ABSTRACTS OF Ph.D. THESES ON HERPETILES

ECOLOGICAL STUDIES ON THE PACIFIC RIDLEY SEA TURTLE, *Lepidochelys olivacea*, ON THE ORISSA COAST

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The present study was undertaken to investigate the ecology of olive ridley sea turtles in Orissa coast. Three species: *Dermochelys coriacea* (Linn., 1766) *Eretmochelys imbricata* (Linn., 1766) and *Lepidochelys olivacea* (Eschscholtz, 1829) were recorded but *L. olivacea* was the only sea turtle nesting in the study area. Present investigation is first such attempt in India to correlate intraspecific variations of populations of *Lepidochelys olivacea* to their ecological functions basing on distribution, dynamics, morphology, morphometry, reproductive biology, migratory behaviour, seasonality of nesting activities, solitary and mass nesting strategies in relation to lunar cycle, reproductive homing, philopatry or the more fine scale nesting site tenacity, etc.

The nesting strategy in general of *Lepidochelys olivacea* involved scattered nesting over wide areas along the entire length of Orissa's coastline. Besides, huge arribadas of thousands and thousands of animals all synchronising at the same time in less than 10 km. stretch of the study site occurred. The study area extended from south of Ekakulanasi muhana (20°52' N, 86°77'E) to Barunei muhana (20°72'N, 87°5'E) along the east coast of India, and formed the coastal boundary of the 141.44 sq.km. Bhitarkanika Wildlife Sanctuary. The beach is remote from human habitation and is separated from the mainland by mangrove creeks. The average width of the rookery (nesting habitat) remained almost constant during an arribada though it was subjected to annual as well as seasonal erosion cycles through out its entire length due to the actions of prevailing wind and surface currents in the Bay of Bengal. In winter, the average width of the rookery is at it's maximum (50-60 meters) and in rainy season it is at it's minimum (5-10 meters). With changes in wind direction from South to North during October-November, within a relatively short period the beach is rebuilt again and supports mass nesting of the olive ridleys.

The climate of the study area is divided into three distinct seasons having considerable influence on the breeding of turtles. The mean sea surface temperatures during winter and early summer were approximately 27°C which correspond to the peak mating and the first and second mass nesting period of olive ridleys, thereafter it increased to about 29°C.

Analysis of data on morphometry did not indicate any difference on the basis of sex although differences between species are distinct. Some of the body characters exhibited significant positive correlations in individuals of different age classes i.e. in hatchlings, yearlings and adults. The minimum size of nesting females which is an indirect indication of size at first maturity was found to be 62.0 cm and 54.0 cm for curved carapace length and straight carapace length respectively. A comparison of this with those of other population showed that the species matures probably at a larger size in the Bay of Bengal than in other parts of its range. The size of hatchlings fell within the range 3.1 cm to 4.85 cm straight carapace length (X = 5.21 cm). The olive ridleys of Gahirmatha appears to be slightly larger in size than those found else-where. It also possibly matures at a slightly larger size in the Bay of Bengal than in other parts of its range.

Detailed quantitative analysis of the carapace and plastral laminae of hatchlings and adults of both sexes were made. Single and double tagging data of 14605 olive ridley females indicated that one year remigration pattern is more common (69.83%) than 2,3, 4 and 5 year remigration pattern. Besides, 343 olive ridley females remigrated 358 times to the same nesting beach.

Inter and intraseasonal tag recovery data revealed the mean distances between original tagging sites and subsequent nesting sites in different seasons and these distances were 1.23 km +/- 0.01 and 0.79 km +/- 0.2 respectively thereby indicating that ridleys show strong nest site fixity when returning to nest either between or within nesting seasons. No inter or intraseasonal beach shifts were recorded.

Recoveries from stranded ridleys during February, 1981 showed that 25% of the tags were obtained from turtles tagged during the same nesting season. The recorded mean interval was 21.5 days +/- 1.29. This indicated that large number of turtles possibly did not leave their breeding grounds and remained in the coastal waters in front of the mass nesting beach for some time. Perhaps the large arribada populations are composed of a number of identifiable sub-groups which distribute themselves in the high seas after an arribada has terminated. Some sort of fanning out in all directions took place between first and second arribadas of a season.

Lepidochelys olivacea was shown to have larger internesting intervals than those of other species of sea turtles. This internesting interval was much longer (46-58 days) for population of olive ridleys nesting at this rookery than for populations in other parts of its range. The maximum number of clutches per year was two and the possible reasons of this longer internesting interval is discussed. Intro-arribada tag recoveries revealed effect of disturbance on nesting emergences as well as regional discrimination of nesting shore and more fine scale nest site fixity tendency. Temporal distribution of multiple nesting emergences is presented and possible migratory route followed by the turtles during their breeding migration to Orissa coast is shown and this includes off shore recovery of a single turtle.

Observations on courtship, mating, timing of sequences of different stages of nesting behaviour and total time spent on land during the nesting emergences were made. Nesting occurred throughout the year with peak nestings during late December to May. In each season there were usually two large arribadas which lasted for 3 to 10 days. Many mini-arribadas also occurred, the duration of which varied from one to four days. Occurrence of different track types in the ascending and descending crawls and various measurements of natural nests were recorded. Mean temperature of sub-surface sand along the trails of ascending crawls influenced nest site selection process. The mean sub-surface temperature showed a decrease of about 1.15°C +/- 0.42 in the wet beach zone (intertidal region) from mean sea surface temperature and thereafter again showed an increase of about 0.65°C +/- 0.44 in the dry beach zone immediately after the high tide line. The mean abrupt increase in the temperature from the dry beach zone to selected nest site was 1.23°C +/- 0.39 (Range 0.68°C to 2.4°C).

Analysis of grain size revealed that 50 to 70% of the beach sands were in the size fraction (<0.5 to 0.20 mm). The modal grain size was <0.5 to 0.25 mm. Only 10.09% +/- 2.74 of the sands fell into the finest size fractions of 0.20 to 0.75 mm and 19.62% of the sands were contained in the two largest fractions i.e. 1.42% +/- 1.54 in the size fraction > 1.00 mm and 18.20% +/ - 5.58 mm in the size fraction 1-0.5 mm respectively.

Clutch size varied from 24 to 186; the weighted arithmetic mean was 116 (N = 1611) during 1977-85. However, no significant differences were observed between mean clutch size during different nesting seasons. Frequency of occurrence of clutch sizes in increments of ten did not represent a normal distribution. Regression analysis between clutch size and adult body size, mean egg size, mean egg weight, etc. showed no significant relationships.

Mean maximum egg diameter of different clutches varied from 3.45 to 3.90 cm and mean egg weight from 23.58 to 34.01 gm. A two way ANOVA of mean maximum diameter of eggs showed significant differences both between nests (F = 35.11, D. F. = 69, P < 0.005) and within individual eggs (F = 2.85, D. F. = 9, P < 0.01). A two way ANOVA of egg weight did not show any significant differences between individual eggs of a nest while there was significant difference between mean egg weight of different nests (F = 26.73, D.F. = 69, P < 0.005). Regression analysis showed that there was direct relationship (r = 0.86) between mean egg size and egg weight of clutches (t = 12.27, D.F. = 53, P < 0.001) indicating the egg size to be a function of egg weight and vice-versa.

Abnormalities in eggs were mainly in the form of two to five eggs joined together, several small eggs joined together by wart like outgrowths or one to many eggs joined with a normal sized egg.

Incubation duration of replanted and field nests were recorded during winter and summer under two different experimental conditions i.e. under natural photoperiod and under constant shade conditions. Daily temperature fluctuation of nests at depths of 25 cm and 40 cm and the corresponding sand temperatures at same depths were recorded during morning and evening hours in both types of incubation conditions. In the first two-third of the incubation period, the difference between the nest and correspondings and temperature at similar depths was 0.5^{0}C or less; in the remaining one-third of the incubation duration, this difference was significant being 1.5^{0}C or more which was due mainly to metabolic heating of eggs. After a lapse 68% and 64% of the incubation duration metabolic heating became prominent respectively for nests incubated under both the conditions. The timings and process of nocturnal emergence of hatchlings are observed in relation to temperature of beach sands.

The overall percentages of infertility and embryonic mortality accounted for 5.97% and 7.06% respectively. The mean hatching success of nests which were not subjected to stress conditions varied from 83.27% to 90.81% with the over all hatching success being 87.72%. A total of 7.18% of the hatchlings could not emerge out to the surface and were found dead in their nest cavities. The emergence success of hatchlings was found to be 92.83%. ANOVA analysis of natural hatch percentages of nests laid in different sections of the beach revealed no significant difference between hatching rates and the mean hatching success was 82.53%.

When depth of sand cover over the top egg mass in the nest was reduced due to wind action, mean percentage of hatching success was considerably lowered by about 50% than the nests where the depth of sand cover was not affected (72.64% +/- 9.39 in control and 32.15% +/- 6.94 in experimental nests). Effect of saline inundation also resulted in lowering of mean hatching success from 83.79% in control sets to 32.21% (for nests inundated only once or twice) and to 2.03% (for nests that were inundated several times; the mean percentages of embryonic mortality for these three types of nests were 6.49%, 63.84% and 89.78% respectively.

In replanted nests in the hatchery detailed investigations were made to illustrate (i) effects of time of transfer of eggs after oviposition and (ii) effects of orientation of vertical axis on mortality and hatching success of eggs. The mean hatching success of control nests when compared with those of treated nests did not reveal any significant difference for nests removed immediately after laying or at 3 hrs, 6 hrs, 9 hrs and 12 hrs after laying in two types of orientation treatments (i.e. in one set, eggs remaining same way up and in other set eggs rotated through 180^0 so that vertical orientation was reversed). However, it did reveal significant difference when nests were removed at 15 hrs, 18 hrs, 21 hrs and 24 hrs after laying, irrespective of orientation treatments. Thus, there was a critical period of less than 12 hours to about 4 weeks after laying during which hatching success were significantly decreased by movement of eggs. This indicated the sensitivity of eggs to movement and disorientation of vertical axis which is very much related to the events which occur in early embryological developments.

Twenty seven arribadas occured during December 1977 to March 1987. These included fourteen large arribadas (involving 1,000 to 100,000 or even more nesters per night in less than 10 km stretch of beach) and thirteen mini arribadas (involving 100 to 1000 nesters); the later included six one day mini arribadas. The temporal and spatial distribution of arribadas mini-arribadas and solitary nesting frequencies were recorded. The average number of nights per month in which there was no turtle nesting activity decreased from January to March and thereafter gradually increased reaching a maximum during June to December. As turtle-less night increased (June-Dec), the average number of nights per month involving one to ten loner nesters decreased. The average number of nights per month with more than ten solitary nesting emergences were found only during January to June; in other months (July-December) the average number of nights per month with more than 10 solitary nesting emergences was zero. Monthly fluctuations in the number of false crawls encountered during solitary nesting emergences revealed that the percentages of false crawls accounted for 9.43% and 13.13% during 1982 and 1983 respectively.

As a result of off shore poaching activities and 'incidental catch' in commercial fishing operations, a total of 3682 adult olive ridleys of both sexes (1388 males and 3294 females) were stranded in approximately 10 km stretch of the rookery during the study period. Such turtles usually arrived during September-October months each year indicating the onset of the breeding season. The number of stranded males were usually more during September-December. However, during January to March this trend was reversed, females outnumbering the males. During April and May the number of stranded turtles was greatly reduced and it comprised exclusively of females. After March till September no stranded males were observed but during June to August females were also not seen.

Experiments on food selection of individuals of two different age groups i.e. (hatchlings and one year old turtles) showed similar trend in food preferences. Given an option of plant and animal food, both hatchlings, and yearlings preferred animal food to plant food. Rearing of individuals exclusively on plant diet showed a decrease in mean body weight, all the hatchlings died invariably within a month and the mean body weight of the yearlings showed a decrease of more than 500 g. within 5 months. Hatchlings preferred oyster meat to all other types of meat diet (total consumption of 2,743 g./ individual over a period of 6 months) followed in order of preference by shrimp (1156 g./ individual) and crabs (1189 g./ individual). Oyster fed individuals exhibited best growth increment in terms of length and weight. For 6 months old turtles, the maximum amount of food eaten over a period of 4 months was oysters (15,057 g./ individual) followed by shrimps (10,563 g./ individual), mixed feed (10,249 g./ individual), fish (9,871 g./ individual) and crabs (7,963 g./ individual).

The increase in body weight and different body parts such as straight carapace length, straight carapace width, plastron length, plastron width, head length, head width, curved carapace length, curved carapace width, total length, body depth, etc of hatchlings reared in captivity exhibited a linear relationship during the early developmental period. Growth rates of different body parts were compared by the structural model $y = bx^K$ to determine the nature of allomatric growth path of a body part with respect to that of another body part and the nature of dependence between the two.

Conservation of olive ridley sea turtles in Orissa coast with regard to protection, management and rational utilisation of this natural resource is discussed.

GROWTH ECOLOGY AND METAMORPHOSIS OF A TROPICAL AMPHIBIA, *Bufo stomaticus* LUTKEN

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Adults of *Bufo stomaticus* Lutken were collected during night hours beneath the light posts and from residential area of Sambalpur University Campus. They were allowed to breed naturally in the froggery. Eggs thus laid were allowed to hatch in the laboratory condition (33° +/- 2°C). The adult biology was studied and different morphometric measurements were made. Experiments to study effect of various environmental factors such as grouping, aeration, food quality and quantity, active space (volume of water per tadpole) and density on growth and metamorphosis were done along with the stagnation of the normal larval life period. The larval energetics was studied by estimating consumption, egestion, assimilation, respiration, excretion and production at different stages.

B. stomaticus breeds during rainy season. About 9,000 to 11,000 eggs were laid by a female after an amplex period of 1-4 days and the eggs were arranged in double strings. There was a significant positive correlation between snout-vent length and body weight, snout-vent length and femur length in case of field population as well as laboratory reared *B. stomaticus* irrespective of sex and age. A significant positive correlation also observed between body weight and gonad weight among field collected individuals. However this relationship was not significant (P. 0.05) in case of laboratory reared juveniles (upto 5 months old) and it might be due to age specific development of different organs.

Laboratory study showed that group (10 tadpoles/tray) rearing favoured larval growth when compared to isolated rearing because of environmental agitation and aeration as well as optimum use of the food materials. However increase in grouping numbers (20 tadpoles/tray) decreased the growth rate as excess grouping led to crowding effect.

The larval life span was broadly catagorised under three stages, I, II and III which are comparable to pre-metamorphic, prometamorphic and metamorphic climax stages. Just metamorphosed juveniles were kept under stage IV. The normal larval life period was found to be 14 days. The growth curve was sigmoid type up to the metamorphic climax (tadpoles with one side forelimb) and then the sigmoidal nature of the curve was disrupted due to decrease of body mass at forelimb stage which further decreased at metamorphosed juvenile stage.

Growth was higher in tadpoles reared in aerated water medium than the tadpoles reared in non-aerated medium. Increase in duration of aeration more than 1 h had not affected positively the larval growth as measurement of DO_2 showed that the water gets saturated after one hour of aeration.

Larval growth and body mass at metamorphic climax were significantly affected by different food types. Tadpoles fed with only goat meat tended to metamorphose at a smaller weight (99.8 mg) and at a later date (24.2 days) when compared with other food types. Results of the experiments on the affect of food quality on larval growth showed that mixed diet promoted best larval growth. Leafy diet in some cases showed tail deformation. The larval growth rate was maximum in 0.8 g mixed food per 10 tadpoles. Deviation from this level proportionately decreased the larval growth and hence the body mass at metamorphic climax. But the time of metamorphosis was not much affected by food levels. In this study tadpoles metamorphosed more or less at the same time (12.5 to 13.4 days).

Although, visual inspection of growth curves indicated higher larval growth rate with increasing active space upto a particular level, but the data were not statistically significant. Thus I conclude that available active space used in this study had no significant effect on growth and metamorphosis of *B. stomaticus* larvae.

In the experiment dealing with effect of density, the mortality rated were computed as : $N_t = N_0 e^{-mt}$
N_t = number of larvae metamorphosed, N_0 = initial density, m = mortality rate and t = average time (days) taken for metamorphosis. The mortality rate as well as the proportion of population that metamorphosed were not functions of initial density. The S-shaped growth curves showed a right hand shift with increasing density and it was attributed to competition for food. Statis-

tical analysis showed that the growth was dependent on initial density and was reflected in weight at metamorphosis. The lowest threshold value was 97.0 mg while the maximum was 212.3 mg. The time of metamorphosis was however, independent of initial density (except very high density population of 320). This could be possible due to differential threshold values and perhaps due to schooling behaviour. Hence individuals of very high density population (320) took longer time (33.5 days) to attain the minimum threshold weight.

International Biological Programme terminology for energy flow has been used for this study. Energy budgeting of *B. stomaticus* larvae indicated that the energy components like consumption, respiration, production and egestion were age specific and varied markedly with developmental process. The total consumption, assimilation respiration etc., per larva increased during the growing period but the rate (per gram body mass) of consumption, assimilation, egestion, respiration etc., show significantly negative correlation with body weight.

Food consumption was not observed at metamorphic climax stage during which energy was obtained from resorption of tail. The production efficiency (P/A x 100) was constant (around 16%) through out the pre and pro metamorphic stages. It is interpreted as an adaptation for rapid growth in these larvae having short larval life span (about 14 days). The respiratory efficiency (R/A x 100) in stage I and II was 62.47 and 51.25% respectively. The convergent nature of P/A and R/P ratios indicated that energy budget change with developmental process of *B. stomaticus* larvae.

Ammonia was observed in urine through out the larval period while urea was detected from the 6th day onwards after hatching. Increase in urea concentration towards the later period of larval life from an early high ammonia concentration (ratio of Urea-N : ammonia-N increased from 0.096 to 3.08) indicated the physiological changes for the terrestrial life of these toads. However, the total energy loss for urine production decreased as urea concentration increased due to differential energy requirements for production of ammonia and urea. Thus more energy was channelised for growth. This physiological strategy helped to achieve the threshold size for metamorphosis in about 14 days.

ECOLOGICAL ASPECTS OF METAMORPHOSIS OF A TROPICAL AMPHIBIA *Rhacophorus maculatus* (GRAY)

Pranabesh Kumar Mishra **1984**
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NOTE

In 1980, before the start of experiments, the frog species of this study was identified by Zoological Survey of India, 34, Chittaranjan Avenue, Calcutta-12 (Letter No. F.237-39/Herpt. Divn/9194, dated 2.6.81) to be *Rhacophorus maculatus* (Gray) (Identification report No. Z. S. I. Let No. 3/1981) and accordingly the title of the thesis was registered under Sambalpur University for Ph.D. degree.

Dr. Alain Dubois of France (Laboratoire des Reptiles at Amphibians, Museum National d'Histoire Naturelle) has very recently informed me, through personal communication that the name of *Rhacophorus maculatus* has been changed to *Polypedates maculatus*. As per Sambalpur University rules, a change in the title of the thesis can not-be made by the candidate and it requires permission of the University and since the thesis was in the binding stage it was not possible to incorporate this change. Therefore, *Rhacophorus maculatus* (Gray) may be considered synonym to *Polypedates maculatus*.

ABSTRACT

Rhacophorus maculatus (Gray) is an arboreal frog of highly secretive habit and live in an arid environment far away from water bodies. A field study was made during its breeding season to study the biology of this species. The breeding phenology of *R. maculatus* is to lay eggs on the ground nearer to temporary water pools which are filled with run off from erratic rains and is very similar to other rhacophorids of Asiatic main land, Borneo and Philippines. Appearance of breeding adults in breeding grounds and oviposition seemed to be influenced by the rise of temperature and rainfall.

Laboratory study shows that group rearing favours growth because of environmental agitation and oxygenation due to the movements and activities of individuals and optimum use of the food patches.

For study of life history *R. maculatus* larvae were reared in groups (n = 20) in the laboratory under controlled food conditions. The growth is sigmoid with faster differentiation process compared to *Rana pipiens* larvae. The initial lag phase of the growth is accompanied by rapid differentiation. The linear phase of the growth is accompanied by little differentiation whereas the slower growth rate towards the end of the larval period is accompanied by rapid differentiation. This might have been an adaptation to avoid desiccation of the breeding grounds.

R. maculatus larvae were reared in isolation and at various degrees of crowding under controlled laboratory conditions and at controlled food level sufficient for the highest density. In laboratory populations mortality rate during the larval period was independant of initial density but the proportion of population that successfully completed metamorphosis was a negative exponential function of density. The results clearly indicate a threshold size for initiation of metamorphic transformation. The degree of crowding ultimately does not affect this transformation size. The real effect of crowding in nullified by the effect of the time.

R. maculatus larvae were reared in laboratory at four densities and at four food levels in a complete block randomised design to study the effect of food abundance and population density on growth and metamorphosis of the larvae. The mechanisms of density effects are independant of the food level. Intraspecific competition and interference mechanism manifest the density dependant growth.

A laboratory study on the energy budget of *R. maculatus* larvae (Stage I-XX), fed with mixed food, was performed. Oxygen uptake by tadpole of *R. maculatus* is a function of body weight. The initial low rate of oxygen consumption is due to a lesser activities of the tadpoles in the absence of the limbs. Emergence of hind limbs increases the activity of the animal and it corresponds with the sudden rise in the oxygen consumption rate. $q0_2$ is the maximum in the earlier developmental stages and it declines as the developmental process proceeds, but attains a second peak during metamorphic climax. This may be due to calorigenic effect (Secondary effect) of thyroxin.

Ammonia is an excretory product at all stages of development of *R. maculatus* larvae. Urea was detected as an excretory product towards the end of premetamorphic stage. Amount of ammonia excretion increases with the growth and development of larvae and reaches its peak at stage XVII then gradually declines as metamorphic climax approaches. Urea excretion begins at stage X and increases through metamorphic process. *R. maculatus* larvae are ureotelic before metamorphosis, predominantly excreting urea from stage XX. This is evidently related to the new environment of the adult. The capacity for urea synthesis in these larvae may allow an additional short period of time to complete metamorphosis.

Older R. maculatus larvae are more efficient in partitioning their food energy for growth. XVII stage is the main energy gathering stage. The individual assimilation (A) calculated according to A_1 = C-FU and A_2 = P+R of *R. maculatus* larvae is almost balanced. Assimilation is around 75% of consumption at different stage of development.

A higher percentage of respiration is accompanied by lesser production. In *R. maculatus* larvae the absolute amounts of energy expended on growth, maintenance and rejects all varied markedly with developmental stages, as did the efficiency of respiration, assimilation and production. The strategic adaptation in the energy budget is to reach quickly the metamorphic size, thus avoiding predation and other environmental hazards.

AUTECOLOGY OF *Rana tigerina* (DAUD)

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Pronounced seasonal variation in number and sexual dimorphism in adult *Rana tigerina* has been found during one year field study. There seems to be a mean threshold size for appearance of vocal sacs as evident in 52 frogs in the range of 120 - 215 mm (average 145 mm +/- 2.62) in length and 250-440g (average 297.98 g +/- 7.13) in body weight. The ranges of length and weight of subadult males without the development of vocal sacs are 32-128 mm (average 94.32 mm +/- 4.22) and 5-260 g (average 94.37 g +/- 10.45) respectively, while the subadult females varied in length from 30-124 mm (average 90.84 mm +/- 3.72) and in weight 7-212 g (average 91.91 g +/- 7.48).

Adult males are smaller than the females. Difference in weight between two sexes of adult stage was statistically significant ($t = 3.13$, $p < 0.01$) while it was not significant in subadult stages. Adults showed annual peaks in number during June-August indicating occurrence of their breeding in first phase of monsoon. The reasons for availability of the frogs in large numbers are assigned to evacuation from their hideouts, which are made unsuitable due to rains.

Peak occurrence of subadults was observed during September-February. Of the total collection, 60% consisted of adults and 40% subadults. The contribution of males and females in the total catch was 45.41% and 54.59% respectively

Abundance of females in catch in most of the months is a possible indication of its passiveness while the male's spawning migration in June at the onset of monsoon and subsequently their return after breeding was well indicated by the catch data. Rise or fall of temperature forces the frogs to take refuge in suitable hideouts either in isolation or groups.

The frogs are generalised but indiscriminate feeders. The diets comprised insects, crabs, earthworm, small fishes, frogs and toads. The non-selective feeding habit is also observed in tadpoles which feed on zooplankton, phytoplankton and insect larvae. Enormous amount of soil and detritus are also observed in the gut of tadpoles. Reasons for occurrence of Ostracoda and Bacillariophyceae in undigested form in the guts of tadpoles have been attributed to parasitism and silliceous cell wall respectively. The non feeding activity was indicated by the emptiness of gut in the larvae with emergent forelimb (metamorphic climax stage).

Gonadal development occurred in summer months with an Initiation in March and ripenning in May. The breeding occurs with the onest of monsoon. The time of opening spawning seems to be regulated by an internal rhythm synchronised with local environments. The hypophysation on freshly caught gravid female was found to be an easy and effective tool for procurement of pure seed in the laboratory without depending upon the monsoon rains.

The metamorphic development occurs through successive stages I, II, III and IV, which are comparable to pre-, pro-metamorphic and metamorphic climax (froglet with emergent fore limbs) and metamorphosed juvenile.

The laboratory experiments, the mixed food (rich in protein, fat and carbohydrate), and extra supply of oxygen into the ambient water promoted the best result on growth and metamorphosis. When food is in short supply, the growth curve assumes 'S' shape (sigmoid growth). In high density inadequate food supply causes stunted growth, delayed metamorphosis and high rate of cannibalism when the food and dissolved oxygen become limiting factors.

The metamorphosis was initiated only after a threshold size was reached. The individuals of lower densities which grow at a faster rate metamorphosed when an average threshold size of 886 mg was reached. The individuals of higher densities which grew at a slower rate metamorphosed by just reaching the minimum average threshold size of 760 mg.

The studies on the larval energetics indicate significant negative correlation between the body weight and age with consumption, egestion, assimilation and respiration. The total consumption and assimilation per larva during metamorphosis increased but the rate of consumption and assimilation significantly decreased.

The assimilation efficiencies (A/C) varied between 80.34 - 87.78% in the larval stages I and II while the average growth efficiencies (P/A) were found to be 22.7 and 27.55% respectively. These efficiencies approximate to the value obtained in airbreathing fishes, which, however, differed from those of toads in North American arid zones. The efficiency for respiratory energy loss (R/A) averaged 61% and 66.1% in first two stages and these values are approximately close to those obtained in some airbreathing fishes. The energy value of egests and excretion is found to be in order of 22.53% and 20.69% in first two larval stages which are nearly similar to the values obtained for fishes.

In respect of growth efficiency, the stage II during the larval development is an important phase in the process of metamorphosis. In this transit phase, the commencement of metamorphosis of larva was initiated on reaching a threshold size (750 mg in about 30 days). Therefore, growth in stages I and II are very important. It depends on food, temperature, oxygen and other factors.

The larvae soon after the stage of metamorphic climax did not require energy consumption and assimilation and the necessary energy to stimulate all drastic changes in this critical stage was derived from the body sources like tail and gills resorption etc.

The total energy budget estimated is as follows :
48.59 - 7.55 = 41.04 kg/g
(Consumption) - (Egestion) = (Assimilation)
41.04 = 9.04 + 25.31 + 3.25 kg/g
(Assimilation) = (Production + Respiration + Excretion)

GROWTH, PRODUCTION AND ENERGETICS OF THE TADPOLES OF *Rana tigrina* (DAUD) AND *Bufo melanostictus* (BLOCH AND SCHNEIDER)

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Field observation suggested perfect seggregation of breeding ground between *Rana tigrina* and *Bufo melanostictus*. Laboratory experiments indicated this seggregation to be an adaptation to the extreme case of competition between their free living larvae.

The entire larval phase of *Rana tigrina* and *Bufo melanostictus* is distinguishable into three distinct stages (i) Premetamorphic, (ii) Pro-metamorphic and (iii) Metamorphic climax, basing on growth and developmental changes. On the whole the normal growth curve of the larvae is described by polynomial regression.

Increasing density in these larvae acts as negative modulator of the growth kinetics and exerts a retarding force in the growth rate process. Regression analyses of the date of growth in weight on initial density of these larvae fitted to Bilski's inverse group stimulation [(Sq. Root(x))/(x-1)] and the empirical relationship is described by the equation Y = K [(Sq. Root(x))/(x-1)] where, Y = size, X = the nos. of animal in a given space and K = a constant.

The best growth is achieved when the food supply complies with the demand (i.e. supply : demand ratio 1). When it is <1, it means food limitation and increased food competition for food and growth is retarded. But when it is > 1, the excess of food are not successfully utilized, which in turn through microbial activity pollutes the culture medium resulting in the depletion of available oxygen.

Group rearing of these larvae favours environmental agitation and oxygenation of the medium. Also, animals in group effectively use the food patches. Thus, grouping favours the growth rate process.

The problem that these larvae metamorphose into terrestrial froglet is a function of the time required for it to attain a size sufficient to initiate metamorphosis, the concept of a metamorphic threshold size. Thus, the length of the larval period is dependent on the initiation of metamorphosis in response to growth and body size rather than an independent variate that determines the time of metamorphosis.

Metamorphosis is an exponential function of Initial density:

$$P_m = N_m/N_o = e^{-sN_o}$$

which, can be fitted by a semilogarithmic model
$1_n P_m = -sN_o$ where, P_m = the proportion of the population completing metamorphosis. N_o = initial density of the population and s = survivality const.

Besides, initial density also affects the transformation size and the time of metamorphosis. The negative exponential model which assumes unequal competitive abilities among the members predict that a few individuals dominate the high density population and successfully complete the metamorphosis. The exponential decrease of the body size as a function of the initial density is the result of functional link between body size and competitive ability.

The length of the larval period and transformation size are not affected by density in optimal food level indicating that density affects through conditions other than food limitations. The "response curve" of supply/demand ratio tends to reach the height in unity, and increasing density tends to lower the height of the curve.

Within the range of 25-38°C metamorphosis is accelerated by increased temperature more than is growth and the larvae tend to transform at the lower size limit. Decreasing temperature below 20°C favoured growth over metamorphosis and the larvae grow beyond the upper limit showing a tendency of facultative neoteny. 20-25°C temperature is the best promotor of growth and metamorphosis and the larvae transform at the upper limit.

The energy components like consumption, respiration, production and rejects of these larvae varied markedly with age. Regression analyses showed that energy flow could be scaled to a constant power of body mass, and the respective efficiencies were independent of body size. In both the cases late premetamorphic stage was the real energy gathering stage.

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