Ceylon Journal of Science 48(2) 2019: 177-184
DOI: http://doi.org/10.4038/cjs.v48i2.7622

RESEARCH ARTICLE

The distribution of terrestrial pest gastropods and their damage to agricultural crops in Kandy and Nuwara Eliya districts in Sri Lanka

P.W.D.B. Maheshini, K.G.D.D. Thilakarathne, G.N. Hirimuthugoda, K.B. Ranawana and S. Kumburegama*

Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

Received: 01/01/2019 ; Accepted: 13/05/2019

Abstract: An island wide survey from 1999 to 2002 in Sri Lanka highlighted the presence of 18 species of exotic snails and slugs, of which most were identified as pests of agriculture crops. However, since this survey, no studies on pest gastropods have been carried out in the country. Hence, the present study was carried out in Kandy and Nuwara Eliya districts in approximately 15 hectares of agricultural land to determine the current status of these gastropods. During the study, a total of 14 terrestrial gastropod species were recorded from agricultural lands of which eight species were recognized as exotic pest gastropods. They were *Deroceras reticulatum, Laevicaulis altae, Mariaella dussumieri, Milax gagates, Lissachatina fulica, Bradybaena similaris, Allopeas gracile* and *Subulina octona.* The damage from pest gastropods was observed in many crops and especially in the seedling or nursery stage plants. The highest damage to crops in Nuwara Eliya and Kandy districts were caused by *D. reticulatum* and *Lissachatina fulica* respectively. The study indicated that the distribution range of many of these pest gastropods, especially *Laevicaulis altae* and *Lissachatina fulica* has increased during the past fifteen years. Elevation is a key environmental factor that affects their distribution in these districts.

Keywords: Pest gastropods, Kandy, Nuwara Eliya, distribution, agriculture, crops.

INTRODUCTION

Members of Class Gastropoda are the most diverse and arguably the most successful group within Phylum Mollusca (Pearce and Őrstan, 2006). This group consists of the snails that typically have an external shell and the slugs that lack an external shell. Among the snails and slugs relatively few species are considered to be pests of agriculture and horticulture (Kozlowski, 2012). In many countries these pests cause severe economic losses to agriculture and horticulture. Often these species are non-natives of that region or country (Wiktor, 2001). Given the opportunity, these species are able to spread rapidly in a short amount of time and some species even penetrate natural habitats (Wiktor, 2001; Kozlowski, 2012).

Sri Lanka has a rich gastropod diversity. This diversity was brought into focus by the Darwin Initiative funded, island wide survey conducted from 1999 to 2002 (Naggs *et al.*, 2003). It highlighted the presence of 253 species of terrestrial gastropods out of which 81% (205 species) are endemic to the country. In addition to the endemic, non-endemic native species, this study also highlighted the presence of 18 exotic species that were introduced accidentally or intentionally to the country (Naggs and Raheem, 2000; Ranawana *et al.,* 2012). Some of these species are known to adversely affect agriculture and horticulture in many countries world over (Naggs *et al*., 2003; Jayaratne *et al*., 2015).

Since this survey, there have been no follow up studies on the pest gastropods and their affects to agriculture in Sri Lanka (Kumburegama and Ranawana, 2001; Kumburegama and Ranawana, 2002). Thus, the present study was carried out to assess the present distribution of the pest gastropods in Kandy and Nuwara Eliya districts in the central province and to evaluate the degree of damage caused by these pest gastropods to agriculture crops in these districts.

MATERIALS AND METHODS

Study site selection

Field visits in agricultural lands including green houses were carried out in six Divisional Secretariats (DS) (Doluwa, Kundasale, Pasbage Korale, Udapalatha, Medadumbara and Yatinuwara) in the Kandy district and five DS (Nuwara Eliya, Kothmale, Haguranketha, Ambagamuwa and Walapane) in the Nuwara Eliya district for a period of ten months from January to October 2017. This study period included both the dry (January to March) and the rainy (May to September) seasons. Sampling for pest gastropods was carried out every two weeks in approximately 15 hectares of agricultural land. During field visits, a field was defined as the land owned by a single farmer. With the consent of the farmer, each field was sampled for terrestrial pest gastropods during the night when the pest snails and slugs are most active. Geo-coordinates, altitude, temperature and relative humidity of each agricultural land visited (including greenhouses) were recorded. The owners were interviewed to record the history of pest gastropod outbreaks in their fields and current pest gastropod control practices.

Identification and sampling of pest gastropods

Snails and slugs encountered during the study were identified using field guides (Naggs and Raheem, 2002;

**Corresponding Author's Email:* skumburegama@yahoo.com
http://orcid.org/0000-0002-7378-872X

Mordan *et al.*, 2003). Visual and time based sampling approach was utilized to sample pest snails and slugs. For each field visited, if a single crop was cultivated, a random sampling for pest gastropods in a total of 10 plots (1 m^2 each) from different parts of the field was carried out. If several crop types were cultivated in one field, 10 plots from each of the crop types were sampled. Each plot was sampled for a maximum period of 15 minutes. The number of pest gastropods of each species per plot was recorded.

In addition the margins of the fields and adjacent home gardens were also observed for the presence of these pest gastropods. However, the pests gastropods encountered in these areas were not used in density or relative abundance calculations.

Data analysis and distribution map preparation

The relative abundance and density of each pest gastropod species were calculated. The relative abundance data were further used to determine significant differences in the distribution of the pest species between the two districts using a Mann-Whitney test in Minitab 18 software. A Canonical Correspondence Analysis (CCA) was carried out using Canaco 5 software to determine the variation of pest gastropod distribution with measured environmental variables of altitude, temperature and relative humidity. The distribution map of the exotic pest gastropods was prepared using Arc Map 10.3 software (Figure 1).

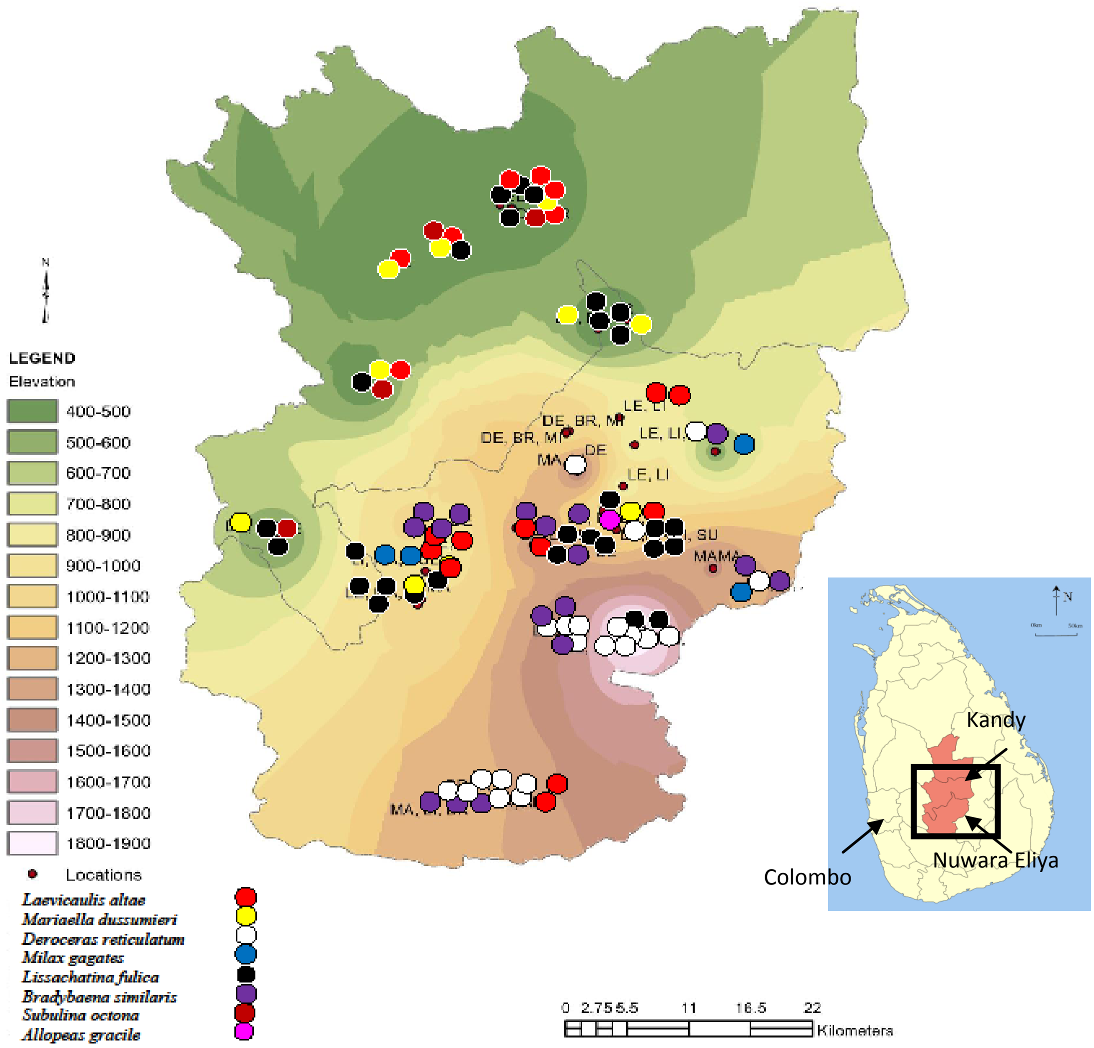

Figure 1: Distribution map of terrestrial pest gastropods observed in agricultural fields in Kandy and Nuwara Eliya districts.

Evaluation of the degree of damage to crop plants

In each field visited the type of crops cultivated were noted. After the pest gastropod numbers were estimated, the degree of damage to crops from these pests was evaluated by randomly examining ten plants from each of the plots. If a single crop is cultivated, ten plots were examined to determine the extent of damage to that crop. But, if several crop types were cultivated in a field, ten plots from each of the crop types were examined to separately determine the extent of damage to each of the crop types. Either direct observation of the snails and slugs feeding or indirect evidence in the form of slime trails at the damaged or grazing site was used to identify the damage caused by gastropod pests. Then by careful observation of the parts damaged, an estimation of the degree of damage (%) to the plant was noted. At the end of the study this data was pooled and analyzed to determine the degree of damage to the different crops.

RESULTS AND DISCUSSION

Gastropod species encountered and their distribution

Since the previous study in the early 2000s, there have been no studies on the distribution, ecology, biology or the impact of pest gastropods to agriculture in Sri Lanka. Hence the present study was conducted to evaluate the current status of these pests in these two districts. During the study, a total of fourteen terrestrial gastropod species were encountered in agricultural lands. Among these, four species of slugs, and nine species of snails and a single semi-slug (with a small shell), *Satiella* sp. (Godwin-Austen, 1908) were identified. However, among these snails and slugs, only eight species were identified as exotic, pest species (Figure 2).

All four species of slugs encountered, namely, *Deroceras reticulatum* (Muller, 1856) (Figure 2A), *Laevicaulis altae* (Ferussac, 1822) (Figure 2B), *Mariaella dussumieri* (Gray, 1856) (Figure 2C) and *Milax gagates* (Draparnaaud, 1801) (Figure 2D) are pests of agriculture and horticulture. Out of the nine species of snails, *Lissachatina fulica* (Bowdich, 1822) (Figure 2E), *Bradybaena similaris* (Ferussac, 1822) (Figure 2F), *Subulina octona* (Bruguiere, 1789) (Figure 2G) and *Allopeas gracile* (Hutton, 1834) (Figure 2H) are the documented pest species (Figure 2).

The remaining six are native snail species (Figure 3). Of these, five species are endemic, namely, *Satiella* sp. (Figure 3A), *Euplecta emiliana* (Pfeiffer, 1854) (Figure 3B), *Euplecta hyphasma* (Benson, 1853) (Figure 3C), *Eurychlamys vilipensa* (Benson, 1853) (Figure 3D) and *Cryptozona chenui* (Pfeiffer, 1847). The remaining species is, *Cryptozona bistrialis* (Beck, 1837) (Figure 3E), which is a non-endemic snail.

Interestingly, it was observed that while the exotic, pest gastropods encountered in the crop fields caused direct, observable damage to different parts of the crop plants, with some species demonstrating voracious appetites, the endemic and non-endemic native species caused no observable damage to the crops even though some of them occurred in large numbers. Often, the endemic and non-endemic snails were found in marginal vegetation of the crop fields and in several instances, they were abundant in adjacent home gardens near the crop fields. On the other hand, most of the pest gastropods occupied crop fields as well as the adjacent home gardens.

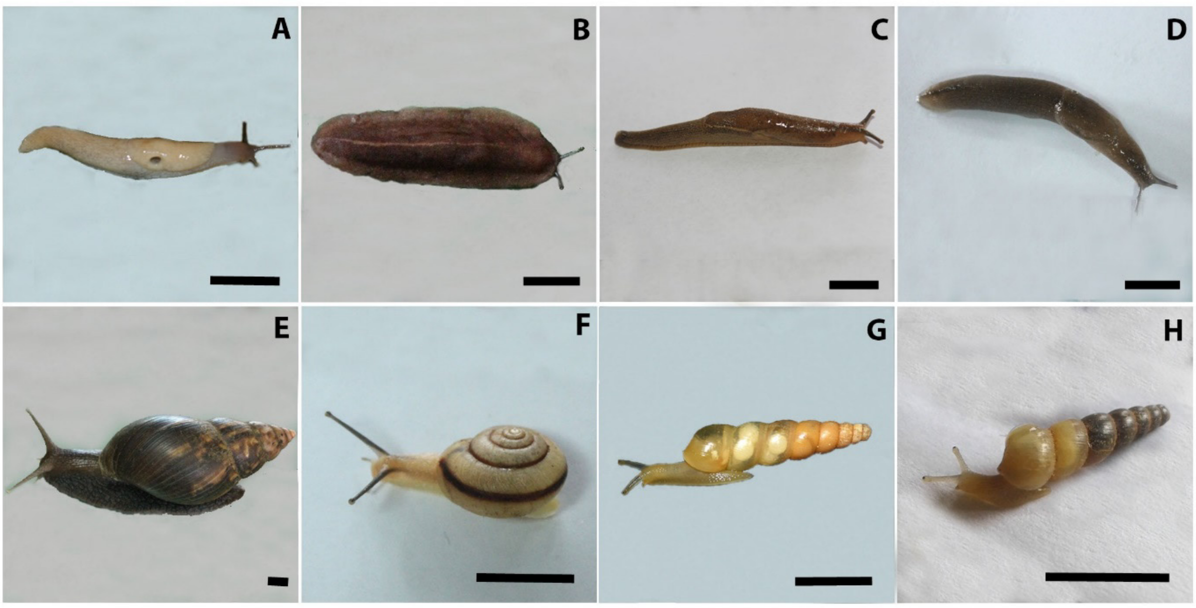

Figure 2: Pest snails and slugs recorded in agricultural fields in Kandy and Nuwara Eliya Districts. Slugs, **A** *Deroceras reticulatum*, **B** *Laevicaulis altae*, **C** *Mariaella dussumieri*, and **D** *Milax gagates* and snails, **E** *Lissachatina fulica*, **F** *Bradybaena similaris*, **G** *Subulina octona*, and **H** *Allopeas gracile*. The scale bar indicate 1 cm.

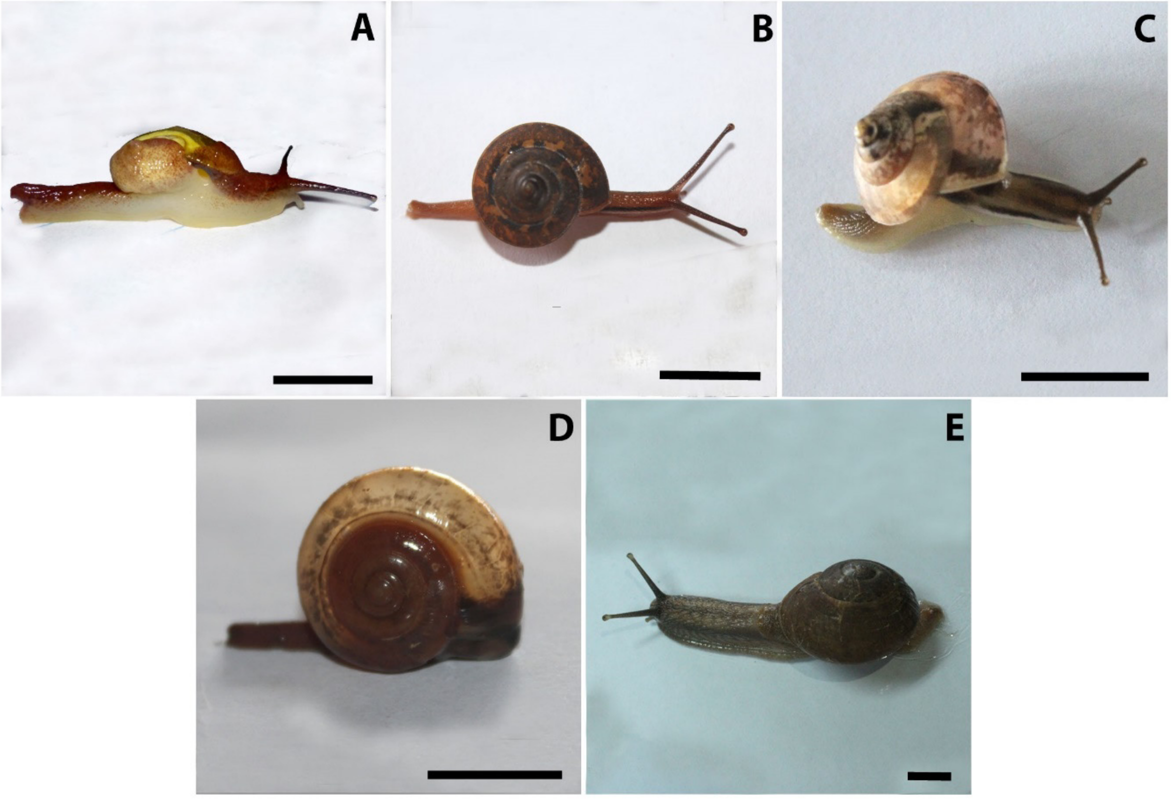

Figure 3: Native land-snails encountered in agriculture fields. Endemic species **A** *Satiella sp*., **B** *Euplecta emilina*, **C** *Euplecta hyphasma*, **D** *Eurychlamys sp*., and non-endemic species **E** *Cryptozona bistrialis*. The scale bar indicate 1 cm.

Density and distribution of the gastropod species

According to the previous study, a total of five species namely, *D. reticulatum*, *Deroceras laeve*, *B. similaris*, and Allopeas gracile were found in Nuwara Eliya district whereas Laevicaulis altae, Mariaella dussumieri, Lissachatina fulica, Subulina octona and Allopeas gracile were found from the Kandy district. However, in this study, all slug species except *M. gagates,* were found in agricultural lands in both districts. *M. gagates* were found only in the Nuwara Eliya district. *D. reticulatum*, which was previously not recorded in the Kandy district, was this time recorded from a single field in the Kandy district at Pussellawa at an elevation of 1,536 m. Overall, this species was recorded from an elevation of 1,139 m up to 1,912 m. Even though *D. leave* was recorded in the previous study, albeit in very low numbers compared to *D. reticulatum*, this species was not encountered during this study. Of the pest snails, *Lissachatina fulica*, the only invasive alien species of land gastropods identified at present in Sri Lanka and *A. gracile,* were recorded from both Kandy and Nuwara Eliya. On the other hand *B. similaris* was found only in Nuwara Eliya district while *S. octona* was recorded from Kandy District. Of the native species of snails *C. bistrialis,* and *E. hyphasma* were found only in Nuwara Eliya district while, *Satiella* sp. was only found in the Kandy district. *C. chenui* and *E. vilipensa* were found occupying agricultural lands in both districts.

Deroceras reticulatum showed the highest relative abundance among all the slugs and snails recorded during the study and this species was the most prominent pest gastropod species in the Nuwara Eliya District occuring in high densities (Figure 4). The second highest relative abundance in Nuwara Eliya and the most prominent species of pest gastropod in the Kandy district was *Laevicaulis altae* (Figure 4). Its densities were typically higher in the Kandy District than in the Nuwara Elilya District. When these data were further analyzed it indicated that the relative abundance of *Laevicaulis altae* (Mann-Whitney test, w= 448; p= 0.004), and *D. reticulatum* (Mann-Whitney test, w= 403; p= 0.031) was significant for the Kandy and the Nuwara Eliya districts respectively. However, the relative abundance of *M. dussumieri* (Mann-Whitney test, w= 382.5; p= 0.684), *A. gracile* (Mann-Whitney test, w= 353; p= 0.352) and *Lissachatina fulica* (Mann-Whitney test, w= 403; p= 0.29) had no significant difference between the two districts (Figure 4).

The influence of environmental variables in the distribution of pest gastropods

The pest gastropods encountered showed a wider distribution than previously recorded in the two districts (Figure 5). They were observed in surveyed fields ranging from a minimum altitude of 455 m to a maximum of 1,912 m, and with temperatures ranging from a minimum of 18.3ºC to a maximum of 29ºC and a relative humidity of 19.6% to 98.2% . Yet, the CCA analysis indicate that the distribution of majority of the pest snails and slugs correlate especially with elevation (Figure 6). For example, the tropical invaders such as *Mariella* d*ussumieri*, *Laevicaulis*

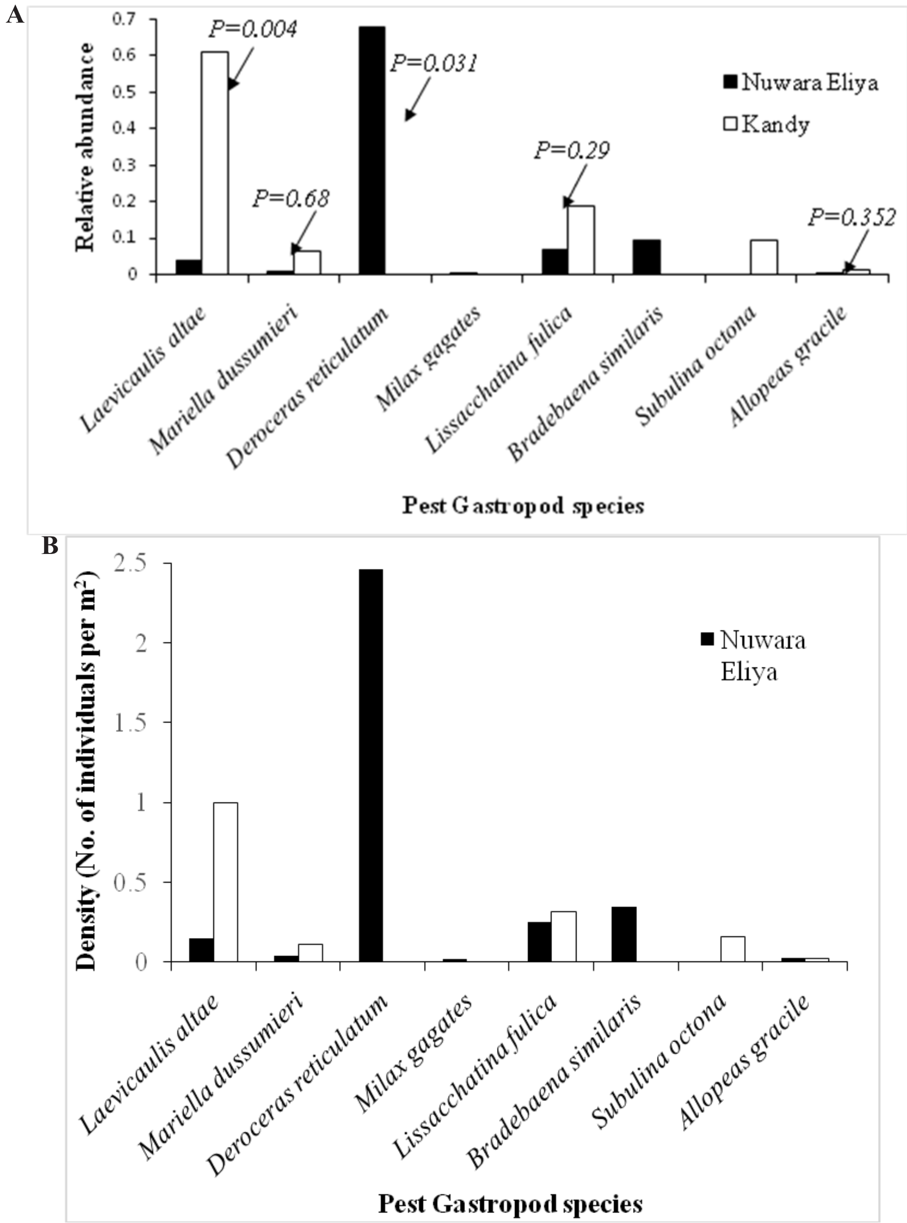

Figure 4: **A.** Relative abundance and **B.** Density of terrestrial pest gastropods in agricultural fields in Kandy and Nuwara Eliya Districts.

alte, *Lissachatina fulica* and *Allopeas gracile* prefer lower elevations with a relatively high humidity (Figure 6). According to Mordan *et al*. (2003), *Laevicaulis altae*, a native of Central Africa, thrive in hotter, lowland areas, thus do not occur in Nuwara Eliya district. However, this slug was found in Nuwara Eliya up to a maximum elevation of 1,139 m, in fields with over 90% relative humidity. *Lissachatina fulica* which was also not previously recorded from Nuwara Eliya, were found in both districts albeit at relatively lower elevations (Figure 6A), in relatively similar densities with no significant difference in their distribution in the two districts ($p > 0.05$) (Figure 4B). It is native to East Africa but has been introduced to many countries throughout the world (Raut and Barker, 2002). This species is probably the most widely introduced and distributed invasive pest species in the world (Estebenet *et al*., 2006).

On the other hand, the introduced European gastropod species such as *D. reticulatum* and *Milax gagates* thrive at higher altitudes (Figure 6). However, according to the CCA, while *D. reticulatum* occupy less humid environments, *Milax gagates* favors humid environments. During this study only elevation, temperature and relative humidity were measured as environmental variables. However, there may be other factors that affect the distribution of these species such as soil pH, moisture and temperature (Ondina et al., 2003; Nunes and Santos, 2012). Although slugs like *Laevicaulis alte* and *Mariaella dussumieri* and snails like *Lissachatina fulica* were previously not recorded from the Nuwara Eliya district, this study indicate that given the opportunity these species will spread to other parts of the island where suitable environmental conditions prevail.

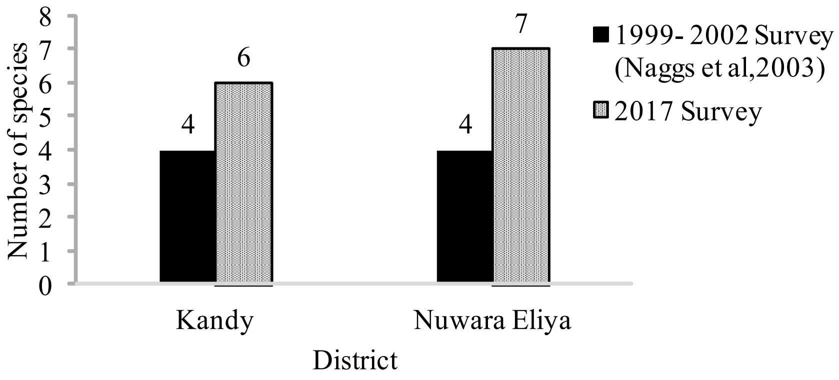

Figure 5: Comparison of the number of terrestrial pest gastropod species in Kandy and Nuwara Eliya districts during the previous survey (1999-2002) and present study.

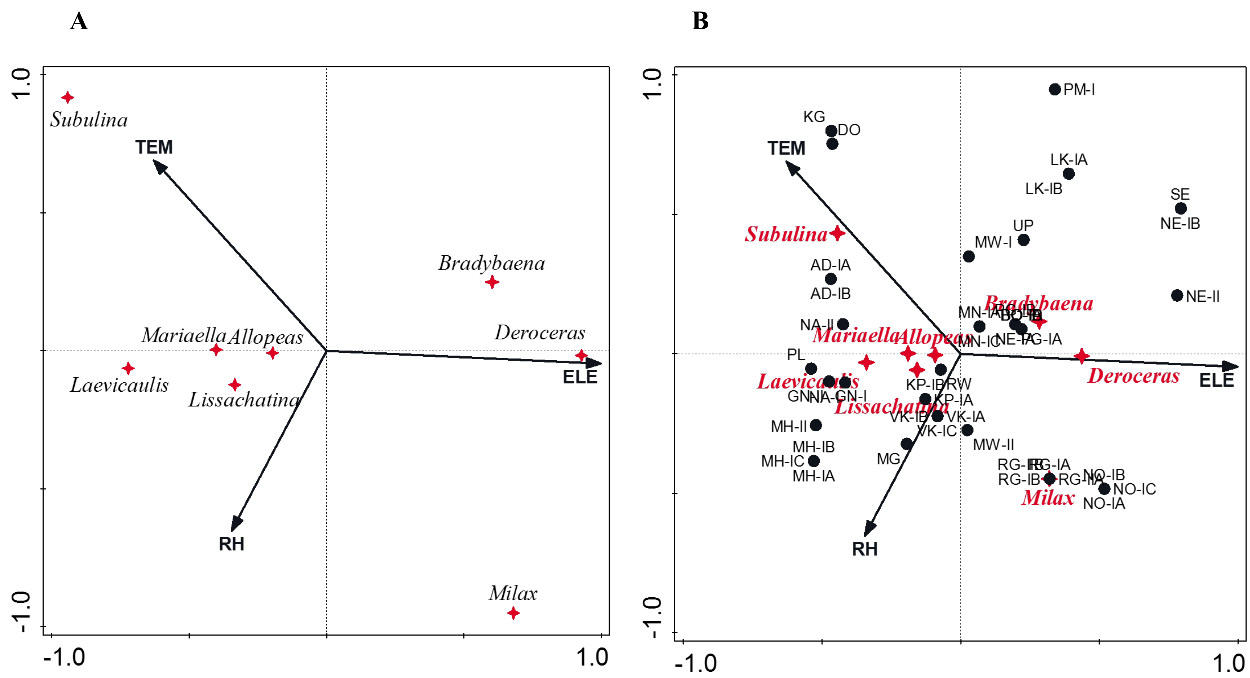

Figure 6: CCA of pest gastropod distribution. **A** Bi-Plot on the correlation of pest gastropod species to environmental factors and **B** Tri-Plot of pest gastropod species in relation to the sites and environmental variables. Species are indicated using (+), sites by (•) and environmental variables: Temperature (**TEM**), Relative humidity (**RH**) and Elevation (**ELE**) by arrows.

Damage to agriculture crops

Pest gastropods are capable of damaging different stages of the plant from seedling to harvesting stages as well as different parts of plants, from roots to stems and flowers and fruits. According to the results the pest snails and slugs caused severe damage at nursery or seedling stage plants (Table 1) in Nuwara Eliya and Kandy districts. The severity of the damage depends on the intensity of the pest gastropod infestation and may cause major crop yield losses to the farmer. Crops such as lettuce, cabbage, cauliflower are highly damaged even at mature stages by these gastropods. *D. reticulatum* is a serious pest of many vegetables, especially of leaf crops such as cabbage and lettuce and the seedlings of root crops such as carrot as observed during this study and the previous study (Naggs *et al*., 2006; Mordan *et al.,* 2003). During the present survey, *D. reticulatum* was also noted as a serious threat to seedling stages of leeks. But, if protected during the seedling stages, this crop was not seriously damaged except for the tips of mature leaves. This slug which showed the highest relative abundance as well as the highest density in the Nuwara Eliya district was the most damaging to vegetable crops in this district (Figure 4, Table 1). The slug, *Laevicaulis alte* previously reported from Matale and Kandy districts in the Central Province attacks a wide variety of crops (Mordan *et al*., 2003). The current study revealed the presence of this species not only in Kandy but also in the Nuwara Eliya district from where it was not previously reported. It was found posing a serious threat to radish and cauliflower cultivations. However, *Lissachatina flulica*, which was less abundant than *Laevicaulis alte*, caused more damage

Table 1: Visual assessment of the degree of damage to crop plants by pest gastropod species.

	Crop	Stage of crop	Gastropod species involved	Degree of Damage (%)	Economic damage (Farmer's perception)
Kandy	Cauliflower	Seedling, mature plant	*Laevicaulis altae*	25%	Very high
Kandy	Cabbage	Mature plant	*Lissachatina fulica*	95%	Very high
Kandy	Cucumber	Mature plant	*Lissachatina fulica*	10%	Low
Kandy	Winged beans	Young leaves, shoots, flowers	*Lissachatina fulica*	5%	High
Kandy	Radish	Leaves	*Laevicaulis altae*	<20%	High
Nuwara Eliya	Leeks	Seedling	*Deroceras reticulatum*	95%	Very high
Nuwara Eliya	Cabbage	Mature plant	*Deroceras reticulatum*	3%	Very low
Nuwara Eliya	Lettuce	Seedling, Leaves	*Milax gagates, Deroceras reticulatum*	10%	Low
Nuwara Eliya	Carrot	Seedling	*Deroceras reticulatum,* *Bradybaena similaris*	10%	High

to vegetable crops especially in the Kandy district (Table 1). It is a voracious feeder of plant matter and it feeds on vegetables, especially lettuce, cabbage and cauliflower, fruits such as papaya, breadfruit and jackfruit and various ornamental plants (Mordan *et al.,* 2003). In addition they were also found to attack flowers and buds of winged beans, pumpkin, as well as mature leaves of cucumber and gourd cultivations. In Sri Lanka at present it is the only pest gastropod species identified as an invasive alien species (IAS). IAS are those upon deliberate or accidental introduction to a country pose a threat to the native biodiversity of that country by possibly outcompeting the native species for resources. Such species can also cause economic losses or endanger the health of humans and livestock (Kozłowski, 2012). Consequently, control and management of these snails and slugs is necessary to reduce the adverse effects on economy and the environment.

Control and management efforts of pest gastropods

Once exotic species become established in a particular area it becomes extremely difficult to eradicate them. Thereafter, proper control practices are required for the management of such species. Because of pest gastropods infestations, farmers face economic losses due to crop damage resulting in yield loss and also due to the costs for labor, chemicals and time required for the management of these pests (Kumburegama and Ranawana, 2002; Raut and Barker, 2002). Farmers practice several controlling methods such as the manual removal of snails and slugs, or use of chemicals such as Metaldehyde (Meta), quicklime, salt, and urea. Particularly in areas where there is high infestation of pest gastropods, a combination of two or more such methods is necessary. As reported by Raut and Barker (2002), the manual collection and removal of snails and their eggs is effective, albeit temporary, in controlling *Lissachatina fulica* in crop lands in Hawaii, Japan and Sri Lanka. During the survey, some farmers were observed manually removing the snails, especially *Lissachatina fulica.* However, farmers tend not to destroy the collected animals but throw them away from the fields in the hope that these animals will not revisit the fields. But majority of the farmers did not solely rely on this practice. Many also utilize chemicals. Among these, Metaldehyde (Meta) is a molluscicide widely used in controlling pest gastropods. It is generally applied as bait mixed with bran. It is a neurotoxin that is effective in controlling pest gastropods either through dermal contact or through ingestion and affects the water balance of the animal (Godan, 1983). But, it can be rendered ineffective if exposed to direct sunlight which damages the properties of Metaldehyde and it can be easily washed off with irrigated water or rain water. Hence, when applying the chemical it is necessary to keep it covered to protect from sunlight and water. As was evident during the study, the improper application of the chemical, where the farmer keeps the molluscicide exposed to the elements fails to control the infestation successfully. Due to the costs involved in purchasing Metaldehyde, some farmers also rely on alternative chemicals such as quicklime, common salt and urea with varying degrees of success.

CONCLUSIONS

Eight species of pest snails and slugs were recorded from Kandy and Nuwara Eliya Districts. Although six species of native snails was also recorded from agricultural lands, damage to vegetable crops by these species was not evident. The most abundant and most destructive pest gastropod in the Nuwara Eliya district is *D. reticulatum.* On the other hand, the most abundant pest gastropod in the Kandy district is *Levecaulis alte.* However, the most damaging to agriculture crops in this district is *Lissachatina fulica*, which is an IAS species in Sri Lanka. Elevation is a key environmental factor that affects the distribution of these snails and slugs in these two districts. Even though many farmers use several control methods, the ineffective application of these methods is an impediment in the proper control and management of these pests. Effort must therefore be made to inform and educate farmers in the importance of proper application of control methods to obtain effective results. This is also essential for controlling the spread of these pests.

ACKNOWLEDGEMENT

We acknowledge the funding provided by the Biodiversity Secretariat, UNDP/GEF project on Strengthening Capacity to Control the Introduction and Spread of Invasive Alien Species (IAS) in Sri Lanka.

REFERENCES

Estebenet, A.L., Martín, P.R. and Silvana, B. (2006). Conchological variation in Pomaceacanaliculata and other South American Ampullariidae (Caenogastropoda, Architaenioglossa). *Biocell*. **30**(2):329-335.

Godan, D. (1983). Pest snails and Slugs- Biology and control, Springer- Verlag Berlin. 135-288.

Jayaratne, S., Ellepola, G. and Bandara, S. (2015). Effects of forest transformation to species composition of land snails in Gannoruwa Forest Reserve, Kandy, Sri Lanka. *Novelty Journals*. **2**(5):24-29.

Kozlowski, J. (2012). Thesignificance of alien and invasive slug species for plant communities in agrocenoses. *Journal of Plant Protection Research.* **52**:67-76.

Kumburegama, N.S.P. and Ranawana, K.B. (2001). Identification of pest snails and slugs of vegetable crops in four districts of Sri Lanka. *Proceedings of the Annual Research Sessions, University of Peradeniya, Sri Lanka.* 6**,**Pp. 117.

Kumburegama, S. and Ranawana, K.B. (2002). Economic importance of pest snails and slugs in vegetable growing areas of Sri Lanka*. Proceeding of the Annual Research Sessions, University of Peradeniya.*7,Pp. 127.

Mordan, P., Naggs, F., Ranawana, K.B., Kumburegama, S. and Grimm, B. (2003).*"A guide to the pest and exotic gastropods of Sri Lanka"*. The Natural History Museum London.

Naggs, F. and Raheem, D. (2002). Sri Lankan snails. *The Natural History Museum, London*. UK.

Naggs, F., Panha, S. and Raheem, D. (2006). Developing Land Snail Expertise in South and Southeast Asia, a New Darwin Initiative Project. *Tropical Natural History*. **6**(1)**:**43-46.

Naggs, F., Raheem, D.C., Mordan, P.B., Grimm, B., Ranawana, K.B. and Kumburegama, N.P.S., (2003). Ancient relicts and contemporary exotics: faunal change and survivorship in Sri Lanka's snail fauna. Slugs & Snails: Agricultural, Veterinary & Environmental Perspectives. *British Crop Protection Council Symposium Proceedings,* 80, Pp. 103 - 108.

Nunes, G.K.M. and Santos, S.B. (2012). Environmental factors affecting the distribution of land snails in the Atlantic Rain Forest of Ilha Grande, Angra dos Reis, RJ, Brazil. *Brazil Journal of Biology* **72**:79-86.

Ondina, P., Hermida, J.,Outeiro, A. and Mato,S. (2003). Relationships between terrestrial gastropod distribution and soil properties in Galicia (NW Spain). *Applied soil Ecology* **26**:1-9

Pearce, T. A. and Őrstan, A. (2006). Terrestrial Gastropoda. In: Sturm, C. F., Pearce, T. A. and Valdés. A. (Eds.). 8. *The Mollusks: A Guide to Their Study, Collection, and Preservation,*American Malacological Society. 8, Pp. 261-285.

Ranawana, K.B., Priyadarshana, T.G.M., Weerakoon, D.K. and Wijesundara, S., (2012). The taxonomy and conservation status of the land snails in Sri Lanka. *The national red list*.

Raut, S. and Barker, G. (2002). *Achatina fulica*Bowdich and Other Achatinidae as Pests in. *Molluscs as crop pests*. 55.

Wiktor, A.N.D.R.Z.E.J. (2001). *Deroceras* (Deroceras) *panormitanum* (Lessona et Pollonera, 1882)-a new introduced slug species in Poland (Gastropoda: Pulmonata: Agriolimacidae). *Folia Malacologica*, **9**: 155-157.