material per stomach ranged from a low of 29% in 1998 to a high of 90% in 2001. Despite the paucity of identifiable contents from 2001 samples. (Gordon Mcfarlane *et al.*, 2005).

The food and feeding habits of round sardine, *Sardinella aurita*, was investigated by Bahar Bayhan *et.al.*, (2015) in the Izmir Bay, central Aegean sea of Turkey, during October 2010 - September 2011. They examined the 434 stomach contents, 39 (9.0%) had empty. Most empty stomach was encountered during autumn (19.1%), followed by (8.0%) summer, winter (2.2%) and spring (2.0%). A total number of 14266 prey items and forty eight species were identified, belonging to six major groups, Polychaeta, Crustacea, Mollusca, Chaetognatha, Tunicate and Teleostei.

The feeding strategies and diet composition of oil sardine, *Sardinella longiceps* caught during January to December 2010 by trawl net off the Parangipettai southeast coast of India was studied in detail. There was a preponderance of empty stomachs in all the months. Diatoms (66.5%) and zooplankton (18.5%) were the major components of the food items. Dinoflagellates (15%) also formed a major part of the stomach content throughout the year. The preferences for the feeding strategies and diet composition of oil sardine, *Sardinella longiceps* caught during January to December 2010 by trawl net off the Parangipettai southeast coast of India was studied in detail. Diatoms (66.5%) and zooplankton (18.5%) were the major components of the food items. Dinoflagellates (15%) formed a major part of the stomach content throughout the year. The preferences for diatoms were found to be higher in male fish (40.04%) than female (38.46%). Copepods were more abundant in male (11.08%) than in female (10.35%). But dinoflagellates were less abundant in male (9.44%) than in female (10.35%). The semi digested matter (41.46%) was higher in male than female (43.32%). The monthly gastro somatic index ranged from 0.85 to 2.40 in male and 0.89 to 2.42 in female and values were generally higher prior to pre monsoon months (Purusothaman *et al.*, 2014).

5.4. Reproduction

Generally the fishes exhibits periodic or cyclic reproductive behavior. A thorough knowledge of maturation cycle understands and predict the annual changes that a population undergoes. This involves morphological and histological observation like changing pattern of the structure and condition of the gonads are used to ascertain the maturity stages. the term maturity stages means the degree of ripeness of the gonad. Periodical microscopic and histological examination of testes and ovaries for at least one year helps in understanding the progression and depletion of gonads throughout the

maturation cycle. Fish biologist have devised scheme to identify maturity in different stages, usually 4 to 5 are even up to 7 to 8 stages(Clark,1934:Hickling and Rutenburg, 1956:Qasim,1973).

It is well known that in most fishes there is a marked seasonal periodicity in egg production. Based on ova diameter studies of ovaries well advanced towards spawning teleostean fishes have been found to exhibit different types of spawning habits(Hickling and rutenburg,1936: De-jong,1940:Qasim and Qayyum,1961).

Maturation refer to the cyclic morphological changes that the male and female gonads undergo to attain full growth and ripeness (Qasim,1973) to understand those changes, it is also necessary to fallow the regular and cyclic changes undergone by the gonad. This can be best done by recognizing the different phases in the cycle by assigning set of unique stages that identify the states of maturity of the gonads, as they pass through the different stages of development and spawn. Thus, different maturity stages are assigned to the gonads, based on the well –defined criteria (Crossland, 1977).

Group I: Fishes in this group have short spawning, once a season. The ova diameter frequency polygon of the mature ovaries of such fishes show only two distinct group of ova, the immature and mature, well separated from each other.

Group II: Fishes in this group spawn only once, but over a long period of time, wherein, the range in size of the mature ova will be approximately half of the total range of ova.

Group III: This group is constituted by fishes which spawn twice in a season, where in apart from the mature and immature group of ova, one more group of ova following the mature group is seen, which has undergone about half maturation process. This represents the maturing group of ova.

Group IV: Fishes of this group spawn intermediately over a long period. In this ovaries of successive batches of ova are not clearly differentiated indicating the maturation process is a continuous one.

5.4.1. Maturity stages

The result of Gonadal maturity of female during August to September showed only, I, II, III, IV and V stages. II and V are predominant. In the month of October, stages I and II are dominant. In November II stages were dominant. In the December Stage II and III present, In January stage II and IV are dominant and lowest percentage present in stage V. In the month of February and March III and IV are present, the highest percentage found in III stages. In the month of April stage V are dominant and the lowest percentage was found in the VI and VII stages.

The reproductive biology of round sardine, *Sardinella aurita* was studied for the first time in the north-eastern Mediterranean Sea. The overall female to male ratio was not statistically different ($P=0.34$) from unity, although it varied monthly and with the length of the fish. The seasonal changes in the gonado-somatic index and the macroscopic characteristics of gonads showed that the round sardine in the northern Aegean spawns between May and July. Male round sardine reach first sexual maturity at (155mm) a smaller length than females (168.3mm). Mean absolute fecundity increased exponentially with body length (Athanasios Tsikliras *et al.*, 2006).

Okera (2006) worked on breeding biology of *S.gibbosa* and *S.albella*. In case of *S.gibbosa*, size at first maturity was 10.5 cm and they spawn only once a season, the spawning period extending from August to November. The maturity and spawning of *S.albella* attained size at first maturity was at 10.1cm. The fish had a prolonged season, which extended from August to February.

S. fimbriata has a single spawning cycle extending from December to March. Majority of the specimens observed were indeterminates (77.7%), followed by females (13.3%) and males (9.7%). Most of the fishes below 100 mm were indeterminate and those above 100 mm showed various degrees of sexual maturity (Bhat, *et al.*, 1989).

5.4.2. Gonado-somatic index

The gonado somatic index of *Dussumieria acuta* was recorded in different months to confirm spawning period. It was found that highest GSI value was recorded 2.8765 in male during August 2015 to April 2016. The lowest GSI value was recorded in 1.9662. In case of female, the GSI value fluctuated between 2.6769 in March and 4.53002 in the month of April the value of GSI decrease early in the month of December and increased gradually from March to April. Maximum value of GSI was in 3.9957 and 4.53002 indicating the appearance of maximum number of mature fish.

Average GSI value of *Sardinella longiceps*, in female maximum GSI value was 5.4962 in the month of September and minimum was 0.4299 GSI value in the month of October. In male the maximum GSI value 4.4962 was observed in the month of September and minimum GSI value was 0.2992 in the month of October (Antony raja, 1972).

5.4.3. Fecundity

Knowledge of total number of eggs produced by fish in a year is important for determining the spawning potential of a fish. Fecundity is usually determined from the number of ova of the mature group in the ovary. For fecundity studies, fishes of stage IV, V and VI were taken into consideration. The fecundity of *D. acuta* ranged from 12642 to 34782 with an average of 21796 eggs.

The minimum weight of the mature *D. acuta* was 32.3 g and the maximum weight was 77.56g, with length varying between 14.6cm to 20.9cm TL. The number of ova increased generally with increase in length and weight are also calculated.

Fecundity study is necessary to know the reproductive potential of fish for determining the number of ova in each ovary .The number of eggs which were found in *S. fimbriata* was ranged from 14513 to 25490 and estimated fecundity varied from 14508 to 25485. On an average the estimated fecundity was 19671 whereas the observed fecundity was 19675 (Kudale et.al 2016).

The rate of egg production in relation to standard length of the fish was double to that of its total weight, the range in fecundity being 4958-43642. Diameter of ova in advanced stages of maturity was ranged from 0.23-0.43 mm whereas, in the immature and maturing stages, the corresponding values were 0.12 and 0.22 mm respectively (Bhat, *et al.*,1989).

5.4.4. Ova diameter

In the present study size of ova diameter measured in stage I ranged from 0.12 mm to 0.19 mm. whereas in stage II it varied from 0.16 mm to 0.50 mm. In stage III ranged from 0.41mm to 0.66 mm. In stage IV ova measured between 0.56 mm to 0.78 mm. However in stage V and VI diameter of ova ranged between 0.82 mm to 1.03 mm and 0.94 mm to 1.12 mm .In stage VII the ova measured from 0.69 mm to 0.81 mm.

5.4.5. Monthly catch trend

During August 2015-May 2016, the monthly Indian oil sardine landings ranged between 38 to 2482 mt with annual total catch of 9182 mt. The percentage of total catch varied from 0.413 %(August) to 27.031(January). The total effort varied from 3243 (December) to 5680 (September) units with total annual effort 43,358 units. The CPUE varied from 2.11mt (August) to 4.68mt (October).

During August 2015-May 2016, the monthly minimum and maximum catches of lesser sardine landings varied between 24 mt (May 2016) to 560 mt (November 2015) with annual catch of 2167 mt. The monthly percentage contribution of Indian Lesser sardine catch to the total catch varied from 1.107% (May 2016) to 25.842% (November 2015). The total effort varied from 3243(December 2015) to 5680 (September 2015) units with total annual effort 43,358 units. The CPUE varied from 2.11mt (August 2015) to 4.68mt (October 2015).

Sardines form an important resource off Mangalore-Malpe coast and the success or failure of their fishery in a way determined the status of marine fishery landings of this region. They contributed to an annual average (1997-98 to 2001-02) catch of 9,060 t. Since a number of gears are employed, the sardines are landed throughout the year along the coast. The fishery has registered a steep increase with the highest catch observed in 2001-02. Several species of sardines supported the fishery, however the oil sardine, *Sardinella longiceps* comprised more than 90% of the catch. (Prathibha Rohit and Uma Bhat , 2003)

VI. SUMMARY

The rainbow sardine is an important pelagic fish inhabitant of good commercial value and contributes along with lesser sardine. The present study is to investigate the length weight relationship, food and feeding habit and reproductive biology and fishery along Mangaluru coast. The study was carried out during August 2015 to April 2016. The important findings of these investigations are as follows.

- The regression co-efficient of female was found to be lower than male. From this observation it may be opined that male gained more weight with increase in length compared to female. From the F-ratio it is evident that there was no significant difference between male and female. Hence pooled equation for both the sexes was derived.

$$\text{Log } W = -2.1387 + 3.04775 \text{ Log } L$$

- Data on seasonal variation in condition (K_n) of both male and female showed that the values were more or less similar in both sexes, indicating almost identical metabolic activity in male and female. The high condition (K_n) was observed was 1.209 during April 2016 in male and 1.460 during August 2015 in female which may be attributed to gonadal development and high feeding intensity.
- The fluctuation in the K_n values with respect to size indicated that the condition of the fish more or less showed an increasing trend with an increase in size of fish. The highest $K_{(n)}$ value observed in male in the size group 22-24 cm can be attributed to intensive feeding. The relative condition factors showed that condition remained low in size range 14-16 and 16-18 cm followed by increase in K_n values for size group 18-20 and 20-22 cm.

- The qualitative and quantitative analysis of gut content of *D.acuta* revealed that this species fed mainly on semi digested matter, shrimp appendages, fishes, fish scales, crab larvae, diatoms, dinoflagellates formed major food items. The fishes which found next highest percentage than digested matter. These findings showed that *Dussumieria acuta* is a zooplankton feeder.
- The percentage occurrence of semi digested matter in the stomach content of *D.acuta* was found to vary with months considerably. Semi digested matter account (74.04%) formed bulk of the stomach contents. Maximum quantity was recorded in January and the lowest quantity was recorded in the month of September (51.03%) in most cases food was in digested condition, which may due to delay in landings of the catch. Fishes were another food items next to semi digested matter. The maximum quantity was found in the month of August (26.2%) and the minimum accounts in the months of January (4.28%). These monthly variation may due to the factors such as relative abundance of fishes.
- The analysis of food content revealed that ,in all the size group starting from 12-14 cm to 22-24cm, food item such has semi digested matter, shrimp appendages , fishes, diatoms and dinoflagellates, sand grains, fish scale found in different proportions. The highest percentage was recorded in the size group of 18-20 cm and the lowest percentage in the size range of 12-14 cm. fishes were second main food items highest percentage found in size range of 16-18 cm and the lowest in the size group of 18-20 cm
- Based on the percentage occurrence of mature fishes in various size groups it was inferred that male and female attained maturity in same size group. The size at first maturity of male and female was 14-16 cm. Considerable variation in the

distribution of sexes was noticed during different months. Male dominated female during study period. The size dependent sex ratio was noticed.

- The sex ratio of male: female was found to be 1:0.74 in the commercial catches showed a dominance of male in population.
- Female always recorded higher Gonado-Somatic Index (GSI) values than male due to higher ovary weight compared to testes. Maximum GSI recorded during January to April indicating the occurrence of maximum number of mature fish during these months.
- The ova diameter ranged from 0.12 mm to 1.12 mm.
- The fecundity of fish ranged from 12,642 to 34,782 eggs, with an average of 21796 eggs per female. Log linear relationship were established between fecundity and total length, fecundity and body weight of fish as well as fecundity and gonad weight.

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ABSTRACT

Studies on biological aspects of rainbow sardine, *Dussumieria acuta*, Valencinnes, 1847, with a note on sardine fishery off Mangaluru coast.

The present study deals with the biological aspects of *Dussumieria acuta* and sardine fishery off Mangaluru coast. The length-weight showed no significant difference between the sexes. Hence the common equation for both sexes was $W=0.0072661L^{3.04775}$ or $\text{Log } W = -2.1387 + 3.04775 \text{ Log } L$. The seasonal and size dependent fluctuation in the relative condition factor of both sexes could be attributed to the reproductive cycle, intake of food and probably other unknown environmental factors. The study of food and feeding habit it was confirmed that fish is the major food item in all the season and all size groups. The ova diameter ranged from 0.12 mm to 1.12 mm, percentage occurrence of mature fishes in various size groups it was inferred that male and female attained maturity in same size group. The size at first maturity of male and female was 14-16 cm. Considerable variation in the distribution of sexes was noticed during different months, Male dominated female during study period. The size dependent sex ratio was noticed. The overall male and female ratio was 1:0.74. The fecundity of fish ranged from 12,642 to 34,782 eggs, with an average of 21796 eggs per female.

ಮಂಗಳೂರು ಕರಾವಳಿಯಲ್ಲಿ *Dussumieria acuta* ದ ಜೀವಶಾಸ್ತ್ರ ಅಂಶಗಳು ಮತ್ತು ಮೀನುಗಾರಿಕೆ ಅಧ್ಯಯನ

ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವು *Dussumieria acuta* ದ ಜೀವಶಾಸ್ತ್ರ ಮತ್ತು ಮೀನುಗಾರಿಕೆಯ ಅಂಶಗಳನ್ನು ವಿವರಿಸುವುದಾಗಿದೆ. ಮಂಗಳೂರು ಕರಾವಳಿಯಲ್ಲಿ ಈ ಜೀವಿಯು ಸಾಧಾರಣ ಪ್ರಮಾಣದಲ್ಲಿ ದೊರಕುವ ಕುಟುಂಬದ ಒಂದು ಜೀವಿ. ಉದ್ದ ಮತ್ತು ತೂಕದ ಸಂಬಂಧಗಳ ಪ್ರಕಾರ ಎರಡು ಲಿಂಗಗಳ ಮಧ್ಯೆ ಹೆಚ್ಚಿನ ಪ್ರಮಾಣದ ವ್ಯತ್ಯಾಸ ಕಂಡುಬರುವುದಿಲ್ಲ. ಆದ್ದರಿಂದ ಎರಡು ಲಿಂಗಗಳ ಸಾಮಾನ್ಯ ಸಮೀಕರಣ $W = 0.0726 L^{3.04775}$ ಅಥವಾ $W = -2.1387 + 3.0477 \log L$ ಆಗಿದೆ. ಎರಡು ಲಿಂಗಗಳಿಗೆ ಸಂಬಂಧಿಸಿದ ಋತುಮಾನ ಮತ್ತು ಗಾತ್ರವನ್ನು ಅವಲಂಬಿಸಿದ ಅಂಶಗಳು, ಸಂತಾನೋತ್ಪತ್ತಿ ಕಾಲ, ಆಹಾರ ಸೇವನೆ ಮತ್ತು ಇತರೆ ಅಂಶಗಳ ಕಾರಣಗಳಿಂದ ಏರಿಳಿತವನ್ನು ಕಂಡಿದೆ. ಆಹಾರ ಮತ್ತು ಅಹಾರ ಹವ್ಯಾಸದ ಅಧ್ಯಯನದ ಪ್ರಕಾರ ಇದು ಸಣ್ಣ ಮೀನುಗಳನ್ನು ಎಲ್ಲಾ ಋತುವಿನಲ್ಲೂ ಪ್ರಮುಖ ಆಹಾರವನ್ನಾಗಿ ರೂಢಿಸಿಕೊಂಡಿದೆ. ಮೊಟ್ಟೆಯ ಗಾತ್ರವೂ 0.12 mm ಇಂದ 1.12 mm ನಷ್ಟು ಇರುತ್ತದೆ. ಗಂಡು ಮತ್ತು ಹೆಣ್ಣಿನ ಪ್ರೌಢವಸ್ಥೆಯ ವಯಸ್ಸು ಒಂದೇ ಆಗಿದೆ. ಸಂಚಿತ ಅವರ್ತನದ ಪ್ರಕಾರ ಗಂಡು ಮತ್ತು ಹೆಣ್ಣು ಕ್ರಮವಾಗಿ 14 -16 cm ನಲ್ಲಿ ಪ್ರೌಢವಸ್ಥೆಯನ್ನು ತಲುಪುತ್ತದೆ. ಲಿಂಗಗಳ ಅನುಪಾತವೂ ಅಧ್ಯಯನದ ಅನುಪಾತದಲ್ಲಿ ಏರಿಳಿತ ಕಂಡುಬಂದಿದೆ. ಹಾಗೆಯೇ ಅಧ್ಯಯನದ ಅವಧಿಯಲ್ಲಿ ಗಂಡು ಮತ್ತು ಹೆಣ್ಣಿನ ಅನುಪಾತವೂ 1:0.74 ನಷ್ಟು ಇರುತ್ತದೆ. ಹೆಣ್ಣಿನ ಫಲಶಕ್ತಿಯು ಸುಮಾರು 12,642 ರಿಂದ 34,782 ರಷ್ಟು ಸರಾಸರಿಯಲ್ಲಿ ಪ್ರತಿ ಹೆಣ್ಣಿಗೆ 21,796 ಮೊಟ್ಟೆಗಳಾಗಿರುತ್ತವೆ.

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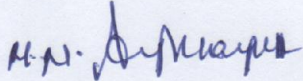
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Certificate

This is certified that the thesis entitled "*Studies on biological aspects of rainbow sardine, Dussumieria acuta, Valencienness, 1847, with a note on sardine fishery off Mangaluru coast.*" submitted by Mr. Halesha, K., I.D.No.MFK 1414 in partial fulfillment of the requirements for the award of Master of Fisheries Science in Fisheries Resources and Management of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar is a record of bonafide research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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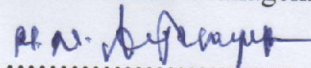

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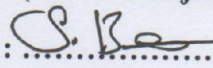
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
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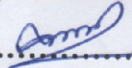

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Table1. Sum of squares and cross products of log length and log weight for males and females of *Dussumieria acuta*

Months	$\sum X$	$\sum Y$	$\sum X^2$	$\sum Y^2$	$\sum XY$	n	b	A	a	$W=a.L^b$	r ²
MALES											
Aug 15.	89.532	113.027	108.573	175.398	137.533	74	3.1407	-2.2726	0.0053	0.005338L ^{3.14077}	0.900
Sep.	78.256	101.802	95.811	163.542	14.913	64	3.1583	-2.2800	0.0052	0.005248L ^{3.1583}	0.926
Oct.	16.547	21.358	19.579	32.824	25.305	27	2.9835	-1.9664	0.0100	0.01008L ^{2.9835}	0.805
Nov.	54.397	69.517	65.817	108.030	84.215	45	2.9846	-2.0630	0.0086	0.008648L ^{2.98465}	0.841
Dec.	52.637	69.994	64.493	114.537	85.864	43	3.0616	-2.1200	0.0075	0.007586L ^{3.061628}	0.926
Jan 16.	60.362	77.116	72.915	119.391	93.227	50	3.0315	-2.1235	0.0075	0.007521L ^{3.03151}	0.914
Feb.	31.133	41.348	37.330	66.270	49.665	28	3.0263	-2.0334	0.0092	0.009258L ^{3.02631}	0.936
Mar.	53.773	72.905	68.871	126.841	93.415	42	3.0330	-2.1474	0.0012	0.001213L ^{3.033051}	0.761
Apr.	55.649	74.123	70.443	125.672	93.942	44	3.2045	-2.3683	0.0042	0.004282L ^{3.204516}	0.762
Total	492.285	641.186	603.829	1032.506	678.074	417	3.0723	-2.1527	0.007036	0.007036L^{3.0723}	
FEMALES											
Aug 15.	34.866	43.182	42.0249	65.400	52.251	31	3.1181	2.31388	0.00479	0.004799L ^{3.118}	0.963
Sep.	38.992	50.512	47.579	80.418	61.751	32	2.9867	-2.0608	0.00869	0.008692L ^{2.9867}	0.880
Oct.	16.547	21.358	19.579	32.824	25.305	30	2.9835	-1.9664	0.01008	0.010081L ^{2.9835}	0.836
Nov.	20.713	26.611	25.272	42.025	32.526	17	3.0960	-2.2070	0.00620	0.006208L ^{3.0960}	0.854
Dec.	22.987	30.145	27.824	47.962	36.509	30	3.0076	-2.0506	0.00889	0.008899L ^{3.0076}	0.866
Jan 16.	33.637	43.314	40.413	67.101	52.047	28	2.9947	-2.0507	0.00897	0.008979L ^{2.9947}	0.386
Feb.	30.398	39.451	35.589	45.699	46.276	26	3.0921	-2.0979	0.00798	0.007981L ^{3.0921}	0.911
Mar.	76.958	105.469	98.741	185.862	135.379	60	3.1593	-2.2944	0.00507	0.005076L ^{3.1593}	0.694
Apr.	66.348	88.939	83.167	153.377	111.668	53	3.0033	-2.0815	0.00828	0.008287L ^{3.0033}	0.897
Total	333.392	438.8464	410.914	720.6701	542.0289	307	3.0172	-2.1248	0.007502	0.007502L^{3.0172}	

$\sum X$ =Sum of log length, $\sum Y$ =Sum of log weight, $\sum XY$ =Products of log length and log weight,

$\sum X^2$ =Sum of square of log length, $\sum Y^2$ =Sum of square of log weight

Table2. Analysis of Co-variance for comparison of length-weight relationship of male and female *D.acuta*

Source of variation	Degree of Freedom(df)	$\sum X^2$	$\sum XY$	$\sum Y^2$	b	Deviation from regression			
						d.f	Sum of square(SQ)	Mean sum of Square(SSQ)	F-ratio
Within males	416	26.2635	80.6916	44.2373	3.0723	415	203.6684	0.49076	* 0.03497
Within females	306	21.1781	63.8986	91.3034	3.0172	305	101.4916	0.33275	
Deviation from the individual regression within sex						720	305.1600	0.42383	
Pooled data	722	47.4416	144.5902	135.5407	3.04775	721	305.1452	0.42322	
Difference between slopes						1	0.0148	0.0148	

* Not significant at 5% level

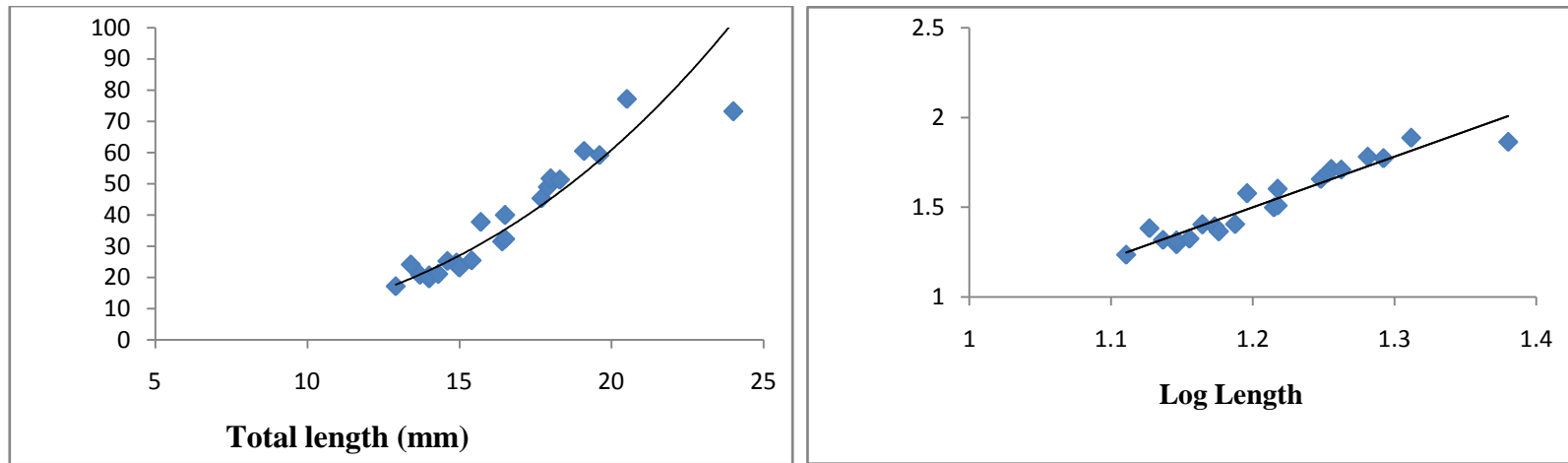


Fig.1 (a).Parabolic and (b) Logarithmic length-weight relationship of *Dussumieria acuta*

Table 3. Seasonal variation in relative condition factor (K_n) of *D.acuta*

Months	Male		Female	
	No.of fish	K_n	No.of fish	K_n
Aug.15	74	1.1542	31	1.4601
Sep.	64	1.0432	32	1.1053
Oct.	27	0.9842	30	1.0812
Nov.	45	0.8431	17	0.9104
Dec.	43	0.7129	30	0.8044
Jan.16	50	0.9269	28	1.0967
Feb.	28	1.0019	26	1.0064
Mar.	42	1.1874	60	1.2368
Apr.	44	1.2094	53	1.3141
Weighted average		1.0070		1.1128

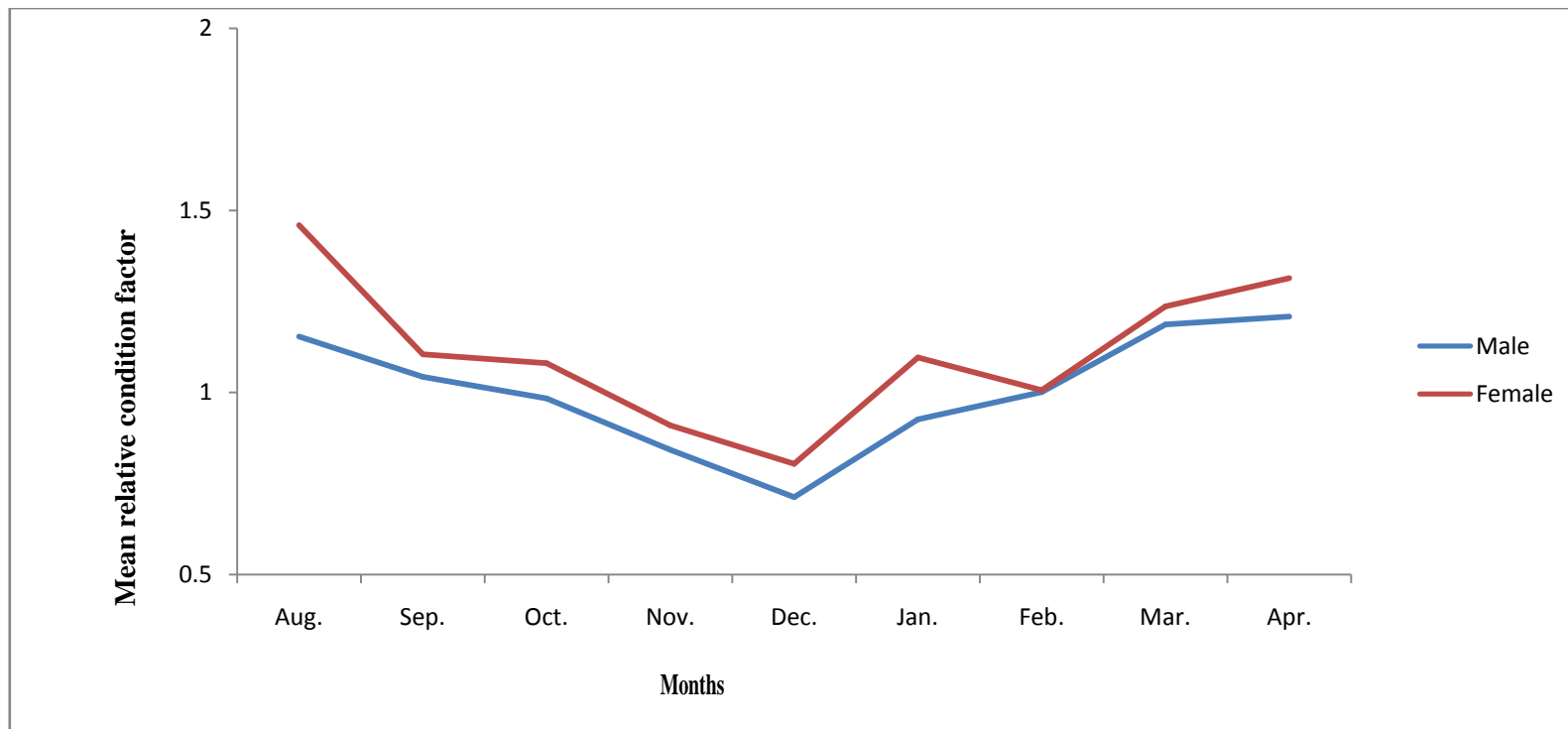


Fig 3.Monthly variation in relative condition factor (K_n) of *D. acuta*

Table 4.Mean value of relative condition factor (K_n) of different size groups of *D.acuta*.

Size groups (cm)	Mid point	Male		Female	
		No.of fish	K_n	No.of fish	K_n
12-14	13	15	0.8894	41	0.9238
14-16	15	174	0.9884	96	1.0321
16-18	17	91	1.2352	88	1.3562
18-20	19	108	1.3217	61	1.4897
20-22	21	24	1.3474	21	1.5356
22-24	23	5	1.9415		

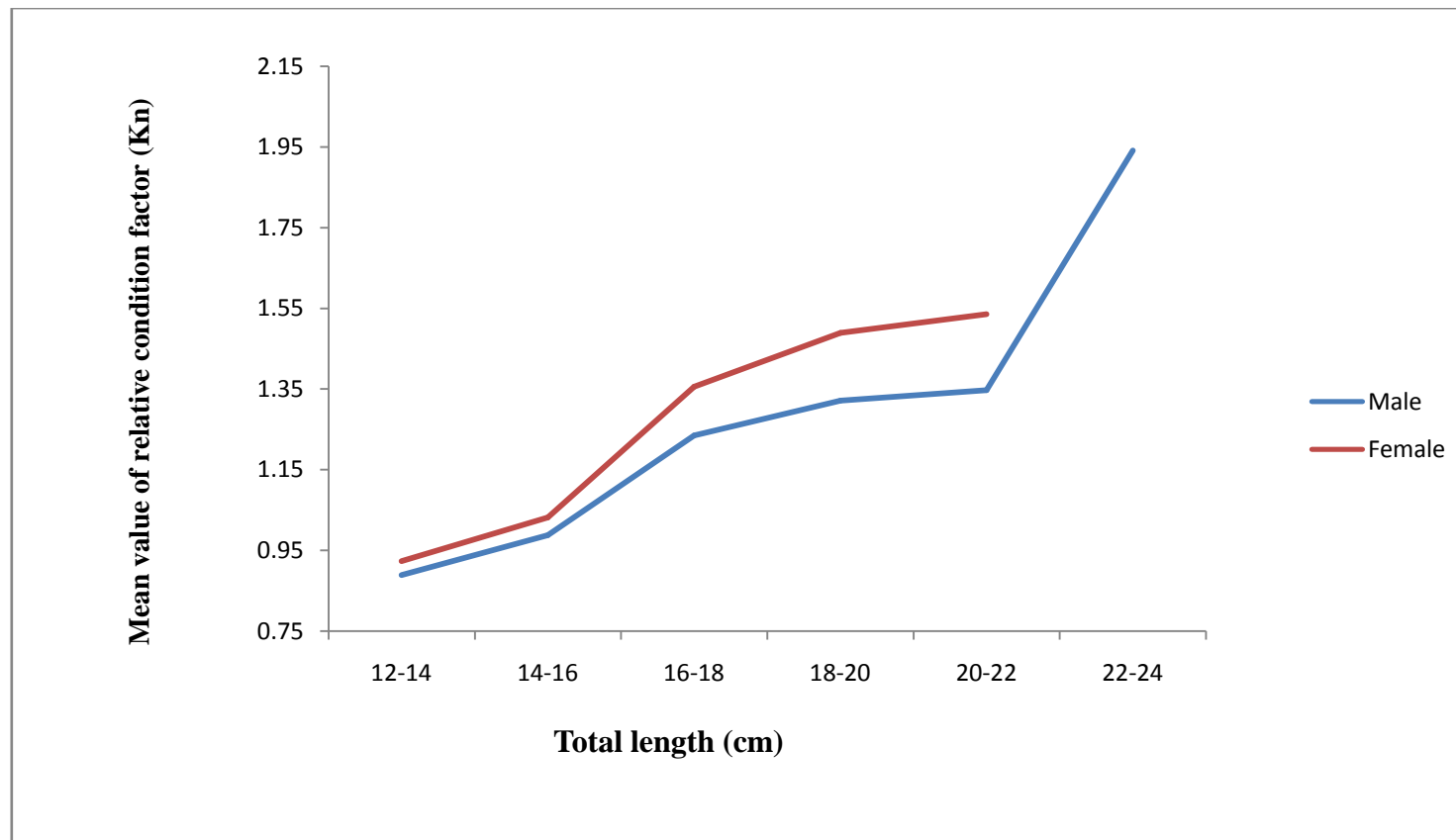


Fig 4. Mean relative condition factor (K_n) values of different size groups of *D. acuta*

Table 5. Month wise catch composition of *S.longiceps* and lesser sardine along Mangaluru coast.

Months	Indian oil sardine(tones)	% of oil sardine	Lesser sardines(tones)	% of Lesser sardine	Total catch	No of effort	CPUE
Aug.15	38	0.413	26	1.199	9193	4350	2.113
Sep.	447	4.868	40	1.845	17781	5680	3.130
Oct.	1450	15.791	508	23.442	15266	3260	4.682
Nov.	1204	13.112	560	25.842	14129	4110	3.437
Dec.	617	6.719	278	12.828	12240	3243	3.774
Jan.16	2482	27.031	254	11.721	16824	4682	3.593
Feb.	1968	21.433	222	10.244	19761	4666	4.235
Mar.	673	7.329	161	7.429	20323	4355	4.666
Apr.	228	2.483	94	4.337	16603	3686	4.504
May.	75	0.816	24	1.107	14580	5326	2.737
Total	9182	100	2167	100	156700	43358	

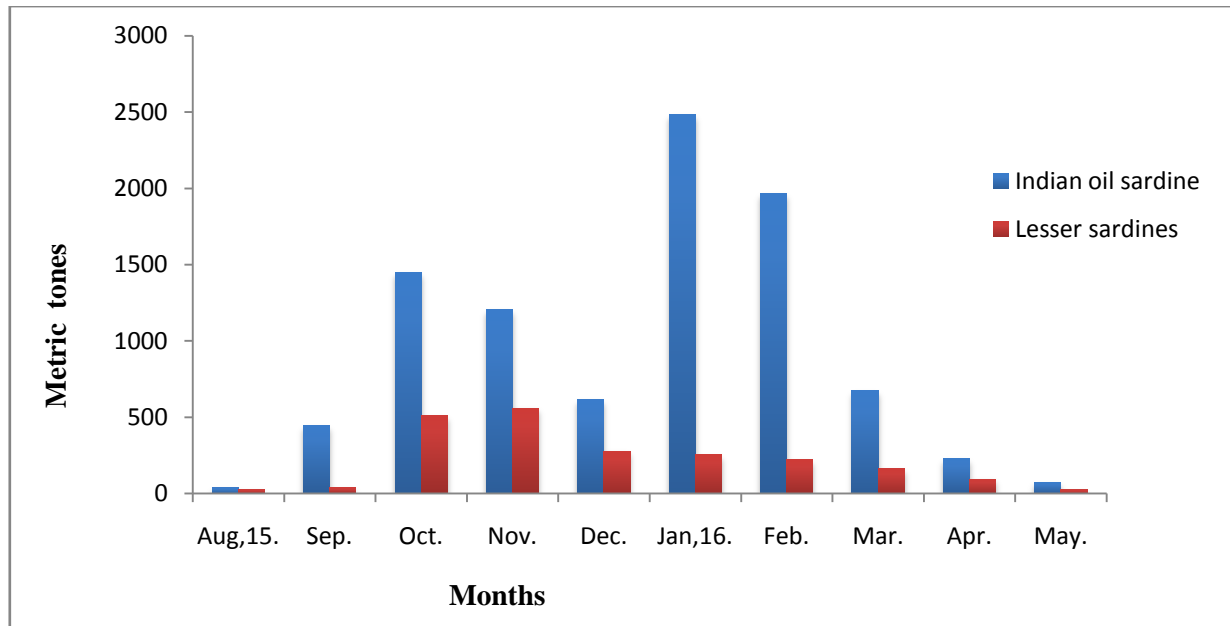


Fig.5. Month wise catch composition of *S.longiceps* and lesser sardine along Mangaluru coast.

Table 6. Qualitative and quantitative composition of gut content of *Dussumieria acuta*

Gut content Months	Shrimp appendages	Fishes	Crab larvae	copepods	Semi digested	Diatoms	Dinoflagellate	Sand grains	Fish scale
Aug.2015	16.5	26.72	1.85	0.20	51.95	0.30	0.42	0.31	1.75
Sep.	18.89	22.20	3.41	-	51.03	0.03	0.55	0.92	2.96
Oct.	12.82	14.82	2.51	1.48	64.13	0.03	0.86	0.56	2.79
Nov.	10.50	14.34	3.69	0.03	69.07	-	0.19	0.15	2.03
Dec.	11.18	16.22	1.70	0.40	67.33	-	0.85	0.55	1.77
Jan.2016	12.17	4.82	2.35	0.79	74.07	1.50	1.03	2.10	1.17
Feb.	8.88	10.55	0.55	0.44	73.66	0.56	1.44	0.44	3.48
Mar.	12.88	9.88	1.18	-	71.00	0.44	1.48	2.77	0.37
Apr.	18.48	16.30	2.07	0.84	59.94	0.051	0.71	1.28	0.32
Pooled average	13.588	15.094	2.145	0.597	64.686	0.416	0.8366	1.008	1.848

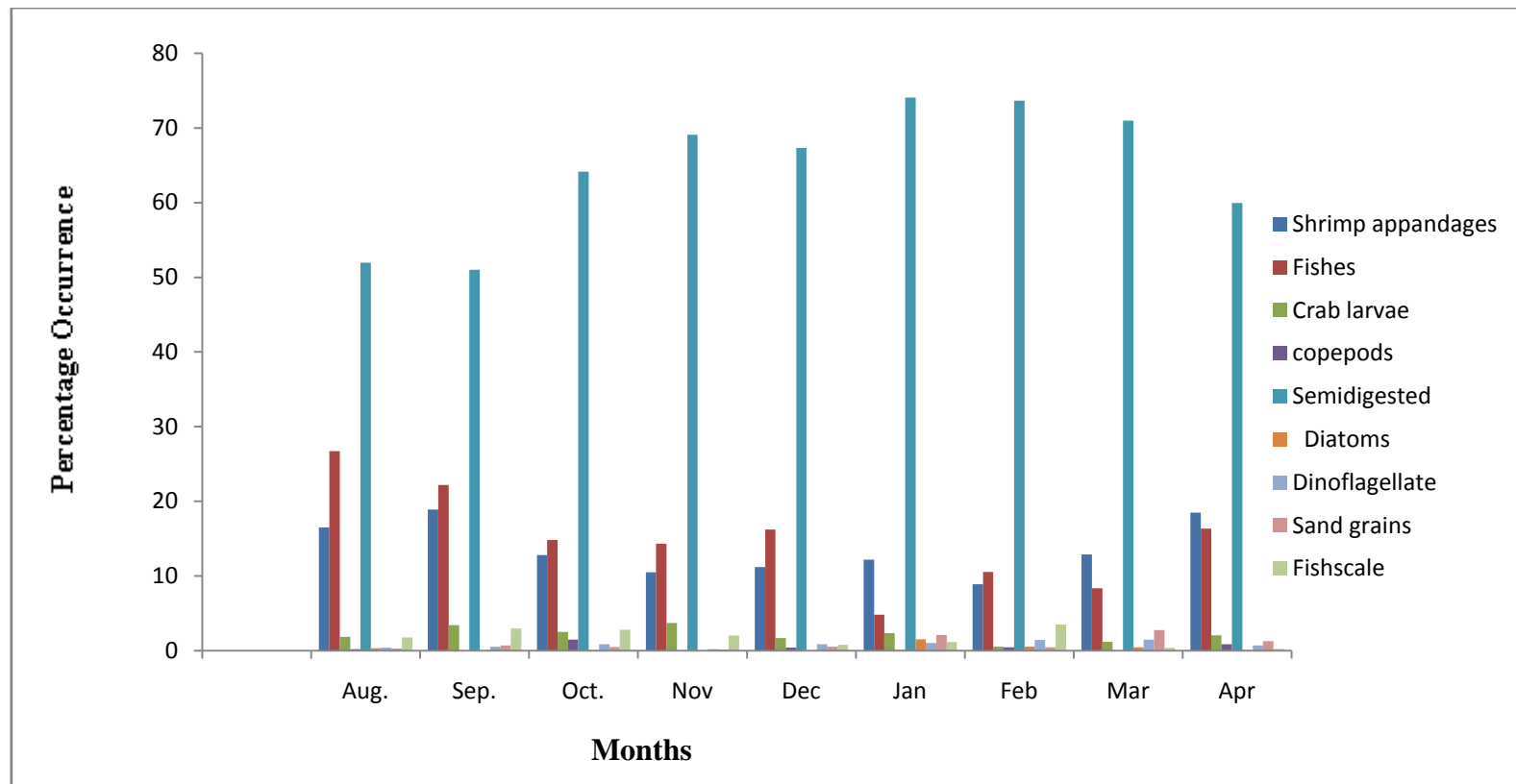


Fig.6.Percentage occurrence of food items of *Dussumieria acuta*

Table7. Percentage occurrence of food items in different size groups of *D. acuta*

Size group(cm)	12-14	14-16	16-18	18-20	20-22	22-24
Food items						
Shrimp appendages	6.67	3.00	4.95	6.02	-	5.00
Fishes	13.00	24.72	52.65	5.00	37.30	30.00
Crab larvae	2.15	-	3.10	3.85	3.18	-
Copepods	-	1.67	2.50	1.99	1.30	-
Semi digested	56.84	48.38	23.25	72.38	36.85	60.00
Diatoms	3.16	-	1.55	1.87	-	-
Dinoflagellate	-	4.38	2.45	-	4.05	-
Sand grains	7.78	9.63	7.80	2.56	11.94	-
Fish scale	10.40	8.22	1.75	6.33	5.38	5.00

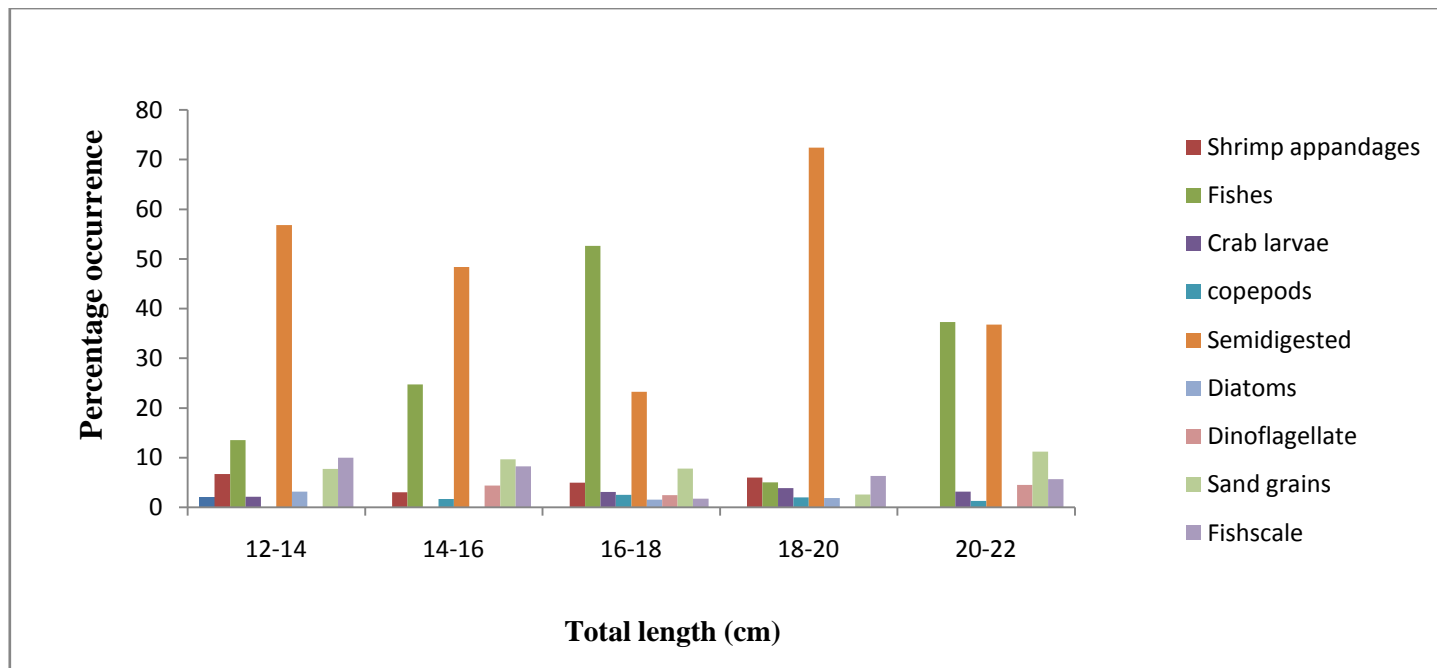
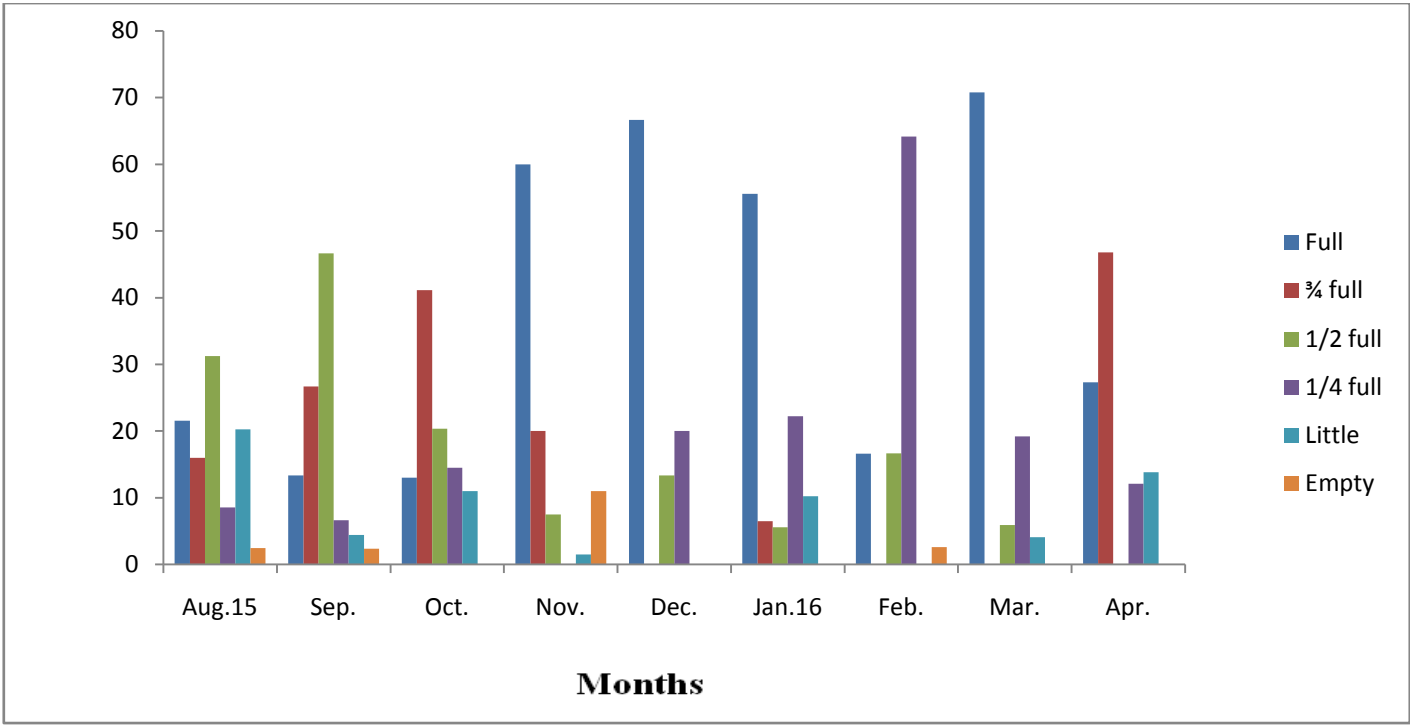


Fig7. Percentage occurrence of food items in different size groups of *D. acuta*

Table 8. Percentage occurrence of various degree of fullness in *D acuta*

Months	No. of Fish examined	Feeding Intensity					
		Full	¾ full	1/2 full	1/4 full	Little	Empty
Aug.15	60	21.53	16.00	31.26	8.53	20.23	2.45
Sep.	75	13.33	26.66	46.66	6.6	4.4	2.35
Oct.	60	13	41.15	20.35	14.5	11	-
Nov.	50	60	20	7.5	-	1.5	11
Dec.	30	66.66	-	13.34	20	-	-
Jan.16	45	55.55	6.48	5.55	22.22	10.2	-
Feb.	30	16.6	-	16.65	64.15	-	2.6
Mar.	50	70.8	-	5.9	19.2	4.1	-
Apr.	24	27.3	46.8	-	12.1	13.8	-



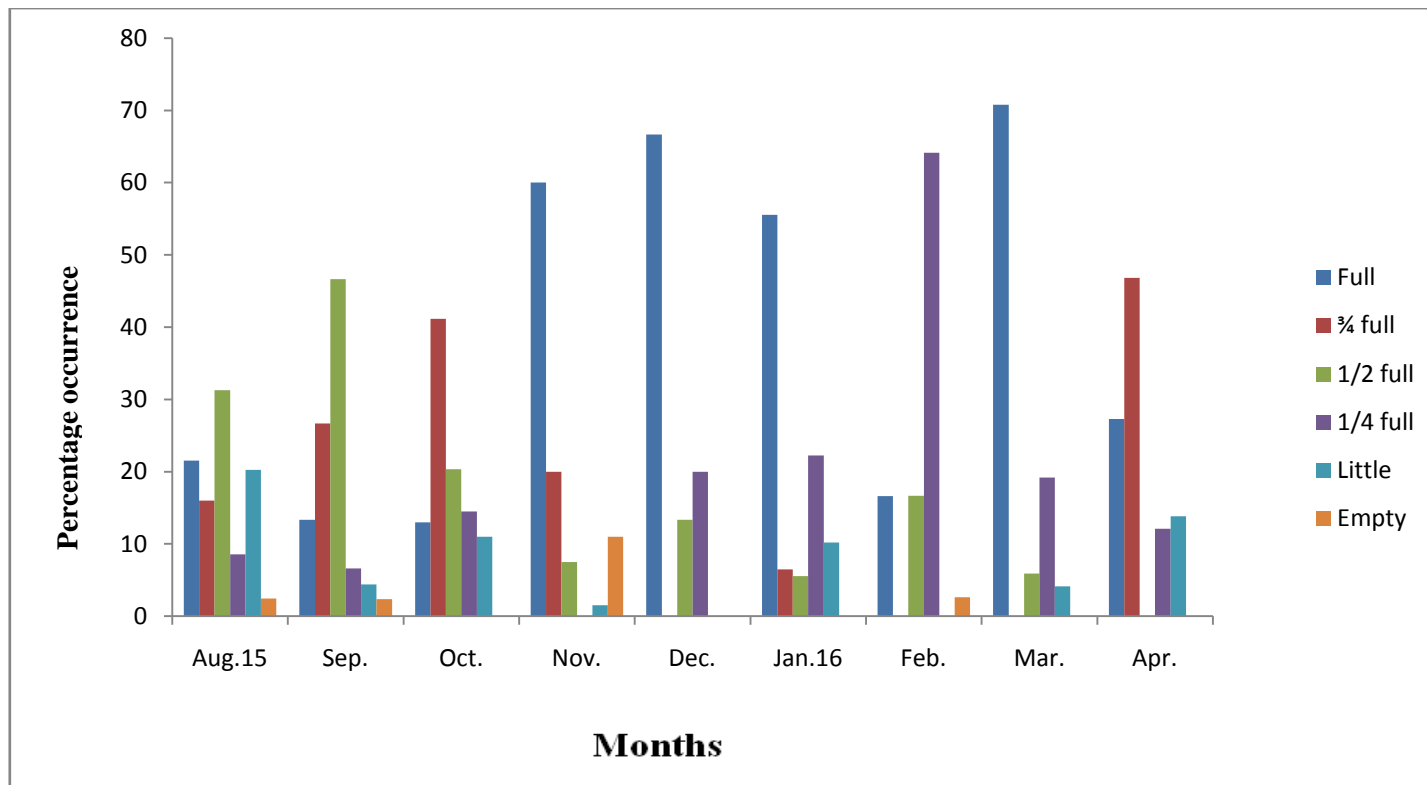


Fig 8.Percentage occurrence of food items of *D.acuta*

Table 9. Percentage occurrence of various degrees of fullness of stomach in *D. acuta*

Feeding intensity Size group(cm)	Full	¾ Full	½ Full	¼ Full	Little	Empty
12-14	41.71	21.42	22.62	11.25	-	3.00
14-16	38.46	12.59	18.35	25.81	4.25	-
16-18	67.33	6.98	11.46	9.00	-	5.23
18-20	48.35	7.21	38.44	13	-	6
20-22	12.18	53.04	19.92	11.65	3.21	-
22-24	79.65	-	20.35	-	-	-

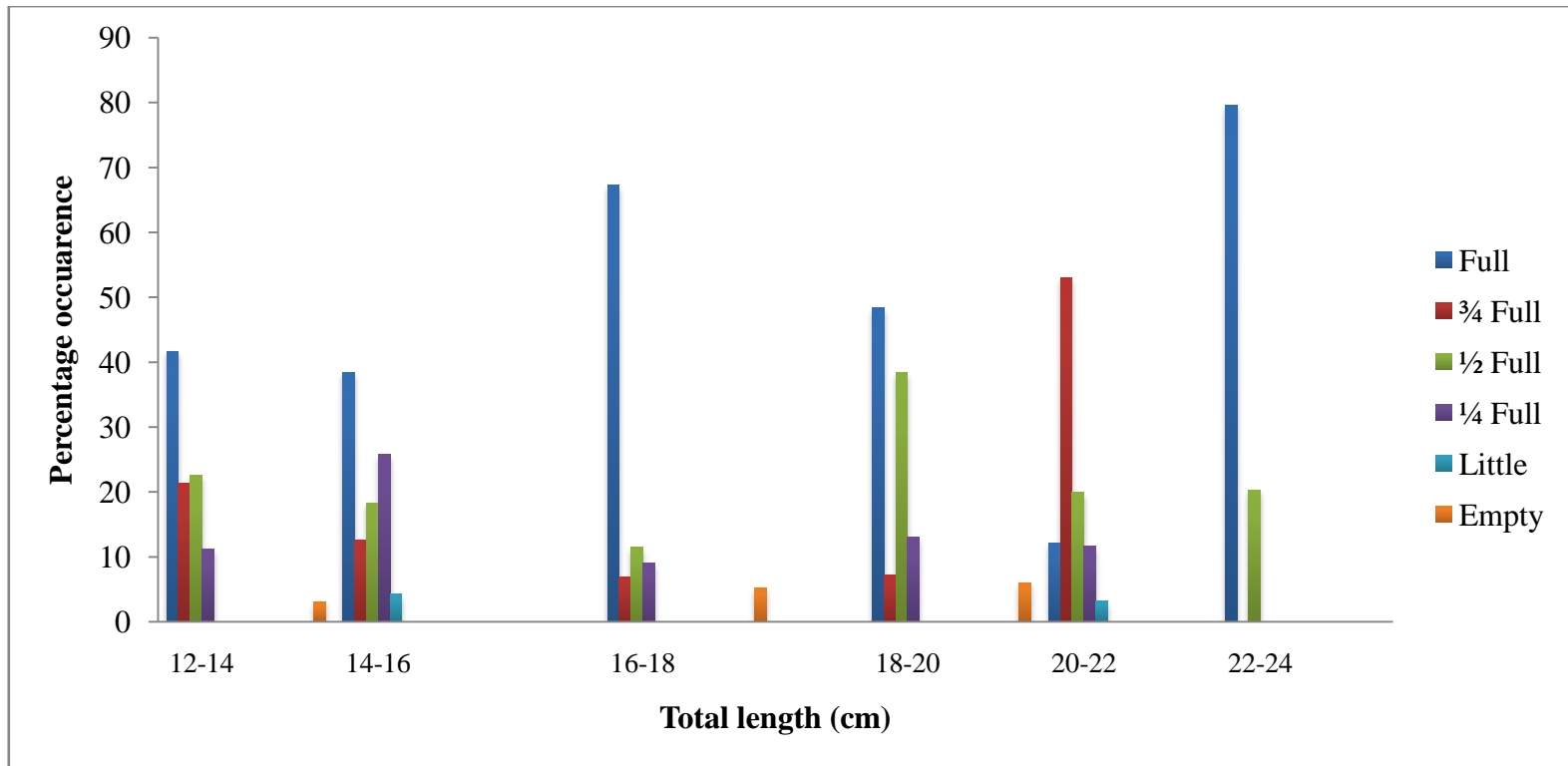


Fig.9 Percentage occurrence of various degrees of fullness of stomach in *D. acuta*

Table 10. Classification of maturity stages of *D.acuta*

Stages of maturity	Description of ova	Mode of largest group of ova(mm)	Maximum size of ova
I	Immature	0.12	0.19
II	Developing Immature	0.16	0.50
III	Maturing	0.41	0.66
IV	Mature	0.56	0.78
V	Advance Mature	0.82	1.03
VI	Ripe	0.94	1.12
VII	Spent	0.69	0.81

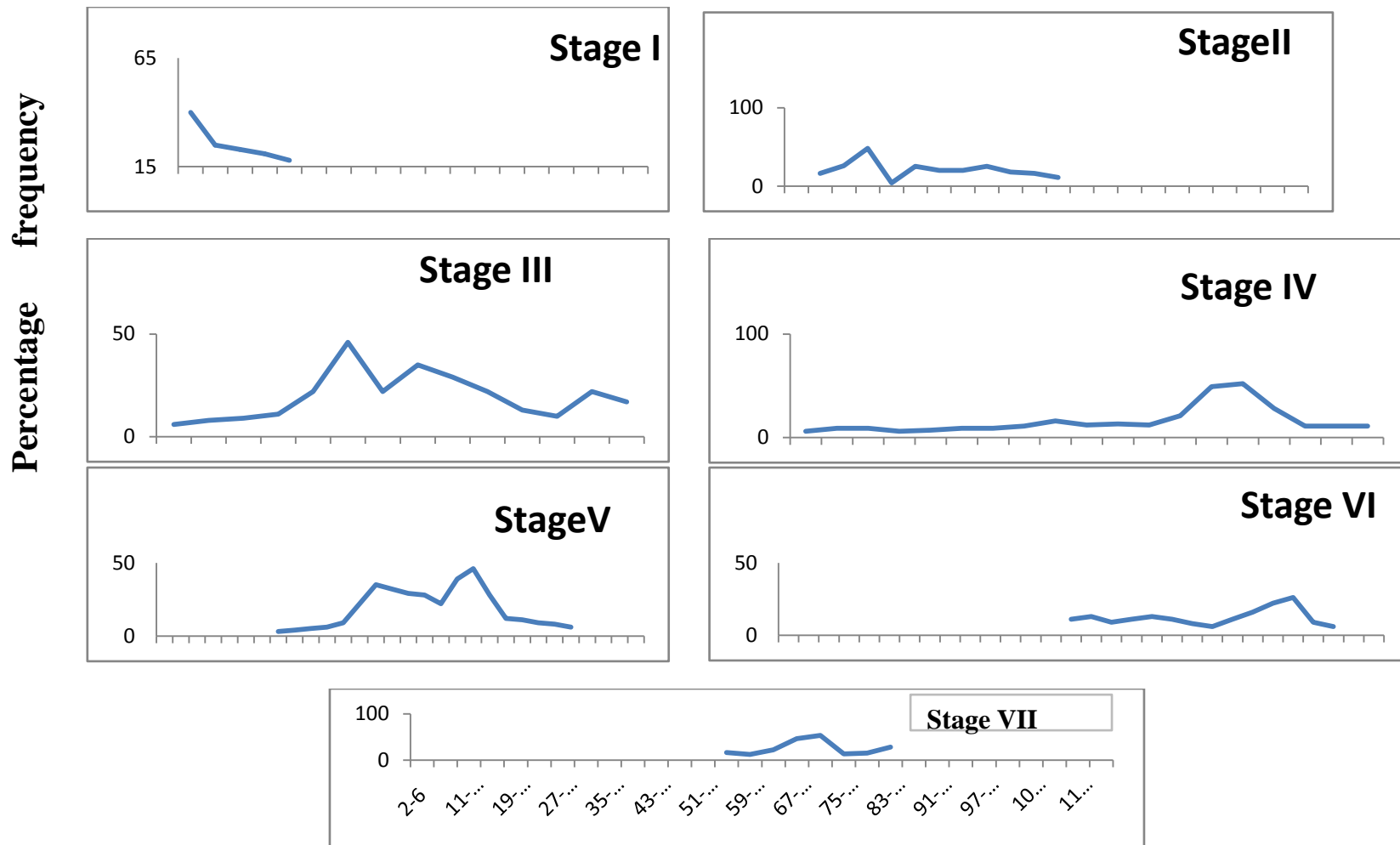


Fig 9. Frequency polygon of ova diameter of *Dussumieria acuta* in various stages

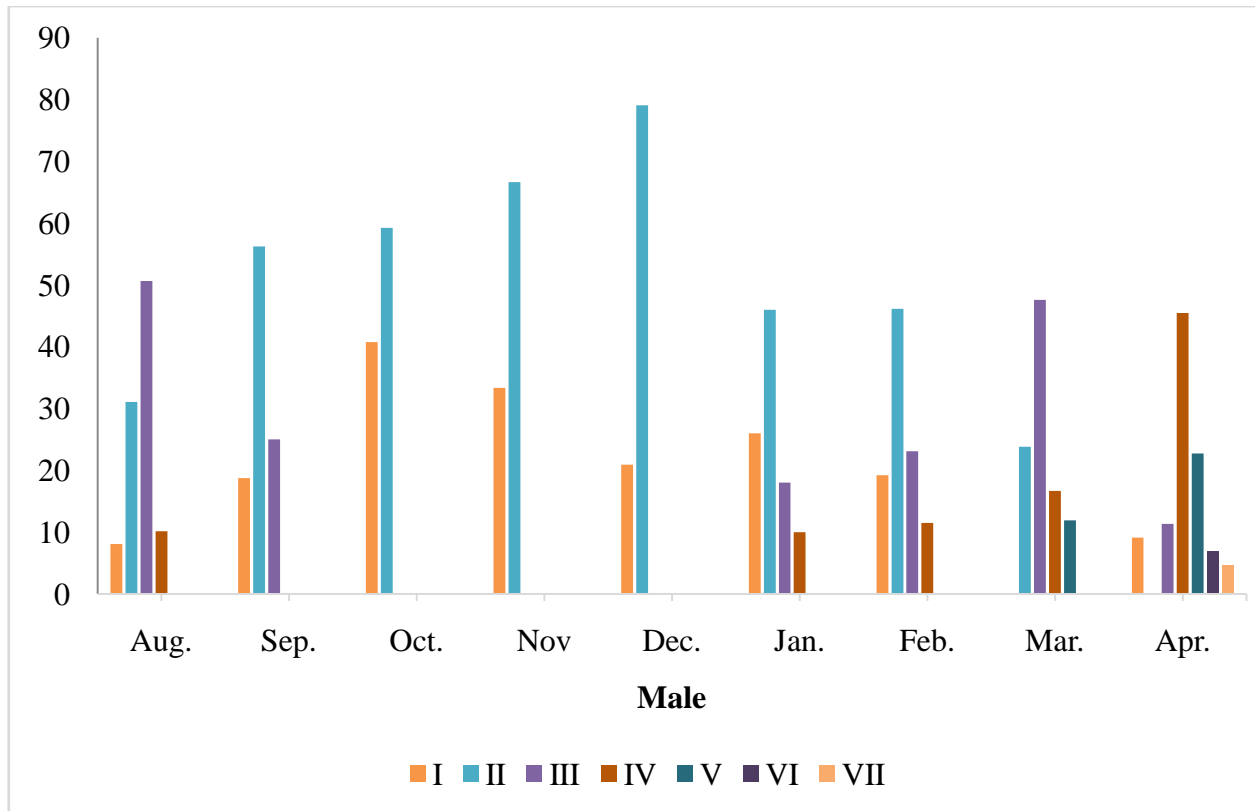


Fig 11. Month-wise percentage occurrence of gonads in different stages of maturity of *D. acuta* -Male

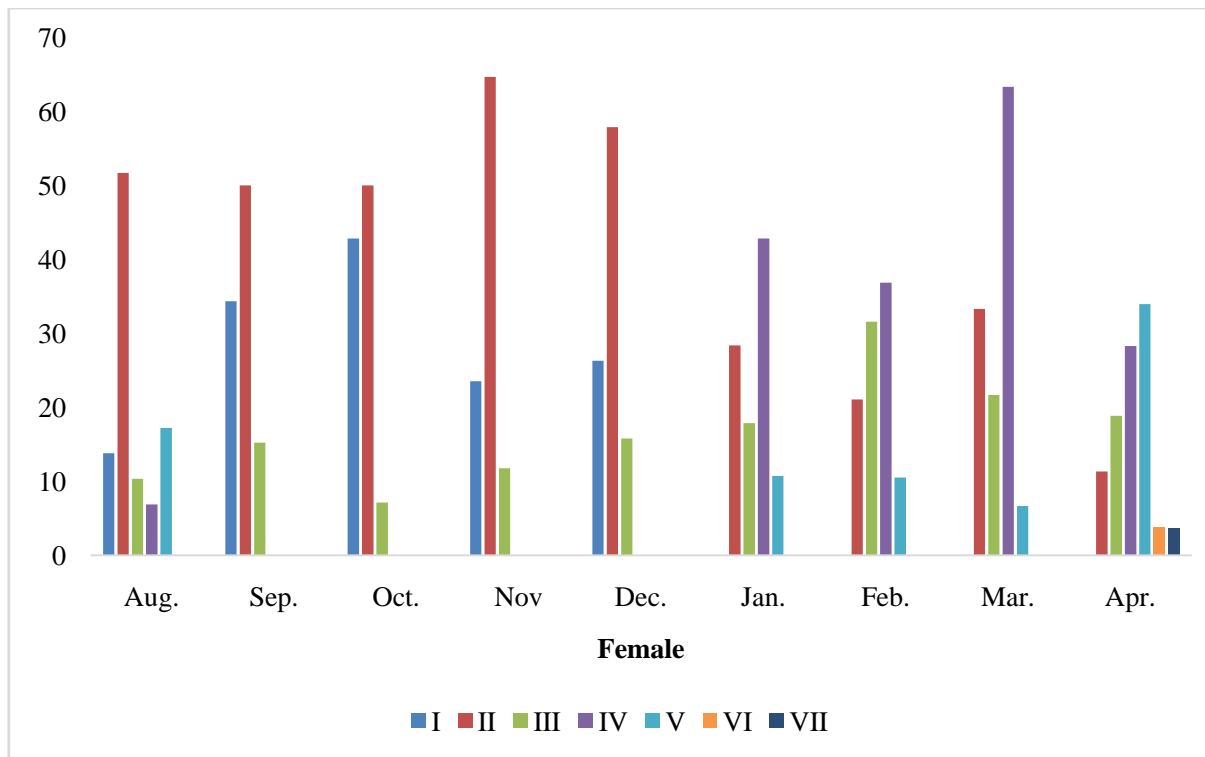


Fig 10.Month-wise percentage occurrence of gonads in different stages of maturity of *D. acuta* -Female

Table 12. Percentage occurrence of different stages of maturity in relation to different size group of *D.acuta*

Size group	No.of fishes	Sex	Maturity stages						
			I	II	III	IV	V	VI	VII
12-14	15	M	83.72	11.65	4.65	-	-	-	-
	31	F	75.00	15.91	9.09	-	-	-	-
14-16	171	M	62.00	22.43	5.15	10.41	-	-	-
	76	F	23.57	19.65	25.00	16.07	4.14	11.57	-
16-18	91	M	12.33	20.14	17.50	25.56	21.78	2.69	-
	85	F	-	-	49.16	31.28	15.17	4.49	-
18-20	108	M	17.94	20.34	13.33	23.33	18.37	6.69	
	61	F	-	-	28.28	43.44	28.28	-	-
20-22	24	M		15	20.75	23.21	25.24	15.8	-
	17	F	-	--	-	17.27	63.64	9.08	10.01
22-24	5	M	-	-	20	45.6	21.6	12.8	
		F	-	-	-	-	-	-	

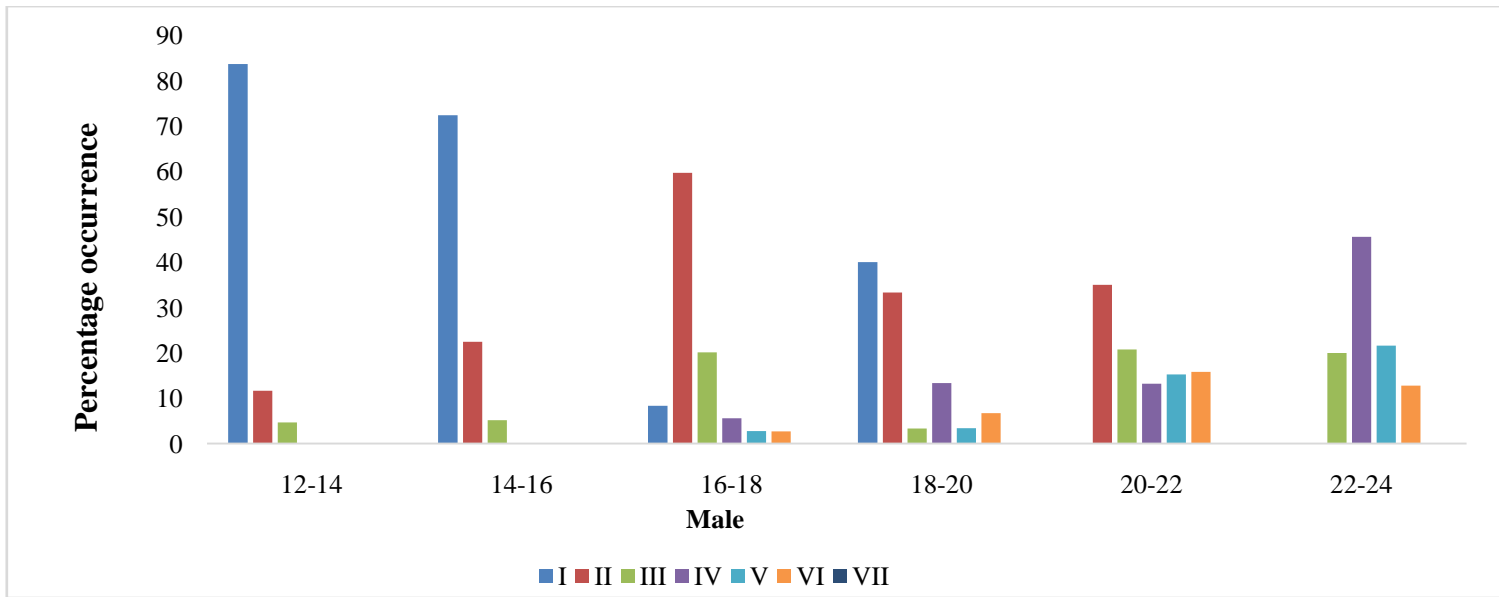


Fig 12. Percentage occurrence of different stages of maturity in relation to different size group of *D acuta*.-Male

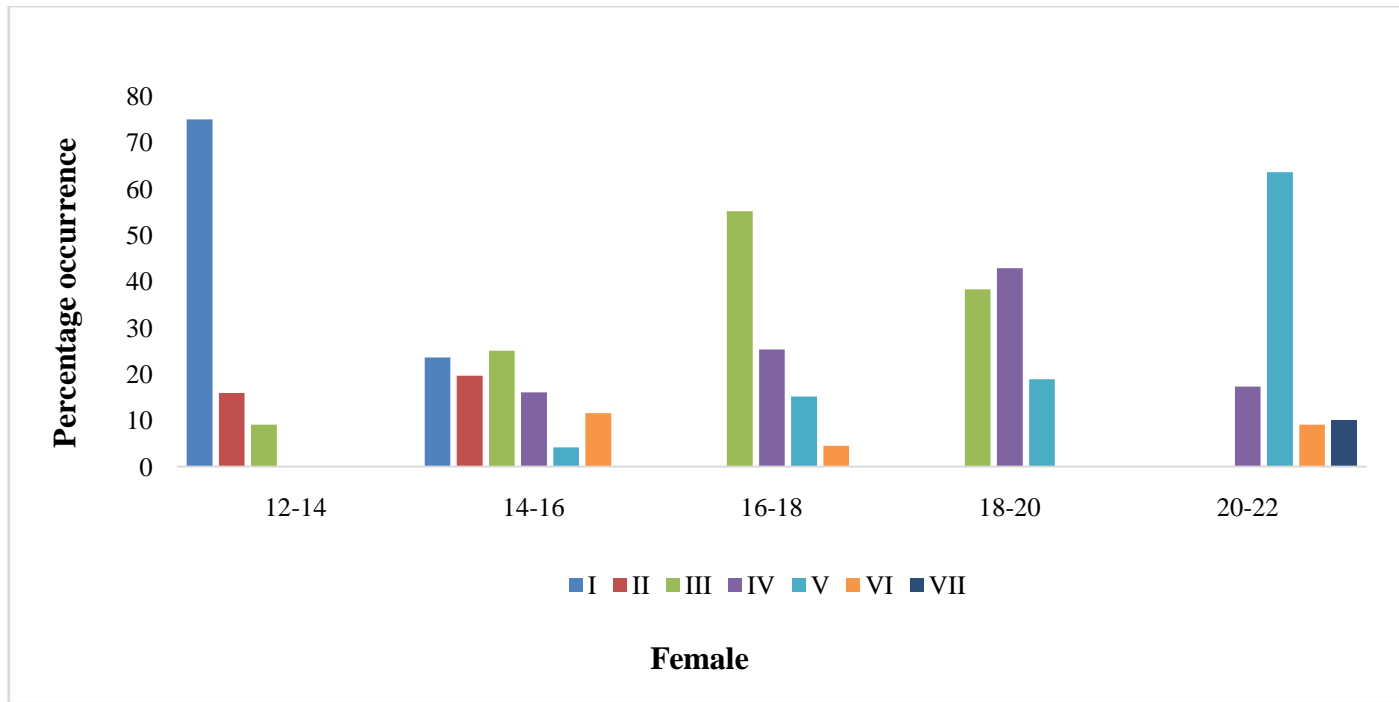


Fig 12a. Percentage occurrence of different stages of maturity in relation to different size group of *D acuta*.-Female

Table 13. Estimation of size at first maturity by cumulative percentage frequency method of *D. acuta*

Size groups (cm)	Mid point	Cumulative percentage frequency	
		Male	Female
12-14	13	-	-
14-16	15	44.93	44.62
16-18	17	66.91	73.28
18-20	19	92.99	93.15
20-22	21	98.79	100
22-24	23	100	-

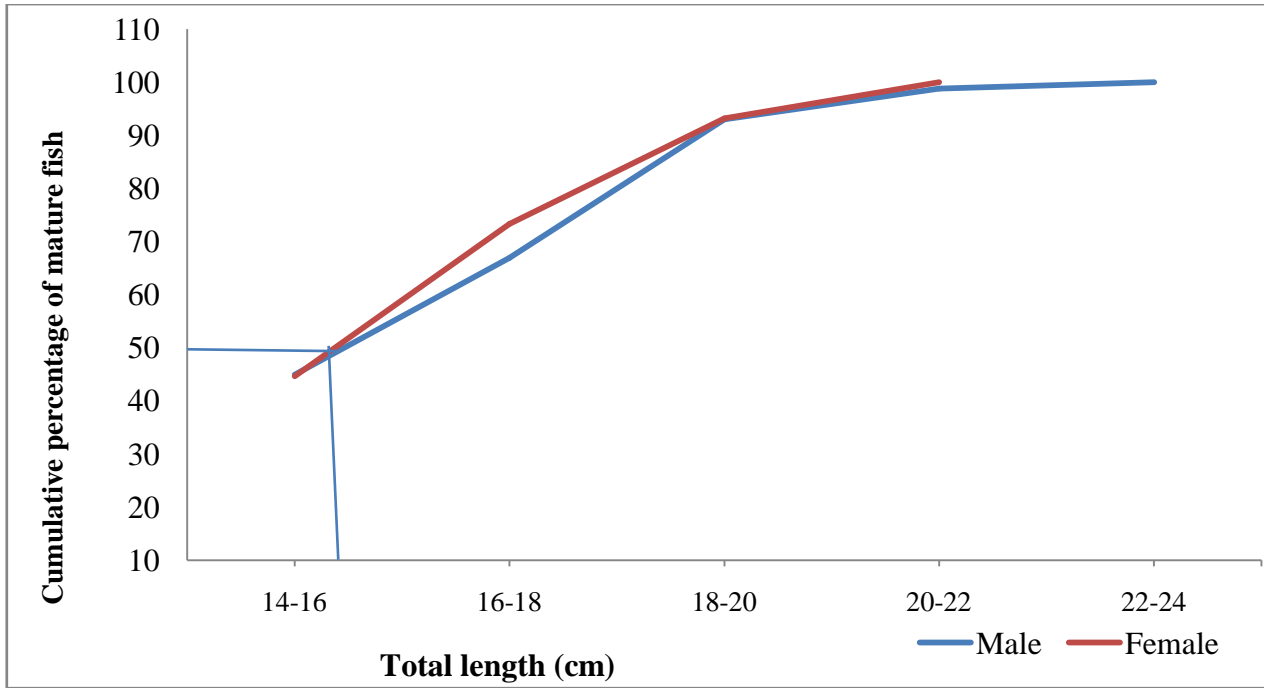


Fig.13. Size at first maturity of *D. acuta*

Table 14. Monthly variations in gonado-somatic index of *D. acuta*

Months	Male		Female	
	No.of fish	G.S.I	No of fish	G.S.I
Aug. 2015	74	2.5394	31	3.1797
Sep.	64	2.3677	32	3.1294
Oct.	27	2.1464	30	2.9635
Nov.	45	2.0125	17	2.8567
Dec.	43	1.9662	30	2.6769
Jan. 2016	50	2.24393	28	3.03175
Feb.	28	2.6499	26	3.5618
Mar.	42	2.731108	60	3.9957
Apr.	44	2.8756	53	4.53002

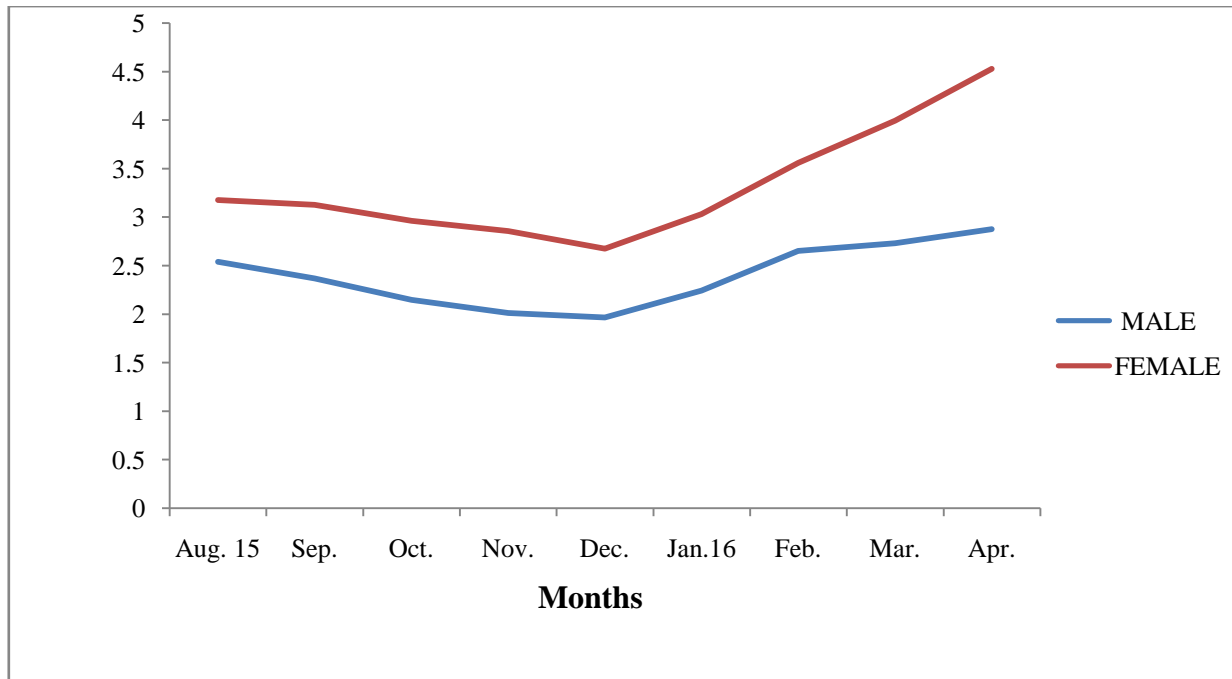
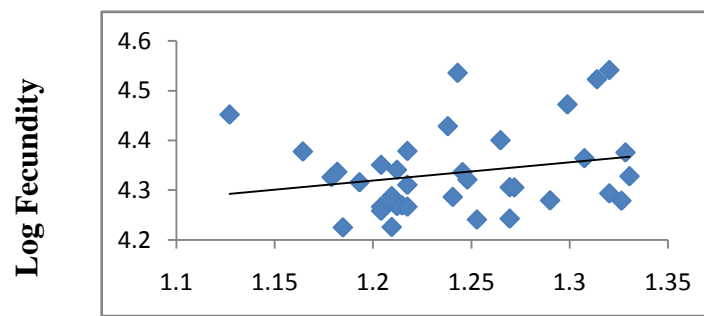


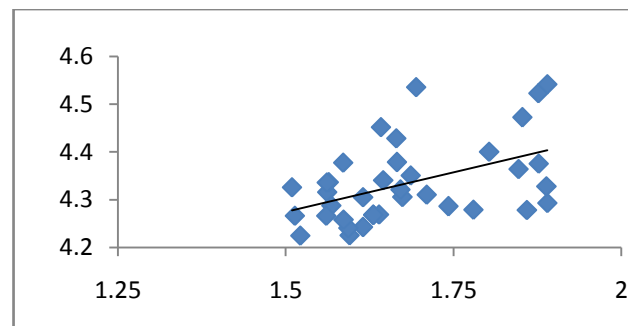
Fig 14.Monthly variations in gonado-somatic index of *D. acuta*

Table 15. Number of mature ova in individuals of *D.acuta*

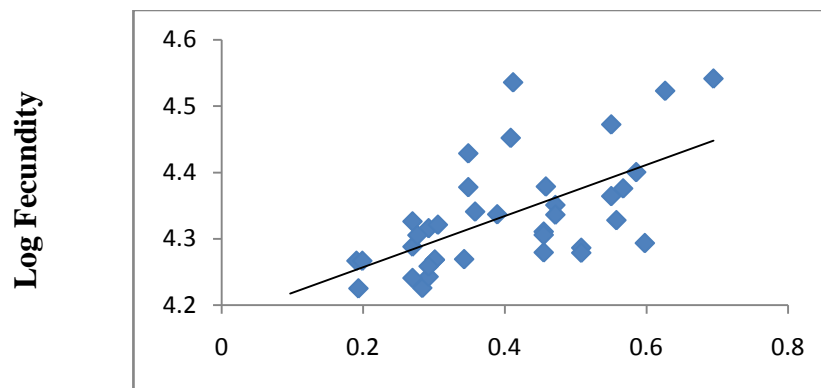
Sl.no	Total length(cm)	Body weight	Gonad weight(g)	Fecundity	Stages of Maturity
1	16.3	44.2	2.28	21923	V
2	16.3	42.69	2.00	18552	IV
3	16.4	43.55	2.2	18590	IV
4	16.5	46.32	2.87	23916	VI
5	15.6	36.46	1.96	20696	V
6	15.6	35.2	1.25	12642	IV
7	16.3	42.69	2.00	18552	IV
8	16.2	39.37	1.92	16824	IV
9	14.6	35.2	1.25	12642	IV
10	16	32.62	1.55	18484	IV
11	16.5	36.33	1.58	18483	IV
12	15.2	36.66	2.45	21719	V
13	15.1	32.3	1.86	21191	IV
14	16	48.56	2.96	22431	V
15	16.5	51.28	2.85	20452	IV
16	13.4	43.85	2.56	28314	VI
17	18.4	63.55	3.85	25141	V
18	17.4	55.28	3.22	19338	IV
19	14.6	38.5	2.23	23863	IV
20	18.6	47.21	2.85	20223	V
21	17.6	36.44	2.96	21688	V
22	18.7	41.25	1.89	20205	V
23	21.2	72.35	3.22	19004	IV



Log length



Log weight



Log ovary weight

Fig 16 a) Logarithmic length and fecundity relationship of *D. acuta*

b) Logarithmic weight and fecundity relationship of *D. acuta*

c) Logarithmic ovary weight and fecundity relationship of *D. acuta*

Table16. Monthly sex-ratio of *D.acuta*

Months	Total no.of fishes	Males		Female		Chi-square values	Male:Female
		n	%	n	%		
Aug. 2015	105	74	70.476	31	29.523	17.608*	1:0.41
Sep.	96	64	66.666	32	33.333	10.666*	1:0.50
Oct.	57	27	47.368	30	52.631	0.158	1:1.11
Nov.	62	45	72.580	17	27.419	12.645*	1:0.36
Dec.	73	43	58.904	30	41.095	0.7123	1:0.69
Jan.2016	78	50	64.102	28	35.897	6.2051*	1:0.56
Feb.	54	28	51.851	26	48.148	0.0744	1:0.48
Mar.	102	42	41.176	60	58.823	14.500*	1:1.42
Apr.	97	44	45.360	53	54.639	0.835	1:1.20
Pooled data	724	417	57.596	307	42.403	16.712*	1:074

* Significant at 5% level

Table 17. Sex –ratio in different size groups of *D. acuta*

Size groups	Total no.of fishes	Males		Female		Chi-square values	Male:Female
		n	%	n	%		
12-14	56	15	26.785	41	73.214	6.0354*	1:2.73
14-16	270	174	64.044	96	35.955	10.533*	1:0.56
16-18	179	91	50.837	88	49.162	0.067	1:0.49
18-20	169	108	63.905	61	36.094	13.07*	1:0.56
20-22	45	24	53.333	21	46.666	0.30	1:0.46
22-24	5	5	100	-	-	-	-
Pooled data	724	417	57.596	307	42.403	16.712*	1:0.74