



Journal of Biological Sciences

ISSN 1727-3048

science
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The Biology of *Lymnaea peregra* (Muller) (Gastropoda: Pulmonata: Basommatophora) with Special Reference to the Effects of Herbicides on its Reproduction

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Abstract: The freshwater snail, *Lymnaea peregra* (Muller) is widely distributed in the UK and is probably the commonest species in Europe. Culture of *L. peregra* in laboratory conditions have paid attention to foods, temperature and water quality, and these directly affect the life history traits, such as growth rate, age of maturation and fecundity. The occurrence of the herbicide, simazine in freshwater habitats does not only have a direct effect on the distribution of snails, but may also have indirect effects on both higher and lower trophic levels. It is more important to determine the influence of herbicides on the population densities of a snail which is needed for both ecological balance and economic importance.

Key words: Biology of *L. peregra*, herbicides, reproduction

Introduction

There are approximately 40 species of *Lymnaea* in the world and about as many again to be described (Hubendick, 1951). Annandale and Rao (1925) recognised 20 species and many varieties in the Indian sub continent. Rao (1989) described only 17 species in India. *L. peregra* has been extensively used in population studies for many years (Taylor, 1890; Boycott, 1938; Russell-Hunter, 1961a, b; Lam and Calow, 1988). The present review deals with the research works so far done on *L. peregra* and some other most related species in Europe.

Habits and distribution: *L. peregra* is widely distributed throughout the British Isles, and is found in all types of freshwater in which molluscs are able to live (Boycott, 1936). The majority of the sub class to which *L. peregra* belongs are freshwater snails living in the ponds, ditches, streams and lakes (Geraerts and Joosse, 1984). This species is probably the commonest freshwater snail in Europe (Fitter and Manuel, 1986), occurring in a very wide variety of freshwater habitats from low land ponds to torrential mountains stream. This widespread distribution is combined with a tolerance of a wide range of water qualities (Dussart and Kay, 1980). *L. peregra* is able to survive for several weeks in ice, provided they are frozen gradually. At the other extreme, *L. peregra* is able to survive temperatures greater than 30°C (McDonald, 1969).

Systematics: *L. peregra* is in the order Basommatophora, sub-class Pulmonata, class Gastropoda and in the phylum Mollusca (Macan, 1950; Hyman, 1967). Classification and systematic accounts of molluscan animals are very variable and contradictory. More recently, it is given attention on freshwater snails of the genus *Lymnaea*. These snails are morphologically variable and their taxonomy is unclear. The literature of the Mollusca is vast, large works covering the phylum as a whole are those of Walker (1918), Baker (1928), Boycott (1936), Berry (1943) Hyman (1967), Bickel (1968), Walter (1969), Harman and Berg (1971), Clarke (1973).

Synonym and identification: *L. peregra* is generally admitted to be a plastic species in regard to shell-shape in that the population from any locality display small, but recognisable differences from populations in other habitats (Boycott *et al.*, 1930). This characteristic has both theoretical and practical interests. Huggins (1918) made a

careful survey of *Lymnaea* populations and found that each occupied habitat contained its own characteristic form and that *L. involuta* and *L. peregra* might be found in neighbouring habitats. He described *L. peregra* and its relations with *L. involuta* and others. *L. peregra* is a mixture of at least two species, *L. ovata* and *L. peregra* on the basis of their morphology and anatomy. *L. praetenuis* is a thin shelled variety of the lake form of *peregra* (Waterstone, 1934). *L. involuta* and *L. burnetti* might be regarded as sub-species and be represented by trinomials, e.g. *L. peregra*, *L. p. involuta* and *L. p. burnetti*. He further suggested that *L. involuta* is a genetic sub-species of *L. peregra*, those semi *involute* forms which breed more or less, but in which the character for involuteness is not germinally fixed, could be regarded as genoclines linking *L. peregra* and *involuta*, similarly with *burnetti*. These snails have been shown to have no anatomical character that justifies their specific separation from *L. peregra*.

A wide range of variation and local races are met with in numerous species of freshwater molluscs and there appears to be reasonable ground for suspecting that such variation in other species differs from that of *L. peregra* in degree rather than in nature. In nature, Lymnaeid snails especially *L. peregra* is of variable shell form, some times it is difficult to identify the species.

Morphology of *L. peregra*: The soft body of *L. peregra* is protected by a thin shell, it is horny, fragile and with an elongated spire. The body whorl is large with a big aperture (Kotpal, 1995). The head has a single pair of non invaginable tentacles (flattened) with eyes at base. The foot is rounded behind, mostly aquatic primitively or by reversion and may acquire secondary gills (Wilber and Yonge, 1964, 1966). The aquatic pulmonates are monoecious, have no opercula, have lost their ctenidia and replaced them with highly vascularized mantle cavities, have relatively light weight shell and are comparatively active animals (Harman, 1974). A member of the Gastropoda class, *L. peregra* may exceptionally reach a shell length of almost 30 mm but more usually reaches a maximum shell length between 15-20 mm (Fitter and Manuel, 1986; Barnes, 1992). In nature, mature *peregra* may vary from 5 mm to as much as 31.5 mm but it would be a difficult and hazardous business to make out how much of this enormous differences heritable (Boycott, 1938) (Fig. 1, 2).

The relationship between shell length and body wet weight of *L. peregra* is positively correlated. The relative growth of the reared population of *L. peregra* showed that there is a positive correlation between shell length and body wet weight ($r^2 = > 0.8$) (Barnes, 1992).

Many authors have been described the various shell shapes of aquatic gastropods both of natural and laboratory generations (Boycott and Diver, 1930; Hubendick, 1978; Evans, 1989). Arthur (1982) noted that the differences in the shell shape of two populations of Irish *Lymnaea* was mainly due to direct environmental effects. He also reported that the similarity between the shell shape of two laboratory cultured populations was caused entirely by a shift in the shell morphometrics of the lotic population to the lentic phenotype, while the shell shape of the natural pond population was retained in the culture, presumably approximating lentic conditions. Lam and Calow (1988) investigated both the field samples and laboratory generation of *L. peregra*. Bradshaw (1984) opined that the phenotypic variability in response to environmental factors can be genetically determined. The controlled breeding experiments suggested that certain lotic and lentic populations are generally fixed to produce big and small apertures respectively. Three shell forms are recognized as occurring in these populations: normally spired, sub-involuta and involuta (Evans, 1989). Particularly, the forms *peregra* and *ovata* distinguished by shell shape are often considered variants of the same species, *L. peregra*.

Reproductive biology of *Lymnaea peregra*: Molluscs reproduce exclusively from gametes, although hermaphroditism (both simultaneous and sequential) and parthenogenesis are common (Boycott, 1938; Bondesen, 1950; Morton, 1978). Most of the aquatic Basommatophores are hermaphrodite and male and female gonopores are generally separate (Hyman, 1967). All members of this adaptable species are simultaneous hermaphrodites, able to reproduce both by self-fertilization and out crossing (Jame and Delay, 1991), the latter generally occurring as soon as copulation is possible.

The reproductive system of Lymnaeidae is quite an elaborate structure, consisting of a bisexual gonad, and male and female ducts with accessory glands (Geraerts and Joosse, 1984). Hermaphroditism is the dominant method of reproduction in pulmonates, particularly lymnaeids are no exception to this rule. Heath (1977) reported that the cost of producing and maintaining two sets of reproductive apparatus in one animal is greater than the cost of building and maintaining single set of apparatus in separate animals. Several patterns of life cycle can be distinguished in the freshwater basommatophorans of the temperate zone (Russell-Hunter, 1961b, 1978; Duncan, 1975; Calow, 1978). The most common is an annual life cycle with complete replacement of generations (univoltine pattern) and breeding in late spring or early summer. The life span is usually approximately one year with recruitment most commonly occurring in June or July (Lam and Calow, 1990). The pattern of two generations per year with complete replacement (bivoltine pattern) has been described for *L. peregra* by Russell-Hunter (1961b). Figure 3 showed the bivoltine pattern of reproduction of *L. peregra*. In natural populations, there can be considerable intraspecific interpopulation variation in the life cycle pattern. For instance, in different natural populations of *L. peregra* five of the eight patterns have been found by Calow (1978).

Cole (1954) and Calow (1978) reported that *L. peregra* is a semelparous species. The semelparous condition is when parents die after reproduction and iteroparous condition is

when parents live on after reproduction to produce again. *L. peregra* has a concentrated egg-laying period and only one or two generations are found in a year (Skoog, 1976). The freshwater pulmonates, particularly the smaller species, tend to have annual life cycle. There may be one reproductive period in the spring or in the fall, or two reproductive periods over the duration of a summer (Harman, 1974). In nature, most of the lymnaeids species have two reproduction times in a year, but in the laboratory few species relate to this rule (Skoog, 1976; Scheerboom, 1978). Barnes (1992) reported only one reproductive period of *L. peregra* in laboratory culture. Figure 4. shows the major features of molluscan life cycles.

Eggs are laid in gelatinous capsules containing batches of up to several hundred eggs which hatch from late spring onwards (Jame and Delay, 1990). A wide variation in eggs capsule size has been noted by Bondesen (1950) and Russell-Hunter (1961a). If the capsule contains only few eggs (up to about 10) the form is oval, if the number increases to more than 15- 16 the capsule begins to show a faint curvature. The capsule has a long thin, often filiform terminal tail. The capsule wall is solid with well developed forked capsular strings. Smaller capsules, for example from forms in running water, have a particularly well developed ramification of the capsular strings (Bondesen, 1950). Bondesen also reported that the eggs are oval and are regularly arranged in a corkscrew spiral up through the cylindrical capsule. Usually, the eggs lie in two rows and the corkscrew spiral shows oblique rows of eggs. If the eggs are arranged in one layer, it is called a zigzag arrangement. Transitional arrangements have been observed in the same capsule (Fig. 5).

Size at reproduction: The size of snails at the onset of reproduction varied with different foods and temperature. The effect of foods and temperature directly affected sexual maturation of *L. peregra*. Turner (1926) found that *L. peregra* attained sexual maturity before reaching full size, with pairs they often laid when 10 mm long, but subsequently grew from 15 - 19 mm. A similar result was recorded by Calow (1970) and he mentioned that the snail, *L. peregra* laid egg capsules when they grew in between the range of 12.8 to 14.4 mm. Calow (1970) has shown that there is a genetically determined mean size at reproduction which is maintained through at least two generations in the laboratory under controlled conditions. He suggested that size at reproduction is determined by environmental conditions. Russell-Hunter (1961a, b) considered that the onset of reproduction is determined both by genetic and environmental factors. The term 'onset of reproduction' as defined by Calow (1970) means the size of snails when they began to produce egg capsules. Islam *et al.* (1998) found that the lowest size at reproduction was 11.5 ± 0.0915 mm and 0.1964 ± 0.00297 g at 18–20°C. However, since there were differences in the size of the parents at reproduction these apparent differences in absolute fecundity may not give a true indication of the cost of reproduction to the parents.

Fecundity: Any value of total production by a single generation of *L. peregra* must include a figure for egg production (Russell-Hunter, 1961b; Young, 1981). The number of eggs must be considered as a) mean total number of capsules produced per individual, b) mean total number of eggs per individual and c) mean total number of eggs per capsule.

Capsules per snail: Freshwater pulmonate snails generally

Islam *et al.*: Effects of herbicides on the reproduction of *L. peregra*

show a high fecundity. In the field, a large number of egg capsules are laid during the reproductive season. When kept in the laboratory, several species can reproduce throughout the year (Van der Steen, 1967). Reproductive activity of *L. peregra* depends on foods and temperature. Capsules of freshwater pulmonates have been studied extensively by Bondesen (1950). The result expressed that when food is suitable for the snail and temperature is favourable to breed, the adult snail laid eggs. Similar results were obtained by Russell-Hunter and McMahon (1976). They found that during the summer, when the temperature is higher and much more food is available, egg masses are produced. Islam *et al.* (1998) found that the maximum capsules/snail was with spinach (8.9 capsules/snail) at 18 - 20°C and the minimum with cabbage (2.7 capsules/snail) at 10.5°C.

Eggs per snail: Most published figures for the total number of eggs are 12 to 1400 (Bondesen, 1950) in field conditions. Islam *et al.* (1998) observed that the maximum eggs/snail/season was 320.74 ± 56.43 with spinach at 18 - 20°C and the minimum was only 68.37 ± 11.66 . This differs from the cultured snails studied by Calow (1978) who obtained 300 to 1100 eggs/snail/season. This is comparable to Skoog (1978) and Young (1975). In captivity some races of *L. peregra* average about 500 eggs/snail/season and can achieve as many as 3000 eggs, other smaller races produce 200 eggs or so.

Eggs per capsule: Generally, the number of eggs per capsule depends on the size of the adult snail but there are great variations (Geraerts and Joosse, 1984). The wide variation in capsule size has been noted by Bondesen (1950) and Gaten (1986). Capsule size decreased later in the egg laying period in *L. peregra* and this agrees with the figures given by Calow (1978). He noted a range of 12-200 eggs/capsule in *L. peregra*. Boycott *et al.* (1932) described the egg capsules of Irish lake forms of *L. peregra*. The egg capsules of the commonest brackish water snail rarely contained more than 20 eggs, 8 to 13 eggs per capsule was the commonest number (Jackson, 1915). Russell-Hunter (1961a) reported that the total egg production per adult *Lymnaea* under natural conditions is complicated by the presence of two distinct type of *Lymnaea* egg masses. The commonest are small egg masses containing 12 to 15 eggs, large ones of 90 to 120 eggs are less common but may make up a greater proportion of the total egg masses to each of the size groups. Islam *et al.* (1998) found that average eggs/capsule were in the range of 25.059 ± 1.406 to 35.473 ± 2.726 . The increase of capsule size gave an increased number of eggs/capsule. Similar results are described by Bondesen (1950).

Culture of *L. peregra*: Culture of *L. peregra* in laboratory conditions has been reported by many authors. Most of them have paid attention to foods, temperature and water quality of the laboratory environment. Surprisingly, little is known about the natural diet of the more common species of British freshwater gastropods.

The influence of food: Availability, palatability, quality and utilization of food are important variables in studies of the regulation of populations and of energy transfer in the ecosystem (Skoog, 1978). The amount of protein, fat, carbohydrate, iron, minerals and vitamins are the main components of an any food (Eisenberg, 1970). The influence of food on the growth, survivorship and reproductive capability of *L. peregra* has been assessed by many workers. Boycott (1936) suggested that in nature, freshwater snail, in general, feed on detritus and algal

periphyton rather than on higher plants but he offered no experimental evidence in support of this view. He mentioned the works of Turner (1926), carried out shortly before his death and therefore unfortunately unpublished, which offered some evidence that *L. peregra* shows a selective performance for different types of algae. *L. peregra* preferred organic detritus in nature (Hunter, 1953, 1957) and unicellular algae (Calow, 1970).

The whole subject of molluscan diets has been reviewed by Graham (1955) but there is little reference in the literature as to the exact nature of diet of this species. Calow (1970) investigated the natural diets of *L. peregra* by crop analysis and stated that crop contents of *L. peregra* revealed complete absence of any portion of higher plants, but the presence of large quantities of unicellular and filamentous algae together with some grits. Similar investigations were made by Hunter (1953). He mentioned that *L. peregra* lives on a variety of substrata and can feed on higher plants directly, on organic detritus of all kinds including dead animals tissue and on suspending micro-organisms on the surface film, as well as on the attached diatoms and other algae of the substrata. Russell-Hunter (1961a) has observed from 1949-1958, numbers of *L. peregra* making considerable migrations to feed directly on vertebrate carrions. They are unspecialized and omnivorous. Freshwater pulmonates, indeed, have an accurate chemoreceptive mechanism (Croll, 1983). Moreover, the species differs in preferred food and assimilation efficiency of different food types (Calow and Calow, 1975). In addition to the overall amount of the energy supplied by a food, its trace element variation, amino acid contents etc. could influence the physiological state of animal's feeding on the food. A specific change in the preferred food has been found for *L. peregra* when switching from somatic growth to reproduction (Skoog, 1978). The influence of rearing condition on the growth, survivorship and reproductive performance of *L. peregra* has been studied by many workers, *viz.* Standen (1951), McClelland (1964), Skoog (1978), Brown (1980), Brendelberger (1995), but none have established the appropriate methods for culturing snails.

Culture of *L. peregra* in laboratory conditions has involved various food types. The quality of food appears important to the snail (Butler *et al.*, 1969). *L. peregra* may be safely reared in aquaria if they are given room and enough food (Boycott, 1936). He pointed out that freshwater snails can make use of cultivated plants like lettuce in the laboratory culture. The artificial food developed by Standen (1951) is suitable for snails but its storage stability is poor. It deteriorates within two weeks even at 4°C (Kendall and Parfitt, 1965). Frank (1963) used green algae and lettuce for culturing snails. Brown (1980) observed considerable scope for investigators to search out an ideal food for snails. Skoog (1978) used different types of natural, artificial and supplementary diets for *L. peregra*. He recorded differences between the diets in terms of effective growth and egg production in *L. peregra*. On a diet of spinach the growth rate was lower than other foods but the number of eggs laid was significantly higher. Calow (1973) reported that typical of most freshwater snails, growth under laboratory conditions was sigmoid. Calow (1970) further investigated the freshwater snail *L. peregra* with cooked food at $18 \pm 2^\circ\text{C}$, at least three laboratory generations originating from exposed and sheltered aquatic habits. He found that the snails from each population had the same rates of growth over the exponential phase and initial size. Similar results were found by Russell-Hunter (1961a, b) and Barnes (1992) both in the field and in the laboratory cultures. Inorganic minerals and filamentous algae were used as foods in laboratory culture by Tanveer (1990).

Islam *et al.*: Effects of herbicides on the reproduction of *L. peregra*

In view of this lack of specific information regarding the diet of *L. peregra*, Islam *et al.* (1998) in the UK undertook the project to determine the food preferred by this species in laboratory conditions. Islam *et al.* (1998) established more successful methods for rearing (growth, survivorship and egg production capability) of *L. peregra* in laboratory conditions and the feeding habits of the test species using spinach, lettuce and cabbage. Of the three foods, spinach proved to be the best. Although some authors, *viz.* Skoog (1978), Lam and Calow (1988) and Brendelberger (1995) have studied these foods individually for laboratory cultures of *L. peregra* and other freshwater species but nobody has compared these three foods for culturing any freshwater snails in laboratory conditions. Spinach has a high caloric value than the other two foods (Aykrout, 1941). The differences found between the diets tested in efficiency for growth and egg production in *L. peregra* suggested that quality rather than quantity of foods is of importance to the snails.

The influences of temperature: Temperature has been found to affect directly life history traits such as growth rate, age of maturity and fecundity in freshwater pulmonates. Growth rates have been shown to be directly related to temperature in natural populations (Burky, 1969; Clappitt, 1970; Skoog, 1976; McMahon, 1975 a, b). Russell-Hunter (1978) reported that water temperature is probably the most important factor determining growth, and time of onset and intensity of the breeding season. The underlying causes are connected to the enhancement of metabolic processes with temperature, nevertheless, freshwater gastropods are able to regulate their growth at non-optimum temperatures if these are not too far removed from the temperature optimum (Vaughn, 1953; Calow, 1973; Imhof, 1973).

Growth rates are the minimal or zero during cold winter months and increase to the maximum in summer, with peak rates generally corresponding to periods of maximum ambient temperature. Laboratory experiments have confirmed that growth rates rise with increasing temperatures in most freshwater pulmonates (Brown, 1979; Prinsloo and van Eeden, 1973; Van der Schalie and Berry, 1973). Calow (1973) investigated the effect of temperature on maturity and first reproduction of pulmonates snails. Lam and Calow (1989) have attempted at explaining intraspecific life history variations in terms of both environmental and genetic factors, and suggested that temperature has an important influence on populations. Some critical spawning temperatures are reported for freshwater pulmonates, including *L. palustris*, 15°C (Hunter, 1975) and *L. emarginata* > 13°C (Van der Schalie and Berry, 1973) but there is no specific indication for *L. peregra*. It is a univoltine population and oviposition is initiated when temperatures exceeded from 9 to 10°C (Byrne *et al.*, 1989).

A field observation by Hunter (1953) may serve as an example. A high temperatures, when the oxygen content of the water was too low, adult specimens of *L. peregra* stayed continuously on the surface for lung respiration, even when not enough food was available at that level. Although *L. peregra* is able to survive over the range 0 to 45°C for few days (McDonald, 1969), it is usually not able to survive continuous exposure to temperatures greater than 30°C. Calow (1970) has recorded the best performance between 16 to 22°C. As temperature increased and fell down about the range, growth rates and egg production rates reduced sharply. A similar result was recorded by Islam *et al.* (1998). The growth rate of *L. peregra* reared at 15°C was lower than for snails kept at 20°C in the initial stage (Lambert, 1990). Harman and Berg

(1971) reared some Lymnaeidae at 35°C.

It is clear that the growth, survival and breeding capability of *L. peregra* are temperature dependent. Environmental water temperature seldom eliminates species living within their normal geographic ranges.

The influence of water quality: Variability in population characteristics of *L. peregra* such as reproduction and growth have been studied in relation to various environmental factors. The distribution of freshwater snails depends on water qualities, e.g. pH, dissolved O₂, calcium, etc. and temperature (Okland, 1969; Williams, 1970; McKillop and Harrison, 1972). It has been reported that the toxicity of most substances is influenced by such factors as temperature, turbidity, pH, dissolved O₂, CO₂, C⁺ and water hardness. Lam and Calow (1988) have investigated the influence of exposure to water movement and Dussart (1979) attempted at explaining the distribution of this species in terms of the physico-chemical variability of water quality. However, few studies have concerned the response of *L. peregra* to pollutants in the field and in the laboratory. The most important chemical variable is dissolved calcium, varying more than 100-fold in freshwaters. In Britain, waters with calcium values of < 3mg/lit. can usually support only *L. peregra*, *Ancylus* and about 4 species of *Pisidium* (Phillip, 1951; Hunter, 1953; Dussart, 1979). *L. peregra* showed a direct metabolic response to environmental calcium (Piggott and Dussart, 1995). Attempts have been made at relating molluscan distribution directly to pH (in Britain, few molluscs live at pH lower than 6.0), but significant correlation is found also with total alkalinity (Macan, 1974; Harman, 1974). Laboratory experiments have shown that four of the pulmonates transmitting schistosomes can breed between pH 4.8 and 9.8 (WHO Study Groups, 1957). Extremely high pH values in the natural waters do not appear detrimental to some species of pulmonates but very low pH values occurring in natural waters may be lethal to freshwater snails (Harman and Berg, 1971) and their eggs must be in contact with dissolved oxygen for development to occur (Richards, 1965). Okland (1969, 1983) has cited several sources that gastropods are not found in Scandinavian lakes that maintain pH values between 4.4 and 5.2. Hydrogen ion concentrations below 5.5 affect oxygen levels to the extent that fish and other aquatic organisms may be eliminated (Schwartz *et al.*, 1962). Calow (1970) suggested that pH of water during culture should be around eight.

Effect of pollutants on reproduction of *L. peregra*: Pollutants of diverse structure may affect the reproductive behaviour which is sensitive to toxic agents. Certain pollutants, notably the organochlorine compounds, have been shown to affect the reproductive system (Jernelov *et al.*, 1978). The use of organisms to assess or indicate water quality in freshwater ecosystems is well established and early works in this field concentrated on the determination of criteria governing lethal responses of individual species (Holdich and Tolba, 1981). More recently, attention has turned to the use of sub-lethal effects of pollution to give a better measurement of the sensitivity of populations and individuals to environmental change (Kierstead and Barlocher, 1989). Chronic exposure to toxic compounds in freshwater may allow individuals to survive but owing to impaired growth, altered reproductive potential or behaviour modification, the population structures and dynamics may be damaged. Reproduction is the single most important function in the life cycle of an organism. The inability of an organism to complete any one

Islam *et al.*: Effects of herbicides on the reproduction of *L. peregra*

stage of the reproductive process severely reduces its lifetime reproductive success. Disruption in reproduction will ultimately affect the abundance and distribution of the species. Therefore, laboratory tests on the long-term impact of sub-lethal pollutant concentrations on organisms should include studies on reproductive success (Sheehan, 1984). Investigations of reproductive performance in response to stress are essential for a better understanding of the impact of long-term exposure to pollutants in the natural ecosystem (Woin and Bronmark, 1992). This review aims at investigating whether such symptoms may be assessed to provide new sensitive methods for the biological assessment of the effect of herbicide (simazine). Freshwater ecosystems are exposed to a number of chemicals, including insecticides and herbicides, that are known to affect the physiology of aquatic organisms in various ways. The ecological effect of contaminants on natural freshwater animal communities are still poorly understood (Baturu *et al.*, 1995). Lagadic *et al.* (1994) reported that in extensive laboratory studies, the direct linkage between individual exposure and changes in population structure is usually lacking, especially for freshwater invertebrates. Exposures to sub-lethal concentrations of a chemical can reduce reproductive success of aquatic invertebrates directly by affecting reproductive behaviour or indirectly through reducing energy resources available by inhibiting feeding and/or increasing metabolic demands (Maund *et al.*, 1992).

Atrazine and simazine are widely used in the UK for weed control (Waters, 1991). The most common chemicals used to control aquatic weeds are Xylene, copper sulphate, 2,4-D acrolein, endothall, dichlobenil and diquat (HMAC., 1974). The main potential sources of herbicide residues in water are direct application, drift from aerial application, run off from treated lands, treatment of ditch bank vegetation, and faulty waste disposal techniques by the manufacturer, homeowner, commercial applicator or farmer (HMAC., 1974). The herbicide simazine is generally non toxic to aquatic fauna (The Pesticide Manual, 1979). The commercially formulated herbicide 'simazine' contains 50% w/v of the active ingredients, 2-chloro-4, 6-bis (ethylamino)-s-triazine in water (Mirfield Sales Services Ltd., UK). There is substantial toxicological information available for freshwater organisms (Addison, 1976), but that on herbicidal sub-lethal effect is limited. Works on the effects of other herbicides on the reproductive behaviour in various species are relevant. The herbicide atrazine, simazine, monuron and 2,4-D were found to increase the toxicity of a range of insecticides to the housefly, *Musca domestica*, *Aedes aegypti* and *Drosophila* (Lichtenstein *et al.*, 1973). Atrazine and simazine reduced the uptake and metabolism of carbofuran in the housefly (Wilkins and Khalequzzaman, 1993). These effects were also observed in the brine shrimp larvae, *Artemia salina* (Wilkins and Metcalfe, 1993) and on the house cricket *Acheta domestica* (Chio and Sanborn, 1977). The LD₅₀ of simazine was determined by Wilkins and Metcalfe (1993) on brine shrimp larvae as >23.12 mg/L water.

The mode of action of simazine is unknown, although the structural requirements for triazine toxicity were studied by Marchini *et al.* (1987). Islam *et al.* (1998) widely observed that the sub-lethal concentrations of simazine directly affected the growth, mortality and reproduction of *L. peregra*.

Mortality: In general, *L. peregra* dies after spawning

(Hyman, 1967), the mortality rate is comparatively high during reproduction and the post reproductive period (Russell-Hunter, 1961a, b). Hansen *et al.* (1972) reported that the adult pulmonate snails generally tolerate extremely high concentrations of insecticides. This can be explained by reduced absorption and other inherent resistance factors in snails. Islam *et al.* (1998) observed that the mortality rate was not significantly different at the onset of reproduction between the snails kept in different sub-lethal concentrations (10µg/L - 5000µg/L) of simazine and those bred in tap water. Mortality started earlier in the controls and at 5000µg/L concentration than other concentrations. They also observed that the length and weight of the snails were reduced as the concentrations of simazine were increased.

Reproductive behaviour: In the freshwater pulmonates, the growth rate becomes lower at the onset of female sexual maturation and during egg mass production (Bohlken *et al.*, 1978; Geraerts and Mohamed, 1981). There is an evidence in the case of midges of possible detrimental interactions with herbicides (Douglas *et al.*, 1993). Woin and Bronmark (1992) found an effect at high concentrations of DDT and MCPA (500µg/L) on the reproduction of the pond snail *L. stagnalis*. Baturu *et al.* (1995) found that the sub-lethal doses of atrazine had no relevant effect on reproduction of *L. palustris*. Islam *et al.* (1998) found that the highest sub-lethal concentration of simazine (5000 µg/L), there was no egg production, which shows that exposure to simazine has a negative effect on the reproduction of *L. peregra*. The lower concentrations of simazine are not toxic by themselves but they reduced the egg laying of *L. peregra* significantly. These results demonstrated that sub-lethal toxicity of simazine to the *L. peregra* can reduce reproductive activities and reproduction may be stopped at higher pollutant concentrations. Although, *L. peregra* is a high tolerant snail, they are very sensitive to the water chemistry, especially to p^H and calcium for reproduction (Harman, 1974). After adding simazine to dechlorinated tap water, p^H values were decreased (Islam *et al.*, 1998). The change of water quality might have affected metabolic rates and reproduction (Skoog, 1976).

Hatchability: There was little evidence of herbicidal impacts on the hatching capability of freshwater snails. However, some snails are directly and indirectly affected by pollutants: there is a reduction in egg capsule production and hatching capability (Harman, 1974). The number of capsules/snail or eggs/capsule or eggs/snail/season and percentage of hatch from each egg capsule of *L. peregra* has been documented by Calow (1978). Lam and Calow (1989) found that the maximum 95.80% of eggs hatched in populations, where p^H was 7.24 and calcium was 33.33 (mg l⁻¹). Islam *et al.* (1998) found that the maximum of 45.97% (± 10.92) eggs hatched with 10µg/L concentration of simazine. It indicates that very low concentrations of simazine do not significantly affect hatching capability.

The present review gives some information on the rearing techniques, and on the assessment of herbicidal effect on the reproductive behaviour of *L. peregra*, both in the field and laboratory conditions. The culture of a species depends upon the food availability and quality, temperature and water chemistry, which influence the growth, maturation and reproduction. The success of reproduction of a species depends on various factors and aquatic organisms can

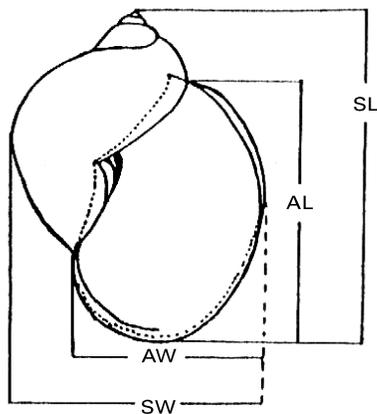


Fig. 1: Shell dimensions: SL=Maximum shell length, SW=Maximum shell width, AL=Maximum aperture length, AW=Maximum aperture width (after Lam and Calow, 1988; Barnes, 1992)

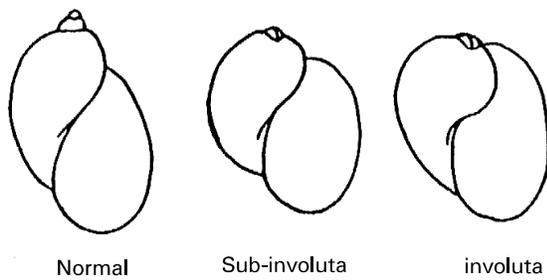


Fig. 2: Shell shape in *L. peregra*; normally spired (normal) sub-involuta and involuta (after Evans, 1989)

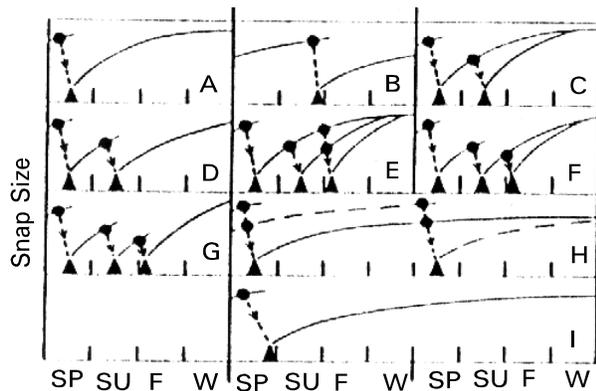


Fig. 3: Patterns of live cycle (A-I) to be found in the freshwater baseommatophorans. Circle, reproductive activity begins; Triangle, egg masses appear. Sp=Spring; SU=Summer; F=Fall; W=Winter (after Calow, 1978)

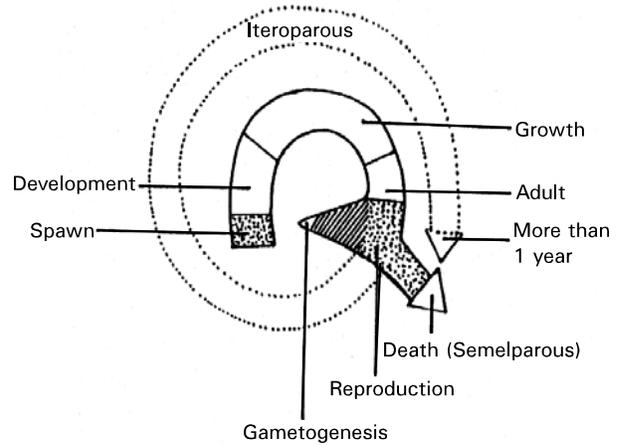


Fig. 4: Major features of molluscan life cycle (redrawn from Calow, 1978)

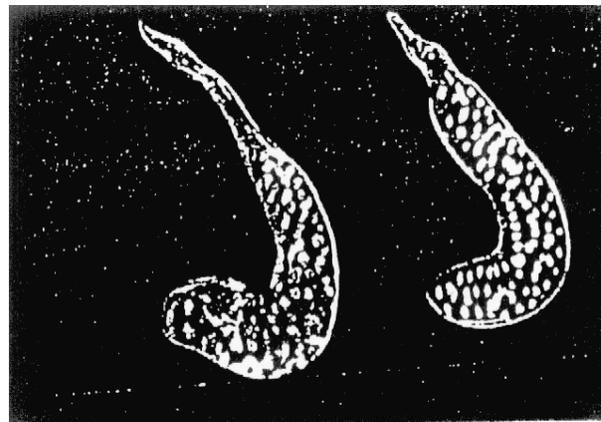


Fig. 5: The egg capsules of *L. peregra* in both, the terminal part is turned anti-clockwise. The left capsule contains 132 eggs and the right capsule 101 eggs (after Bondesen, 1950)

survive successfully only in unpolluted aquatic environments. Herbicides and pesticides are widely used to manage agricultural pests and their application has greatly contributed to stepping up agricultural production, but none of the herbicides or pesticides employed are absolutely specific, and due to their indiscriminate and wide spread use, several non target organisms like, snails, fishes, crabs, etc. are adversely affected (Gautam *et al.*, 1993). The desired effect of herbicides is to kill weeds, retard their growth, or selectively alter the plant cover. Simazine is one of the red listed herbicides in the UK, which is harmful to the freshwater ecosystem and is most dangerous to the aquatic environment (The UK Pesticide Guide, 1991). It is, therefore, necessary to check any hazardous materials to maintain ecological balance and an unpolluted ecosystem.

Acknowledgement

The first author remains grateful to the ODA in UK for financial support. He is thankful to the University of Rajshahi, Bangladesh, for granting him study leave.

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