REVIEW OF LITERATURE
Chronobiology is a subject of recent interest. Though the chronobiological studies were initiated some two hundred and odd years ago, the importance of the time factor has been explored only very recently. Since a thorough review of rhythmic phenomenon in plants and animals is voluminous, here an attempt has been made to summarise the most important evidences concerning the physiological and behavioural rhythms and an extensive survey of the work on fish has been presented in this chapter.

Circadian rhythmicity can be observed at all levels of organization except apparently in the prokaryotes. As early as 1729, the French astronomer, De Marian reported on the persistence of diurnal movements of leaves. After a lapse of a century, De Candolle (1835) demonstrated that the period length of the rhythm of leaf movements in *Mimosa pudica* was about 22 to 23 hrs. when maintained in constant darkness. Since then, many scientists including plant physiologists Wilhelm Pfeffer and Charles and Francis Darwin have started investigating this interesting phenomenon. Having studied circadian leaf movements for over 40 years, Erwin Bunning (1971) admitted that leaf movements were "only an expression of the plant's kindness towards botanists, in allowing them to discover and record circadian rhythms within the plants".
The brown alga *Dictyryta dichotoma* shows a free-running rhythms of gamete discharge when maintained in the laboratory (Bunning and Muller, 1961). Driessche (1966) reported that there is a significant circadian variation in the chloroplast movement of the large unicellular green alga *Acetabularia*. Chloroplast movement in *Ulva* is circadian and here the thallus transmission increases at night and decreases during the day (Britz et al., 1976). The circadian leaf movements of *Phaseolus angularis* has been worked out extensively by Hoshizaki and Hamner (1964) and Alford et al. (1970). Similar works have been done in Biloxi soybean (Brest et al., 1971). The leaf sleep movements in tropical trees such as *Albizia julibrissin* and *Samanea saman* is reported to be circadian (Salt et al., 1974 a,b). Till 1960 the rhythmic pattern of plant movements were studied only in leguminous plants. Later Halaban (1968, 1969) in *Coleus blumei* and *C. frederici* and Engelmann et al. (1974) in *Kalanchoe* studied the leaf and petal movements and reported to have circadian variations.

Nearly all animals from protozoans to mammals have been shown to possess the time measuring ability. Kalmas (1935) observed the rate of binary fission in *Paramecium* is rhythmic even when entertained in continuous darkness. In *Euglena gracilis* phototactic sensitivity rhythm is reported by Phol (1948); Bruce and Pittendrigh, (1956). The cyclic nature of asexual reproduction in *Plasmodium* and the environmental
influences are vastly studied (Stauber, 1939). The occurrence of the microfilaria larva, *Dirofilaria immitus* in the bloodstream according to Hinman, (1936) is rhythmic. Similar observation are made by Hawking and Thurston (1951a, b) and Hawking (1953, 1955).

In Coelenterates daily periodic changes in the frequency of swimming movements of medusa has been noted (Colguhoun, 1944). Bohn (1903) explained the tidal rhythm of green flatworm, *Convoluta rosoffensis*. Ralph (1957) investigated the oxygen consumption of *Lumbricus terrestris* and described both diurnal and lunar cycles. The nocturnal activity of the earthworm and its persistence in both the halves of the worm are reported by Baldwin (1917) and Szymanski (1918).

Vertical diurnal rhythmic migration of planktonic Crustacea was reported by Cushing (1951). Harris and Wolfe (1955) have shown a complete cycle of vertical migration of *Daphnia magna*, in a tank filled with suspension of Indian ink in tap-water. The diurnal migration of planktons has been established by Eyden (1923), Fox (1925), Rose (1925) and Welch, Chace and Nunnemacher (1937). Recently Hart (1977) explained the feeding rhythm in copepods. Several authors working in different parts of the world, have shown that the daily periodicity of the drift is a reflection of the rhythmic
nature of the animal's locomotor activity (Tanaka, 1960; Waters, 1962; Muller, 1963; Elliott, 1965).

Dawn and dusk rhythm of flight activity in the mosquito *Aedes aegypti* was studied extensively by Taylor and Jones (1969). Many nocturnal terrestrial arthropods possess a clear endogenous 24 hours periodicity and emerge from the comparatively constant conditions within their day time retreats under stones, bark, logs and fallen leaves under the stimulus provided by some internal physiological chronometer (Cloudsley-Thompson, 1954, 1955, 1956 etc.). Corbet and Tjonneland (1956) have shown that flight activity is bimodal in many East African Trichoptera, the main flight occurring at dusk with a lesser activity peak at dawn. In the Australian fruit fly *Dacus tryoni* the rhythm of pupal eclosion can be set by a light cycle applied to the female parent (Bateman, 1955).

When isolated from the environmental time cues, a circadian oscillator free - runs and reveals its natural circadian period which deviates slightly from 24 hours. However, in the presence of natural solar - day Zeitgeber, such as the cycles of light intensity and temperature, the periodicity of the endogenous oscillator is adjusted. To exemplify this, a vast amount of work has been done in *Drosophila pseudoobscura* (Pittendrigh, 1960, 1965, 1967;
Pittendrigh and Bruce, 1959; Pittendrigh and Minis, 1964; Frank and Zimmerman, 1969).

In green shore crab *Carcinus maenas*, maximum locomotor activity was noted during the daytime high tides and at night (Naylor, 1958). Fingerman (1960) reported the circadian rhythm of activity, fiddler crab *Uca* coincides with its circadian rhythm of oxygen consumption. Brinck (1949) explained the circannual rhythm of activity and ecdysis in *Baetis rhodanni* and *B. macani*. In crabs the circadian locomotor rhythm was established by Palmer (1971).


In vertebrates extensive work has been done in the early years of this century. Under normal environmental conditions the European tree frog, *Hyla arborea* showed a bimodal pattern of activity (Szymanski, 1914). In *Tritururus* sp, adults are arhythmic but the tadpoles possess a well-organized endogenous nocturnal activity (Kalmus, 1940).
Many of the toad species, *Bufo fowleri* and *B. americanus* show a nocturnal pattern of activity (Higginbotham, 1939). On the other hand, *B. marinus*, found in the Panama rain forest is predominantly day active (Park, 1940).

Park (1938) obtained diurnal pattern of activity in the lizard *Mabuya mabuya* and *Anolis frenatus*. Similar observations were made by Kayser and Marx (1951) in *Lacerta agilis* and *L. muralis*. Hoffmann (1969) found that the circadian activity pattern can be modulated by temperature. Hennig (1977) reported the tonic immobility duration is longer in light than in dark in two species of lizards, *Anolis carolinensis* and *Hemidactylus turcicus*. Recently, the circannual rhythm in pituitary and plasma gonadotrophin, gonadal steroids and thyroid activity were reported in the Chinese cobra, *Naja naja* (Bona Gallo et al., 1980).

Of the endothermic animals many birds, larger mammalian herbivores and their predators tend to be day active (Kramm, 1974; Gopal and Srinivasan, 1979). Small mammalian herbivores and their predators which include cats and rats are mainly nocturnal in habit (West and Pohl, 1973; Gopal and Indira, 1979).

With a few exceptions, birds are mainly diurnal in habit. Aschoff (1967) reported that the light intensity which
is one of the "Zeitgebers" (clue-giver) causes the phase shift in the entrainment of the rhythm. When the duration of light is doubled the rhythm of *Fringilla coebebs* is delayed (Aschoff, 1977). Hoffman (1965) explained that the rhythm of day-active birds when measured in constant conditions tend to have shorter days (less than 24 hr). Gopal and Srinivasan (1979) reported that the time of feeding affects the circadian cloacal temperature rhythm in the fowl.

Hermann Pohl (1977) showed that the light intensity can play a significant role in the circadian period length, metabolic activity time, metabolic rate and parameters that characterize the form of the rhythm. The circannual rhythm of activity in starling (*Sturnus vulgaris*) is reported by Gwinner and Turek (1971); Pohl (1972, 1974); Gwinner (1975).

But for the desert regions predation and the availability of food are probably the chief environmental factors in mammalian circadian periodicity of activity (Hediger, 1950). Deserts having a characteristic environmental conditions forced the smaller animals such as African jerboas and *Dipodomys* spp. to be nocturnal in habit so as to avoid the day time heat. They live in borrows during the day time and emerge to feed only at night time (Schmidt - Nelson and Schmidt - Nelson, 1950). The larger animals such as camel resist extreme conditions by sweating.
It is well established that daily activity and physiological rhythms are endogenous in nature which are synchronized by the environmental cues (Kramm, 1973). The persistence of endogenous rhythm in tonic immobility was reported by Hennig and Dunlop (1977). Recently, Indira and Gopal (1979); Gopal and Indira (1980); Indira (1981) reported that food deprivation and meal time can modulate the circadian rectal temperature in the rat.

There is considerable amount of literature on the physiological rhythms in shift-workers and human subjects (Van Loon, 1963; Colguhoun et al., 1968, 1969; Rajavel, 1978; Gopal et al., 1979). The activity, physiological and biochemical rhythms in human subject were extensively studied by Aschoff (1969); Aschoff et al. (1967); Zig mond et al. (1969); Curtis and Fogel (1971); Lobban (1971); Gopal et al. (1977).

Earlier scientists utilized only the pattern of locomotor activity as their tool to describe the biological rhythm. But rhythmic or cyclic phenomena can be observed in all levels of biological organization, from cells to organs and to organisms and communities. Many of them comprise "physiological rhythms" whose periods of frequency is in no way reflects the influence of meteorological or locomotor periodictites (Jones, 1937; Reinberg Ghata, 1957; Aschoff and
Paul, 1976; Hart, 1977). Substantial revival of interest in the study of the physiological mechanisms by which organisms adapt to the temporal conditions of their surroundings has resulted in a strong body of evidence supporting the idea that these overt rhythms are expressions of a biological time measuring system.

A number of diverse observations on circadian pattern of rhythmic activity are available in fish species. Most of the literature dealing with the recorded daily periodic activities in fish contains no information about the endogenous nature of these rhythms. Many of them were not concerned with this problem and some observations appear to demonstrate a lack of significant periodicities in the activity of certain species. Only during the last few years sufficient experimental evidence in favour of the endogenous nature of circadian rhythms of activity became available in some species of fish (Schwassmann, 1971). In general, on account of their aquatic habitat primary factors of the physical environment such as light tend to be less important directly to fishes and secondary considerations especially of predation and the availability of food are governing factors in the time at which the activity takes place.
Locomotor activity rhythm:

The common gold fish *Carassius auratus* has been shown to be diurnal, the rhythm persisting in constant conditions for longer than that observed in most of the other species (Szymanski, 1914; Spencer, 1939). On the basis of gill-net catches, Hart (1937) noticed that different species have active periods at different times of the day and night. Spoor and Schloemes (1939) reported that high catch of fresh water rock-bass during morning and evening hours could result from a rhythmic activity pattern. Analysis of gill-net catches (Carlander and Cleary, 1949) indicated that some species such as sanger, yellow pike perch and others are more active at night, whereas perch and northern pike show their main activity during day time.

Other studies which show a daily activity pattern with peaks at dawn are those of Sushkina (1939) on herring larvae and of Oliphon (1951) on a species of greyling. Neave (1942) reported the adults of the migratory fish *Oncorhyncus tschawytscha* and *O. kisutch* migrate to the upstream mainly during day time. He observed no significant effect was found between diurnal fluctuation in number of migrants and volume or temperature of the river water.

In gold fish *Carassius auratus* the persistence of diurnal activity rhythm recorded in constant light conditions
reflect the endogenous nature of the rhythm (Spoor, 1946, 1948). Similar results were obtained in this fish at different environmental factors by Hirata (1957, 1958, 1960a).

Brown and Webb (1948) reported that temperature plays a significant role in affecting the circadian activity rhythms in fish. Similar observations were made by Kalmus (1966).

Ii et al. (1952) reported the existence of diurnal rhythm in salmonoid fish *Salmo irideus* which tend to be more active during day time. Schooling behaviour of fish also shows a daily pattern. For example, Steven (1959) noted that schools of *Hepsitia stipes* and *Ballystome simator* disperse at night and that these fish show an activity pattern of increase with decreasing illumination.

Balls (1951) recorded the daily vertical movements of fish schools. He reported that an upward migration in herring schools during night and movement to deeper waters at day-break. Richardson (1952) reports that this migration may be a direct response to the light intensity changes. Hunter (1966) observed schooling behaviour of the Jack mackerel in constant illumination and these schools became more compact at a time which corresponded to the early hours of darkness of the Thines and preceding light regime. Vandenbussche (1966) reported evidence
suggestive of the presence of diurnal fluctuations in *Rasbora* in the readiness to school in response to external stimuli. The influence of light as an important factor in the control of activity pattern was also reported by Swift (1960, 1962). He observed that the activity commenced with a sharp rise at dawn each day in *Salmo trutta*. Several field and laboratory studies employing various methodologies have been conducted on brown trout to measure their activity patterns and the environmental factors that influence them (Swift, 1964; Chasten, 1968). Davis (1962, 1964) and Davis and Bardach (1965) reported that the diurnal activity rhythm of *Lepomis macrochirus* is highly influenced by the light factor. Predawn activity peak in this species suggests that this could be due to the onset of light which may be an influencing factor. Further Von Seydlitz (1962) reported higher catches of *Sebastes marinus* during day time than at night. Lissmann (1946) was able to explain the neurological basis of the locomotor activity in the spiny fish *Scyllium carricula*.

A diurnal rhythm in phototactic behaviour was reported by Kawamoto and Konishi (1955) for *Girella punctatus*. Jones (1956) reported that locomotor activity of *Phoxinus* is more during light hours but this pattern reversed if their tank contained a hollow brick where they could hide from light. Whereas if a cover was provided, the minnows were active around sunrise and sunset. Similar crepuscular activity peaks
were obtained by Darnell and Melorotto (1965) in *Ictalurus melas*. Muller and Scheriber (1967) demonstrated the existence of an endogenous swimming activity rhythm in polar circles. Muller (1968) obtained a long free running period, which is in coincidence with the environmental light conditions. Further he studied in 1969 that *Salmo trutta* found near polar circle are day active during winter and night active in summer. A similar observation was made by Andreasson (1969) in *Cottus poecilopus*. Hirata (1955) found that *Oncorhyncus keta* fry has two behaviours of both schooling and milling. Schooling was found during day-time and milling occurred at night time.

Kobayashi et al. (1965) and Kobayashi (1958) reported that the migratory fish *O. keta* is more active during twilight periods. Further Nishiyama (1957) recognized that the rhythm patterns of salmonoid show change according to their sexual stage. Hirata (1960 b) reported that the migratory fish *Oncorhyncus nekra* show a lower co-efficient of activity when compared to the non-migratory fish.

Although an earlier investigation by Jones (1955) failed to record evidence in favour of an inbuilt rhythm of locomotor activity in ammocoete larvae of a lamprey, *Lampetra planeri*, Kleerekoper et al. (1961) were able to demonstrate a persistent endogenous activity rhythm using photoelectric
sensing system. Strack and Davis (1966) reported *Rypicus subbifernatus* to be active at night and is endogenous. The persistence of endogenous diurnal rhythm of swimming activity was also reported by Harder and Hempel (1954) on sole, and flounder; Wikgren (1955) on the burbot and Kruuk (1963) on sole, *Solea vulgaris*.

Studies by Hasler and Villemonte (1953) on the fresh water perch and the extensive work of Barlow (1958) in the dog fish show a daily cyclic pattern in the circadian swimming activity. Emery (1973) reported the crepuscular nature of *Micropterus dolomieni* during natural light dark condition. Horn and Riggs (1973) reported that significant differences in air-breathing between day and night from which they inferred greater overall nocturnal activity.

Richardson and McCleave (1974) studied the locomotor activity rhythm in juvenile Atlantic Salmon (*Salmo salar*) in various light conditions. Nocturnal activity in the hornshark *Heterodontus francisci* at different light intensities were studied by Finstad and Nelson (1975). Kroneld (1974) reported the existence of diel rhythmicity even in eye eliminated burbot, *Lota lota* L. circadian and circannual activity differences in heart beat and locomotor activity of *Cyprinus carpio* L. was reported by Kneis and Seigmund (1976). Baumann and Kit- chell (1974) reported the diel pattern in the distribution of

Reynolds and Casterlin (1976) reported crepuscular activity rhythm in black basses *Macropterus salmonoides* and *M. dolomierii*, *M. salmonoides* shows an additional midday peak and in *M. dolomierii* peak activity occurred at the beginning and end of dark periods. Activity records in constant light conditions showed these activity rhythms to be endogenous. Similarly, Srinivasachar et al. (1976) reported that light has no influence on the 3 parameters such as food intake, growth and conversion efficiency in *Heteropneustes fossilis*. It feeds equally well during day and night time.

Spieler et al. (1977a) showed that body weight gain and gonadal growth in the gold fish *Carassius auratus* could be minimised by subjecting them to a cyclic temperature and light regimes in which the temperature peaks occurred during the fourth preceding onset of the light period. Further Spieler et al. (1977b) reported a circadian rhythm of preferred temperature which has been shown to have physiological and ecological value. Pride and Young (1977) using ultrasonic telemetry to monitor heart beat frequencies of free ranging brown trout,
observed that heart rate peaks were often found before dusk and at dawn.

Luckhurst and Luckhurst (1978) observed the coral-reef fishes along the depth gradient. *Apoon phenax*, *A. maculatus* and *A. lachneri* were shown to be marked by higher in density at night than that observed during the day in shallow waters. Muller (1978) reported that *Salmo trutta* and *Phoxinus phoxinus* show a rhythmic pattern of activity; the former is crepuscular and the latter is day active (Peter et al., 1978).

Bachmann et al. (1979) described a bimodal crepuscular locomotor activity pattern in brown trout. Reynolds et al. (1978) reported that the bowfin *Amia calva* exhibits an endogenous circadian rhythm of preferred temperature with a peak of 32.0°C during the day and a minimum of 28.3°C at night. They further inferred no clear rhythm of locomotor activity is evident in this species. Johnson (1976) reported that there is significant variation in the thermal tolerance of *affinis*. *Gambusia affinis* / The persistence of locomotor activity rhythm in *Chrysemys picta* even in asynchronous cycle of temperature and photoperiod suggests the endogenous nature of the rhythm (Graham and Hutchinson, 1978). Fernholm (1974) studied the circadian variation in behavioural pattern in the hag fish *Eptatretus burgeri*. Ebeling and Brady (1976)
reported that there is a significant day to night variation in the activity of reef fishes in a Kelp forest off Santa Barbara, California. Edel (1976) was able to record the change in activity rhythm in maturing American eels (*Anguilla rostrata*). Grawshaw (1975) reported that there exist a body temperature rhythm in *Leponis* spp.

**Reproductive rhythm in fish world**

Reproduction in fish is a typical example of cyclic phenomenon, some times once in every two or three years but more usually once or several times a year. But if the rhythm is defined as a succession of reproductive cycles, rhythmicity can hardly be an innate characteristic, since this cyclic reproductive activity is usually considered to result from an adaptation to a changing environment mediated through the endocrine system. Fish living in a large variety of biotopes leading to a great diversity of reproductive pattern. It is possible to increase the frequency of rhythm without any chemical treatment if the environment is properly conditioned. The following few pages review the reproductive rhythm in some of the fish species.

Coneius plumbeus (Ahsan, 1966) and Cymatogaster aggregata (Miebe, 1968). The higher temperatures retard the early stages or intermediate phases of gametogenesis. A similar situation has been reported in the cyprinodontid, Epiplatys bifasciatus which occurs in the Zio river of Africa (Loiselle, 1909). Baggerman (1957) suggested, since none of the experimental conditions she tested could maintain continuous breeding in Gasterosteus aculeatus, termination of the cycle is endogenously controlled. De Vlaming (1972b) reported in Gillichthys mirabilis, seasonal temperature changes may be involved in the regulation of sexual cycle. A correlation between seasonal cycle and reproductive cycle has been drawn by Barlow and De Vlamig (1972). De Vlaming (1972c) confirmed that the termination of reproductive cycle is not endogenously timed. Gonadal regression is not obligatory since low temperature treatments prevented gonadal involution at the normal time.

In Orzias latipes, eggs are laid just before dawn almost every day, during breeding season (Robinson and Rugh, 1943). This has been confirmed by Herbbs (1976), who reported that during reproductive season Menidia curdina lays eggs mainly in the morning. Yamauchi and Yamamoto (1973) reported that under artificial illuminations (14L/10D) spawning occurs 30 minutes after light onset in Medalea. Trichopsis sp. spawn normally at the end of the light period (Marshall, 1967).
Norcross et al. (1974) observed in *Pomatomous saltatrix*, daily spawning activity near sun down. Similar observations were made in sardine by Gamulin and Hure (1956). Henderson (1963) studied the influence of light and temperature on the reproductive cycle of the eastern *brook trout, Salvelinus fontinalis* (Mitchell). Kiener (1963) suggested that the duration of breeding season varied with the altitude and probably with temperature.

Billard (1968) reported variations in the duration of reproductive cycle in guppy (*Poecilia reticulata*) where the intervals between two parturitions were longer and more variable in winter than summer. Morean (1970) observed that the gametogenesis and breeding in *Tilapia* occurs in the austral summer and coincided with the highest temperature. Food availability and growth rate was also maximum during this period. Zambrano (1971) found that the secretary activity of the pituitary gonadotrophic cells, are altered by temperature. De Vlaming (1972d; 1974) reported that low temperature treatments prevented gonadal involution in *Gillichthys mirabilis*. Meier et al. (1973) suggested that even handling of animals have effect in change of testicular weights.

Long photoperiod and warm temperature were found to accelerate gonadal recrudescence in cat-fish, *Heteropneustes fossilis* (Anand and Sundara Raj, 1974). The effect of food
seems to influence the gametogenesis in aquarium fish (Quasim, 1973). They exhibit continuous gametogenesis provided the food availability is sufficient.

Brusle and Brusle (1975) found gametogenesis occurs entirely in rising photoperiod and temperature in *Epinephelus*. Breton and Billard (1977) observed in salmonoids that the main factor affecting gonadal development is light. Spieler *et al.* (1977) showed that body weight gain and gonadal growth in the gold fish *Carassius auratus* could be maximized by subjecting them to a cyclic temperature and light regimes.

**Biochemical rhythms:**

Most of the physiological aspects are mainly controlled by the biochemical components of the body. Hence, when a physiological system elicits a rhythm, that should be the reflection of the cyclic phenomenon of these biochemicals. Daily and seasonal variation of biochemical aspects have been described only very recently. The following few pages review the investigations on the rhythmic nature of these biological chemicals.

**Prolaction:**

Circadian variation in the levels of serum prolactin has been demonstrated in gold fish *Carassius auratus*.
Juvenile Kokaue salmon, *Oncorhynchus nerka* (Leatherland et al., 1974) and in striped mullet *Mugil cephalus* (Spieler, 1975; Spieler et al., 1976). Spieler et al. (1978) reported that temperature can induce phase shift in the daily rhythm of serum prolactin in gulf Killi€fish. Diurnal variations of the fattening response to prolactin in the golden top Minnow, *Fundulus chrysotus* (Lee and Meier, 1967) and in cyprinodontid fishes, *Cyprinodon variegatus* and *Fundulus similis* (De Vlaming and Sage, 1972; De vlaming et al., 1975) provides the strong body of evidence that an animal is physiologically different at different times of the day. Recently Prack et al. (1980) demonstrated that Prolactin has different seasonal effects on carbohydrate and lipid metabolism in the gold fish, *Carassius auratus*.

**Thyroid hormones:**

Spannhof et al. (1973) reported that the existence of a circannual periodicity in the thyroid hormones in herring *Clupea harengus*. Similar observations were made in brook trout *Salvelinus fontinalis* and in plaicid *Pleuronectes platessa* by White and Henderson (1977) and Osborn and Simpson (1978). Osborn et al. (1978) reported the presence of seasonal and diurnal rhythm of thyroid in *Salmo gairdneri*.
Sex hormones:

Seasonal variations in the blood level of corticosteroid hormone have been described for a number of teleosts e.g., sockeye salmon, *Oncorhynchus nerka* (Idler et al., 1959; Schmidt and Idler, 1962); King Salmon, *O. tschanyscha* (Hane and Robertson, 1959); Atlantic salmon, *Salmo salar* (Idler and Freeman, 1968); Winter flounder, *Pseudopeuronectes americanus* (Campbell et al., 1976) plaice, *Pleuronectes platessa* (Wingfield and Grimm, 1977). Only recently the daily fluctuations in the blood level of corticosteroid hormone have been demonstrated in several species of teleosts such as gold fish *Carassius auratus* (Singley and Chavin, 1975; Fryer, 1975); carp, *Cyprinus carpio* (Redgave, 1974); Gulf Killifish, *Fundulus grandis* (Garcia and Meier, 1973; Srivatsava and Meier, 1972); Channel cat fish *Ictalurus punctatus* (Boehlke et al., 1966).

Delahunty et al. (1977) reported that the timing of feeding may synchronize the pattern of daily cortisol cycles in gold fish, *Carassius auratus*. Sex and photoperiod tend to influence the circadian variation of serum cortisol levels in gold fish (Peter and Hontela, 1977; Peter et al., 1978). Similar observations were made in serum gonadotropin levels in gold fish (Montela and Peter, 1978).
De Vlaming and Vodicnik (1977a, b) reported that pineal is the main organ which regulates the daily levels of pituitary gonadotropin in *Notemigonus crysoleucas*. Further, Vodicnik et al. (1978) confirmed this by subjecting the fish to various photoperiod and temperature regimes.

Meier et al. (1973) studied the plasma chloride levels in *Fundulus grandis* and *F. chrysotus* and reported circadian variations. Recently Van Vuren and Hattingh (1978) reported that haemoglobins of fresh water fishes show a circannual rhythm in their natural environment. Carrillo et al. (1980) stated that the serum amino acids have dial fluctuations. On the rhythmic nature of physiological and biochemical aspects of *Tilapia mossambica*, no report is available. Hence, the present investigation was initiated to know whether any such pattern exists in the biochemical components of the serum such as glucose and chloride levels.

**Feeding rhythm:**

Circadian period of feeding and metabolism are most important physiological factors which has attracted most attention in recent years. Many reports have been published on feeding and metabolism (Rogers and Leung, 1973; Elliott, 1976; Mugford and Thorne, 1979 etc.). However all of them are based on qualitative or quantitative analysis of stomach content without considering the time factor. From this point
of view, the following are the few works in this field and the present investigation elaborately deals with the feeding pattern at different times of the day.

Muzinic (1931) found that the herring have two main feeding periods, one in the early morning and another afternoon until night fall. A pronounced daily rhythm in feeding activity of gold fish was reported by Hirata and Kobayashi (1956 and Hirata, 1957). Such diurnal variations in the pattern of feeding and locomotor activity are quite common and were documented in controlled laboratory experiments on salmonoids by Hoar (1942, 1958). Kobayashi and his associates further investigated the fish feeding by quantitative and persistent analysis (Kobayashi and Hirata, 1957a, b; Hirata, 1958, 1960a, b; Terao, 1959; Nishiyama, 1957). Their experiments were conducted with the aid of an automatic feeding recorder (Kobayashi et al., 1956).

The study by McNaught and Hasler (1961) on schooling and feeding behaviour of white basses reported that the maximum feeding activity of these fishes coincides with high concentration of their planktonic food organisms at the surface during morning and evening. Blaxter (1965) studied the feeding chronology of herring larvae and their ecology in relation to feeding. Weasner (1960) reported that food intake plays a significant role in the circadian activity
rhythm. He could observe a change in the activity pattern in food deprived animals. Javaid (1971) observed in *Heteropneustes fossilis* and *Puntius sophora* a diurnal periodicity in the feeding activity. The diel feeding pattern of blue gill *Lepomis macrochirus* was reported by Baumann and Kitchell (1974).

Brett (1971) reported that the sockeye salmon, *Oncorhyncus nerka* exhibit a diel vertical migration in lakes involving a cyclic change in temperature with dawn and dusk feeding periods near the surface.

Mathur (1973) reported the diel periodicity in feeding of the black banded daiter, *Percina migrofasciata*. Similar pattern of feeding chronology was observed in young white carp, *Pomoxis annularis* in Conouingo Reservoir by Mathur and Robbins (1971). Hirata (1973) observed a diurnal feeding and metabolic rhythm in juvenile Atlantic Salmon.

Nishikawa and Ishibashi (1975) studied the influence of feeding in the activity rhythm of mudskipper, *Periopthalmus cantonensis*. In pacific ocean smelt, Churikov (1976) observed a monocyclic nature of feeding activity and he could observe a maximum feeding activity during night hours. Wootten and Evans (1976) reported the food availability controls the frequency of spawning in *Gastreosteus aculeatus*. 
Vinogradov (1977) reported the existence of diurnal feeding rhythms and diets of the silver hake, *Merluccinus bilinearis* (Mitchill) and the red hake, *Urophycis chrus* (Walbaum). Bisson (1978) reported the feeding activity is highest during day light hours.

Earlier work by Clausen (1936) demonstrated a daily periodicity with morning and late afternoon maxima in oxygen consumption for the large mouth bass and low activity during daytime alternating with increased activity at night in the black bull-head. A similar correlation of oxygen consumption with the degree of activity was demonstrated by Spoor (1946). Many other studies recording oxygen consumption of fish were not concerned with the demonstration of a periodically changing pattern (Schuett, 1933, 1934). In the present investigation an attempt has been made by taking oxygen consumption as a physiological measure to record the circadian rhythm and the influence of certain factors on it.