Fecundity and fertility of the mangrove crab *Sesarma rectum* Randall, 1840 (Grapsoidea) from Ubatuba, São Paulo, Brazil

Leme, M. H. A.

Programa de Pós-graduação em Ciências Ambientais, Universidade de Taubaté, Estrada Municipal Dr. José Luiz Cembranelli, 5000, 12081-010, Taubaté, SP, Brasil. e-mail: mhleme@uol.com.br

Abstract

Ovigerous females of the crab *Sesarma rectum* Randall, 1840 were sampled over two years in a mangrove forest (23° 29'S and 45° 09'W) located in Ubatuba at the northern coast of São Paulo State, Brazil. Reproductive attributes: incubation time, egg size, fecundity and fertility (number of hatching larvae) were analyzed. The duration of the embryonic development was 20 days at 25 °C. The mean diameter of early-stage eggs was 0.465 ± 0.01 mm with a corresponding volume of 0.052 ± 0.003 mm^3. In the final embryonic stage (just before eclosion), the eggs had a mean diameter of 0.611 ± 0.02 mm, thus a mean volume of 0.12 ± 0.01 mm^3 (n = 16). The eggs increased in volume 131% from the initial to the final stage. Fertility was lower than fecundity, indicating substantial loss of eggs during the incubation process, as observed in many other brachyuran crabs. Based on these results, we can deduce that is important to evaluate female fertility as an estimation of the actual reproductive potential.

Key words: incubation time, egg size, fecundity, fertility, *Sesarma rectum*

Introduction

Fecundity in brachyuran crabs is commonly defined as the number of eggs produced per female per clutch (Reid and Corey, 1991). However, a more complete definition has been given by Corey (1987) and Stechey and Somers (1995) for crayfish, who defined fecundity as: 1) potential fecundity, from the number of oocytes counted in the ovaries; 2) realized fecundity, from the number of eggs actually extruded and attached to the pleopods; and 3) actual fecundity, which refers to the number of juveniles hatched. Instead of crayfish, marine brachyuran crabs hatch as larvae, which passes through several zoeal stages. Thus, the term fertility will be used in the present work as the number of larvae produced at hatching per female.

Just after egg extrusion by a female, several factors may contribute to egg losses in brachyurans. These factors include loss from mechanical attrition from contact with the substrate during the female's activities (Wolcott and Wolcott, 1982; Henmi, 1989), or because of increased egg size during incubation (Corey, 1987), or parasitism (Shields *et. al.*, 1990). Furthermore, not all the eggs produced by a female may be viable; in fact, most are infertile (McMullen and Yoshihara, 1971). Therefore, estimating production in later brood stages is also useful in order to determine mortality during incubation and the actual contribution of a given parental stock of both economically important and ecologically key-role species (Kuris, 1991; Oh and Hartnoll, 1999).

The sesarmid *S. rectum* is a very common and abundant crab inhabiting mangrove forests, where they construct burrows in the substrate in the upperlittoral border, in drier grassy areas (Tavares and Albuquerque, 1989). Like other mangrove-dwelling sesarmids, this species may play a paramount role in contributing to the turnover of food in that ecosystem (Lee, 1998). This species occurs on the shores of the western Atlantic Ocean from Florida (USA) to southern Brazil (Melo, 1996). Several aspects of its biology have been studied, such as larval and juvenile development (Fransozo and Hebling, 1986; Fransozo, 1986/87, Negreiros-Fransozo and Fransozo, 1991), food habits (Brogim and Lana, 1997) and population structure (Leme, 2002). However, its reproductive traits and other biological aspects are still poorly known.

The goal of this study was to examine the size-specific fecundity and fertility (modified from the "realized" and "actual" fecundity terms used by Corey, 1987), the incubation time and the egg size at the initial to the final stages of the crab *S. rectum*.

Material and Methods

Ovigerous females of *S. rectum* were collected by hand at low tide in a mangrove forest (23° 29' 20" S and 45° 09' 53" W), located near the city of Ubatuba on the northern coast of the State of São Paulo, Brazil, over a two-year period from March 1996 to February 1998. During monthly surveys, the ovigerous females were placed in individual plastic bags to avoid appendage and egg loss. In the laboratory, the embryonic stage of the eggs were checked and measured to the nearest 0.1 mm, using a caliper (maximum carapace width, CW).

Captured females were separated in different trials according to the developmental stage of their broods. For ovigerous females bearing a newly laid egg mass, a sample of 10 eggs was removed and placed under a stereomicroscope provided with a micrometric eyepiece for measurements. Some of these specimens (n = 23) were frozen for later egg counting (fecundity), while the remaining females were kept alive in order to determine incubation time (n = 9), increase in egg size, and fertility (n = 14) by counting hatched larvae. This latter group, together with females incubating eyed eggs at capture (considered to be eggs in the intermediate stage), were conditioned individually in plastic containers with 2 cm of filtered seawater diluted to 20 ± 2‰. Small stones were placed in the containers to serve as a substratum. Trial containers were placed in an incubating chamber where the temperature (25 ± 1 °C) and photoperiod (14 h L/10 h D) were held constant, close to summer environmental conditions in Ubatuba. Crabs were fed on mangrove leaves and pieces of shrimp's muscle. The water was changed and the food replaced daily. From each ovigerous female analyzed, a sample of 10 eggs was removed each day, to check the developmental stage of the embryos and to measure their diameter for later estimation of the egg volume by the equation for a sphere.

In this study, incubation time was estimated from females carrying eggs at the very beginning of development when they were captured. For analyses of the egg size increment, I considered the initial (INI) size as that measured in eggs full of yolk, still lacking a visible animal pole; the intermediate stage of eggs (INT) as the measurements of eggs with early embryonic pigmentation; and the final size (FIN) as that obtained from eggs a day prior to hatching.

To determinate the fecundity (EN) of *S. rectum*, eggs were carefully removed from the pleopods using fine forceps and a brush. Special care was taken to separate the individual the eggs. The number of eggs was estimated by taking ten 1-ml sub samples from a 75-ml homogenized water solution. Counting was performed under a stereomicroscope. The total number of eggs laid by a single female was then estimated by extrapolation.

Fertility (F) was estimated by counting larvae hatched in the laboratory from females monitored each day until hatching. After larval release, the water where the female was kept was filtered through a 150 mm plankton net. Zoeae were then preserved in 4% formalin. The number of larvae was estimated using the same procedure as for counting eggs.

Size-specific fecundity and fertility were expressed using the allometric model after log transformation of the data. The number of eggs (EN) and number of larvae were plotted against size (CW), and a linear regression was fitted to a log-log scatter plot. Slopes (regression coefficients) were tested against the theoretical 3.0 value using Student's *t*-test, and decisions were made based on the 95% statistical significance level. Slopes and intercepts (angular coefficients) of size-specific fecundity and fertility relationships were compared using the ANCOVA (Zar, 1999).

The mean hatching rate was determined by dividing the mean number of hatching larvae by the mean number of eggs and then multiplying by 100 according to Lobão *et al.* (1986).

Results

At 25 °C, embryogenesis requires 20.4 ± 2 d (n = 9) in *S. rectum*. The embryonic pigments, which characterize the intermediate stage of eggs, appear near the midpoint of embryonic development, *i.e.* at day 12. The initial egg color is dark wine. During development, the color changes to brown tones, and then to light gray 24 h before hatching. The larvae always hatched at night, close to a new or full moon times.

Egg size clearly increased during embryogenesis (Fig. 1). The mean diameter of eggs in the initial stage was 0.46 ± 0.01 mm (n = 9), thus a mean volume of 0.052 ± 0.003 mm^3. In the final stage the eggs had a mean diameter of 0.61 ± 0.02 mm, thus a mean volume of 0.12 ± 0.01 mm^3 (n = 16). This corresponds to an increase of 131% in volume.

The mean number of eggs laid by *S. rectum* was 9,882 ± 3,262 and varied from 6,420 to 18,170 for females ranging from 19.0 to 31.0 mm CW.

The number of eggs increased together with female size (Fig. 2). The slope obtained from the linear regressions of egg number on body size (CW) did not differ from the theoretical slope of 3.0 (t = 2.27, $P < 0.01$), indicating an isometric relationship.

The mean number of hatched larvae was 8,065 ± 3,082 and varied from 2,955 to 12,135 for females ranging from 19.4 to 31.1 mm CW (Fig. 2). The slope did not differ from 3.0 (t = 0.18, $P < 0.01$), also indicating an isometric relationship.

The regression between EN and CW was compared with the regression between F and CW to examine differences in the number of eggs laid and the actual number hatching. An ANCOVA showed that the slopes of the regressions were not significantly different between the two processes (F = 1.38, $d.f.$ = 1, 33, P > 0.05), but the intercepts did differ (F = 60.93, $d.f.$ = 1, 34, $P < 0.0001$), indicating that fertility was lower than fecundity. The mean hatching rate determined for *S. rectum* was 82% indicating that approximately 18% of eggs are lost or unviable.

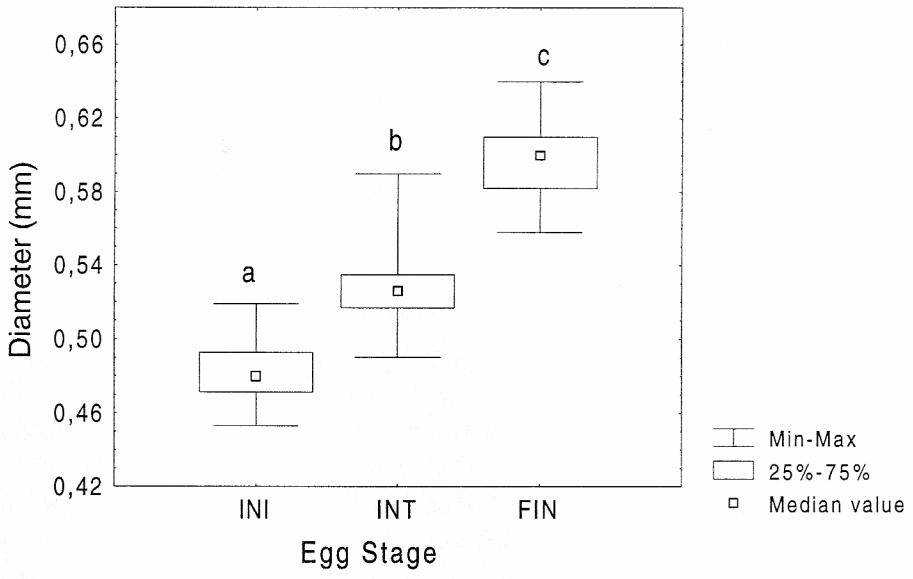

Figure 1: Mean sizes of eggs in different developmental stages of *S. rectum*. Box-plots with at least one same letter above did not differ statistically (ANOVA, p < 0.05). (IN = initial embryonic stage; INT = intermediate and FIN = final).

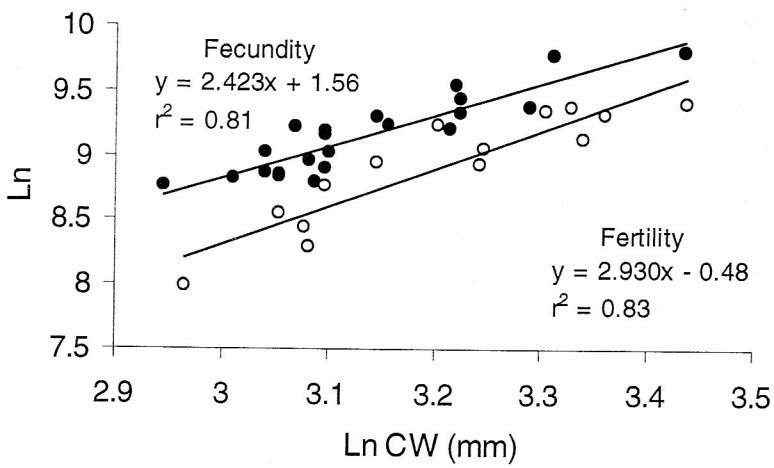

Figure 2: Size-specific egg number fecundity (solid circles) and fertility (open circles) of *S. rectum*.

Discussion

Incubation time in brachyurans may be highly variable, and is strongly influenced by temperature (Wear, 1974; Kobayashi and Matsuura, 1995) and by egg size (Steele and Steele, 1975). Embryos of *S. rectum* require, on average, 20 days to hatch at 25 °C, which corresponds to the mean temperature in the study locale during the summer months. However, the ambient temperature may vary widely, contributing to accelerating or slowing incubation times in the natural population.

Egg size is an important variable for characterization of reproductive traits concerning the evolution of life histories in crustaceans (Hines, 1986). Interspecific differences are related principally to the early development modes, i.e., planctotrophic, lecithotrophic, or direct, among others (Mileikovsky, 1971; Vance, 1973).

In many cases, egg size has been discussed with regard to the amount of energy which will be available for embryonic development. It is usually postulated that larger eggs possess more yolk, providing large larvae at eclosion (larvae in advanced stage of development), or larvae that hatch with larger amounts of yolk reserves remaining (Clarke, 1993; Lardies and Castilla, 2001). Since the advanced larva must spend more time in the egg, the incubation time for larger eggs must be extended (Steele and Steele, 1975; Rabalais and Gore, 1985).

Semiterrestrial grapsoid crabs usually have 3-5 zoea stages (Rabalais and Gore, 1985). According to Diesel *et al.* (2000), increased egg size toward land is an evolutionary trend related to the abbreviation of larval stages in more terrestrial environments.

The semiterrestrial crab *S. rectum* produces large eggs and has three zoea stages in its larval development (Fransozo and Hebling, 1986). Similar egg sizes are reported for its congeners *S. reticulatum* (Say, 1817) (0.45 mm) by Seiple and Salmon (1987); and *S. curacaoense* De Man, 1892 (0.55 to 0.60 mm) by Hartnoll, (1965), which has only two zoea stages. Larger eggs than these are observed in grapsoids which are considered truly terrestrial, such as the bromeliad crab *Metopaulias depressus* Rathbun, 1896 studied by Hartnoll (1964) and *S. jarvisi* Rathbun, 1914 studied by Diesel and Horst (1995), in which the egg size reaches up to 1 mm in diameter and the larval development is abbreviated.

The eggs produced by *S. rectum* practically doubled in size during the course of embryonic development. This is not unusual for brachyuran crabs (Henmi, 1989; Zimmerman and Felder, 1991; Kobayashi and Matsuura, 1995; Luppi *et al.*, 1997; Bas and Spivak, 2000). However; the rate of increase may be highly variable. The major process accounting for increments in egg size is osmotic water uptake (Wear, 1974), and temperature seems to be an important factor affecting the rate of absorption of water by the eggs (Kobayashi and Matsuura, 1995), as well as the salinity factor (Bas and Spivak, 2000; Giménez

and Anger, 2001). According to Pandian (1970), this uptake provides ecophysiologic advantages for both the egg and embryo, and may play an important role during the hatching process (Wear, 1974; Saigusa, 1992).

However, substantial increase in egg volume during embryonic development, as demonstrated in this study, could be a potential cause of egg loss (Corey, 1987; Lardies and Castilla, 2001; Thatje *et al.*, 2004). Atresic or infertile eggs were also monitored in this study, and no swelling was observed. The clutch was eventually aborted or ingested by the female.

In brachyuran crabs, the evolution of offspring number is governed by the trade-off between egg size and egg number due to allometric constraints of body size (Hines, 1982). Therefore, fecundity is determined primarily by female body size. The slope b = 3.0 of the linear regression of egg number on size indicates an isometric relationship (Somers, 1991), which means that the larger the female, the larger the clutch size (number).

Studies on the realized fecundity in brachyuran crabs have been conducted using specimens carrying early eggs, because egg loss is common in nature. Since not all the eggs in a clutch are viable and egg loss is frequent, fertility estimates may provide a better parameter for the quantification of the production of offspring. This study showed that the number of hatched larvae in *S. rectum* might be considerably lower than the number of eggs extruded.

Acknowledgements

I wish to thank Dr. Maria Lucia Negreiros-Fransozo (UNESP, Botucatu) for her continuous advice and my colleagues from NEBECC (Group of studies on crustacean biology, ecology and culture) for their help during fieldwork. Financial support was provided by FAPESP as a doctoral fellowship (# 96/0596-3).

References

Bas, C. and Spivak, E. D. 2000. Effect of salinity on embryos of two southwestern Atlantic estuarine grapsid crab species cultured *in vitro*. Journal of Crustacean Biology, 20: 647-656.

Brogim, R. A. and Lana, P. C. 1997. Espectro alimentar de *Aratus pisonii, Chasmagnathus granulata* e *Sesarma rectum* (Decapoda, Grapsidae) em um manguezal da Baía de Paranaguá, Parana. Iheringia, Sér. Zool., (83): 35-43.

Clarke, A. 1993. Egg size and egg composition in polar shrimps (Decapoda; Caridea). Journal of Experimental Marine Biology and Ecology, 168: 189-203.

Corey, S. 1987. Intraspecific differences in reproductive potential, realized reproduction and actual production in the crayfish *Orconectes propinquus* (Girard 1852) in Ontario. American Midland Naturalist, 118: 424-432.

Diesel, R. and Horst, D. 1995. Breeding in a snail shell: ecology and biology of the jamaican montane crab *Sesarma javirsi* (Decapoda: Grapsidae). Journal of Crustacean Biology, 15: 179-195.

Diesel, R.; Schubart, C. D. and Schuh, M. 2000. A reconstruction of the invasion of land by jamaican crabs (Grapsidae: Sesarminae). Journal of Zoology, 250: 141-160.

Fransozo, A. 1986/87. Desenvolvimento dos estágios juvenis de *Sesarma* (Holometopus) *rectum* Randall, 1840 (Decapoda, Grapsidae) obtidos em laboratório. Naturalia, 11/12: 77—87.

Fransozo, A. and Hebling, N. J. 1986. Desenvolvimento larval de *Sesarma (Holometopus) rectum* Randall, 1840 (Decapoda, Grapsidae) em laboratório. Revista Brasileira de Biologia, 46: 353-364.

Giménez, L. and Anger, K. 2001. Relationships among salinity, egg size, embryonic development, and larval biomass in the estuarine crab *Chasmagnathus granulata* Dana, 1851. Journal of Experimental Marine Biology and Ecology, 200: 241-257.

Hartnoll, R. G. 1964. The freshwater grapsid crabs of Jamaica. Proceedings of the Linnean Society of London, 175: 145-169.

Hartnoll, R. G. 1965. Notes on the marine grapsid crabs of Jamaica. Proceedings of the Linnean Society of London, 176: 113-147.

Henmi, Y. 1989. Reproductive ecology of three ocypodid crabs. II. Incubation sites and egg mortality. Ecological Research, 4: 261-269.

Hines, A. H. 1982. Allometric constraints and variables of reproductive effort in brachyuran crabs. Marine Biology, 69: 309-320.

Hines, A. H. 1986. Larval patterns in the life histories of Brachyuran crabs (Crustacea, Decapoda, Brachyura). Bulletin of Marine Science, 39: 444-466.

Kobayashi, S. and Matsuura, S. 1995. Eggs development and variation of egg size in the Japanese mitten crab *Eriocheir japonicus* (De Hann). Benthos Research, 48: 29-39.

Kuris, A. M. 1991. A review of patterns and causes of crustacean brood mortality. Pp. 117-141 *In* Wenner, A. and Kuris, A. eds. Crustacean issues. Crustacean egg production. Vol. 7. A.A. Balkema, Rotterdam.

Lardies, M. A. and Castilla, J. C. 2001. Latitudinal variation in the reproductive biology of the commensal crab *Pinnaxodes chilensis* (Decapoda: Pinnotheridae) along the Chilean coast. Marine Biology, 139: 1125-1133.

Lee, S. Y. 1998. Ecological role of grapsid crabs in mangrove ecosystems: a review. Marine and Freshwater Research, 49: 335-343.

Leme, M. H. A. 2002. A comparative analysis of the population biology of the mangrove crabs *Aratus pisonii* and *Sesarma rectum* (Brachyura, Grapsidae) from North Coast of São Paulo State, Brazil. Journal of Crustacean Biology, 22: 553-557.

Lobão, V. L.; Rojas, N. E. T. and Valenti, W. C. 1986. Fecundidade e fertilidade de *Macrobrachium amazonicum* (Heller, 1862) (Crustacea, Decapoda) em laboratório. Boletim do Instituto de Pesca, 13 (2): 15-20.

Luppi, T. A.; Bas, C. C.; Spivak, E. D. and Anger, K. 1997. Fecundity of two grapsid crab species in the Laguna Mar Chiquita, Argentina. Archive of Fishery and Marine Research, 45: 149-166.

McMullen, J. C. and Yoshihara, H. T. 1971. Deposition of unfertilized eggs in unmated king crabs, *Paralithodes camtschatica* (Tilesius). Transactions of the American Fisheries Society, 100: 583-584.

Melo, G. A. S. 1996. Manual de identificação dos Brachyura (caranguejos e siris) do litoral brasileiro. São Paulo, ed. Plêiade, 603p.

Mileikovsky, S. A. 1971. Types of larval development in marine bottom invertebrates, their distribution and ecological significance: a re-evaluation. Marine Biology, 10: 193-213.

Negreiros-Fransozo, M. L. and Fransozo, A. 1991. Growth and determination of three juvenile crab species (Crustacea, Decapoda, Brachyura). Papéis Avulsos de Zoologia 37: 277-283.

Oh, C. W. and Hartnoll, R. G. 1999. Brood loss during incubation in *Philocheras trispinosus* (Decapoda) in Port Erin Bay, Isle de Man. Journal of Crustacean Biology, 19: 467-476.

Pandian, T. J. 1970. Ecophysiological studies on the developing eggs and embryos of the European lobster *Homarus gammarus*. Marine Biology, 5: 154-167.

Rabalais, N. N. and Gore, R. H. 1985. Abbreviated development in decapods. Pp. 67-126 *In* Wenner, A. M. ed. Larval growth. A. A. Balkema, Rotterdam.

Reid, D. M. and Corey, S. 1991. Comparative fecundity of decapod crustaceans, II. The fecundity of fifteen species of anomuran and brachyuran crabs. Crustaceana, 61 (2): 175-189.

Saigusa, M. 1992. Observations on egg hatching in the estuarine crab, *Sesarma haematocheir*. Pacific Science, 46 (4): 484-494.

Seiple, W. and Salmon, M. 1987. Reproductive, growth and life-history contrasts between two species of grapsid crabs, *Sesarma cinereum* and *S. reticulatum*. Marine Biology, 94: 1-6.

Shields, J.; Okazaki, R. K. and Kuris, A. M. 1990. Brood mortality and egg predation by the nemertean, *Carcinonemertes epialti*, on the yellow rock crab, *Cancer anthonyi*, in southern California. Canadian Journal of Fishery and Aquatic Science, 47: 1275-1281.

Somers, K. M. 1991. Characterizing size-specific fecundity in crustaceans. Pp. 357-378 In Wenner, A. and Kuris, A. eds. Crustacean issues Crustacean egg production. Vol. 7, A. A. Balkema, Rotterdam.

Stechey, D. P. M. and Somers, K. M. 1995. Potential, realized and actual fecundity in the crayfish *Orconectes immunis* from southwestern Ontario. Canadian Journal of Zoology, 73: 672-677.

Steele, D. H. and V. J. Steele. 1975. Egg size and duration of embryonic development in Crustacea. Internationale Revue der gesamten Hidrobiologie, 60: 711-715.

Tavares, M. S. and Albuquerque, E. F. 1989. Levantamento preliminar dos Brachyura (Crustacea: Decapoda) da lagoa de Itaipu, Rio de Janeiro, Brasil. Atlântica, 11: 101-108.

Thatje, S.; Lovrich, G. A. and Anger, K. 2004. Egg production, hatching rates and abbreviated development of *Campylonotus vagans* Bate, 1888 (Crustacea: Decapoda: Caridea), in subantarctic waters. Journal of Experimental Marine Biology and Ecology, 301: 15-27.

Vance, R. R. 1973. On reproductive strategies in marine benthic invertebrates. American Naturalist, 107 (955): 339-352.

Wear, R. G. 1974. Incubation in British decapod Crustacea, and the effects of temperature on the rate and success of embryonic development. Journal of the Marine Biological Association of the United Kingdom, 54: 745- 762.

Wolcott, T. G. and Wolcott, D. L. 1982. Larval loss and spawning behavior in the land crab *Gecarcinus lateralis* (Fréminville). Journal of Crustacean Biology, 2: 477-485.

Zar, J. H. 1999. Biostatistical analysis. 4th ed. New Jersey, Prentice-Hall, 663p.

Zimmerman, T. L. and Felder, D. L. 1991. Reproductive ecology of an intertidal brachyuran crab, *Sesarma* sp. (nr. *reticulatum*), from the Gulf of Mexico. Biological Bulletin, 181: 387-401.

Received: 15th Dec 2004
Accepted: 11th Jan 2005