MSc Conservation and Biodiversity

ASSIGNMENT COVER SHEET – Research Project

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Project Title: Distribution, Habitat Association, Species Abundance and Perceptions of Residents towards Achatina fulica in Anguilla

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Cover page

Title: Distribution, Habitat Association, Species Abundance and Perceptions of Residents towards *Achatina fulica* in Anguilla

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Abstract

Invasive species affect biodiversity and have been associated with high economic costs and other implications for society. One invasive mollusc, which is currently causing considerable damage to the livelihood of people in the Caribbean, is the Giant African Snail (*Achatina fulica*). The invasion of this mollusc in the Caribbean Island of Anguilla has posed a major challenge to the authorities and residents alike. Here, I investigated the overall distribution of *A. fulica*, examined the association of *A. fulica* with three different habitats (grasslands, woodlands and shrubs), recorded its microhabitats, and probe the perception of residents towards the introduced mollusc. I found that there were significant differences in the snails' abundance among geographic areas, habitat types and microhabitats. The results indicated that *A. fulica* was widely distributed in all major habitat types, thereby suggesting that any eradication programme will be extremely costly. The study also revealed that residents considered the snail to be a pest and were supportive of assisting the authorities in managing the destructive mollusc.

Key Words

Giant African snail, invasive species, microhabitat, mollusc, biodiversity, Anguilla, pest.

Introduction

Biological invasions (invasive or alien species) are harmful non-native animals, plants and microorganisms that have the potential to affect terrestrial and marine biodiversity (Perring et al., 2002; Mooney, 2005). In recent times, they have been viewed as a global threat to biodiversity and conservation managers (Simberloof, 2002). These alien species, once established outside of their native range, have the potential to severely alter native ecosystems (Gabriel et al., 2001). Additionally, research has shown that oceanic islands are not only more vulnerable, but suffer greater damage as a result of invasive species (Donlan et al., 2003; Dowd et al 2003). Scientists attribute this theory to many factors, one being that these agents/vectors are away from their natural enemies (predator, parasites, and pathogens), and therefore they have the freedom to adapt and spread rapidly in their new environment (Dowd et al 2003, Molongoy et al 2006). Additionally, studies have associated invasive species with the cause of extinctions in some islands (Donlan et al 2003; Gurevitch and Padilla, 2004).

The island of Anguilla and the rest of the Caribbean Region are no strangers to invasive species. According to Kairo and Ali (2003), the Caribbean region has a total of 552 invasive species (of which Anguilla have 9). These include various species of snakes, insects, noxious weeds and other micro-organisms which have altered the region’s ecosystems, affected its economies and posed a serious threat to the health and well being of the residents. One particular invasive which is currently seen as a major threat to the Caribbean Region is the Giant African snail (*Achatina fulica*), whose origin is Eastern Africa.

Achatina fulica is recognized by the Global Invasive Species Programme (GISP), as one of the 100 most destructive biological invasions in the world. This herbivore has a voracious appetite and is known to feed on over 500 species of plants (Simberloof, 2003). Apart from this, *A. fulica* poses a potential health risk to humans, as some of its specimens are associated with an intermediate host of a nematode parasite *Angiostrongylus Cantonensis,* which is commonly known as the rat lung worm

(Civeyrel and Simberloff , 1996; Carvalho et al 2003). This vector has the potential to cause eosinophilic meningoencephalitis and brain damage in humans (Upatham et al 1988).

The first known record of *A. fulica* in the Caribbean Region was documented in the French island of Guadeloupe in 1984 (Mead and Palcy, 1992; Civeyrel and Simberloff, 1996; Raut and Barker, 2002). Subsequently, specimens of *A.fulica* have dispersed and successfully established populations in other islands of the Caribbean archipelago including Martinique (1988), Barbados (2000), St. Lucia (2000), St. Maarten/St. Martin (2000?) and Anguilla (2000).

As in many other nations, the authorities and the residents throughout Anguilla are concerned about the potential threat of the Giant African Snail. This concern has propelled the authorities to launch an organized campaign towards the eradication of this invasive mollusc. However, due to concerns voiced by a few concerned citizens (over the possible side effects of the molluscicide bait being use), the campaign was prematurely stopped after three months.

It is important to note that although several scientific studies have been conducted on *Achatina fulica* throughout the Pacific region, most of them have focused on its potential as a disease carrier, its agricultural impact and/or various biological and natural attempts to control the mollusc. A review of other literature simply provided an overview of the snails' biology and its potential use as a food source. However, this is the first study to assess *Achatina fulica* in various parameters within its physical environs, while at the same time evaluating it socio-economic impact on society. Therefore, this study was designed to investigate a) the distribution of *A. fulica* in Anguilla, b) the topographical habit of *A. fulica*, c) the physical location/micro-habitat associated with *A. fulica* and c) the perception of residents towards *A. fulica*. In addition, as there are no preliminary data on endemic or introduced snails on Anguilla, baseline data was also collected on specimens of the island's terrestrial malacofauna.

The main predictions tested in this study are that there will be significant differences in the distribution of *A. fulica* among villages, habitat types, microhabitats, and that the perception of residents in relation to the mollusc will be dependent on the level of impact they have experienced as a result of the invasive snails.

Materials and Methods

This study was conducted on the island of Anguilla (18.2 N, 63.1W) from March to July 2006. The approach for this research took the form of two components, namely, extensive fieldwork whereby data was collected from several sampling sites, and the distribution of a questionnaire, which sought to ascertain the perception of residents towards the invasive *A. fulica.*

Rapid survey of the islands for *Achatina fulica*

Prior to the commencement of sampling study sites, I gathered information from the Department of Agriculture in order to ascertain the distribution of *A. fulica* on the island. I then conducted a rapid assessment throughout all of the villages (including those not listed by Department of Agriculture) to ascertain the presence or absence of *A. fulica* on the island. This approach involved having brief informal discussions with 5-10 residents (selected at random) from villages throughout the island to determine whether they have seen or heard of the mollusc in their community. Once the residents identified areas in their community where *A. fulica* was known to inhabit the area was searched for a fixed period of 20 minutes for evidence (live snails or shells) of the introduced mollusc. Those villages that provided evidence of a positive infestation of the mollusc were recorded and a GPS unit was used to determine the exact location of the specimen(s). Upon completion of the research, villages that were not infested with *A. fulica* during the initial rapid assessment survey were re-visited to determine whether infestation of the snails had occurred in the area.

Study Sites

For the purpose of this research, the study sites were selected from the list of those villages that were positively infested with specimens of *A. fulica* during the initial rapid assessment survey of villages. Five of these villages were randomly chosen for sampling the distribution of the introduced snail. These villages were Upper South Hill, Little Harbour, Stoney Ground, George Hill and Cauls Bottom (see Fig. 1). It is important to note that for each study site, I examined three fairly homogenous distinct topographic structures (habitats). These habitats were categorized as grasslands (5-10 cm tall), shrublands (35-75 cm tall) and woodlands. The vegetation on the island does not have a distinct woodland habitat. Therefore, in keeping with the range established by Walker et. al (2005), areas with trees between 305-915 cm were classified as woodlands type habitats.

Criteria for site selection

I examined each of the five villages in the study to allocate areas that were suitable to be classified as grasslands, shrublands and woodlands. Areas with dense vegetation are extremely difficult to conduct sampling of poorly mobile organisms (Craze and Mauremootoo, 2002). Therefore areas with semi-scattered and accessible vegetation were selected for sampling *A. fulica*'s abundance in shrubland and woodland type habitats. However, the final criterion for the site selection of the mollusc was that the areas under investigation must have had at least two dead (shells) and live specimens of the species *Achatina fulica*.

Sampling of sites

Achatina fulica is mainly nocturnal, therefore sampling only took place during the early morning (at the break of dawn) when the snails were still very active. In order to ascertain the density of *A. fulica* in each habitat, I randomly established a ten (10) metre transect- with 2 x 2 m quadrats - on alternate sides for the grassland study sites (each transect had 5 quadrats). Subsequent transects were established every 10 metres. This process was repeated 8 times, giving the sampled area a total of 40 quadrats (N=40) for each grassland habitat. Again, due to the level of difficulty associated with constructing quadrats in dense vegetation, the sampling technique for shrublands and woodlands were slightly altered. Sampled areas were selected based on accessibility. However, the same number and size of quadrats for these sites was constructed. Using the protocol established for other studies on mollusc (see Cowie, 1999), timed sampling (5 minutes) was used to sample each quadrat. For each quadrat, I scoured for *A. fulica* in various physical locations/microhabitats such as in the leaf litter, on vegetation, under rocks/fallen wood, on tree trucks and on rocks/stony ground. For grassland habitats, snails embedded in the grass were recorded as being in the leaf litter. A total of 600 quadrats were sampled for this study (N=600).

All individuals of *A. fulica* that were in each quadrat were then counted, and its physical location/microhabitat association (live specimens) was documented on a data sheet. Additionally, all other species of gastropods that were found in the quadrats were recorded with reference to their morphology. A hand held Garmin Foretrea 201 GPS (Garmin, Kansas, USA) unit was utilized for acquiring the coordinates of all quadrats on the study site. Since wet weather is usually associated with *A. fulica* being more active, the weather condition was also recorded on the data sheet. Wet days were defined as overnight rain or the presence of dew in the habitat during the sampling, while dry days were defined as the lack of precipitation in the habitat under study.

Interviews/Survey

The perception and participation of the public is an integral component when addressing the issue of invasive species (Simberloof, 2003; Maguire, 2004; Gewin, 2005). Therefore, I conducted a survey to ascertain the views of the public with reference to *A. fulica*. I designed a questionnaire and randomly interviewed 140 residents (N=140) on the island. The survey was distributed to households of infested villages (not necessarily those villages of the study sites). One individual (18 years or older) from each household was asked a range of questions including (but not limited to), time of introduction, methods of control and impact of snails (see appendix 1). It was hoped that by acquiring such vital feedback from the respondents, the practitioners, residents and environmental managers would have a better understanding of the impact of invasive species in relation to socio-economic factors.

Results

Distribution of *A. fulica*

The survey indicated that 20 villages were infested with specimens of *A. fulica*. All of the infested areas were adjoining villages. There were a total of 17 villages that were infested prior to the commencement of the study, while 3 villages became infested during or after that period. At the completion of the survey, only one village to the west (Long Bay) and the most eastern villages of the island were free of the introduced snail (Fig. 1).

Abundance and Microhabitat/physical location

The survey yielded a total of 2,544 snails (876 live and 1668 dead) belonging to the species *Achatina fulica* that were collected from the sampled sites. I performed a Kruskal-Wallis test (adjusted for ties) to determine whether there were significant differences in the number of snails among villages. The results ($H=49.6$, d.f=4, $P < 0.001$) indicated that there were significant differences in the number of snails among villages. This test was also performed to determine whether there was a significant difference in the number of snails among the 3 vegetation types. According to the result ($H=63.16$, d.f =2, $P < 0.001$), it indicates that there were significant differences among the snails in different habitat types.

The data further showed that the village of Stoney Ground had the highest density of *A. fulica,* while George Hill had the least amount of these snails. However, the study indicated that the village of South Hill had the highest density of live *A. fulica*, while Caul's Bottom had the least amount of live snails (fig. 2). In terms of the dead *A. fulica*, Stoney Ground recorded the highest density of the species per square metre, whereas George Hill had the least amount of snails. Additionally, the data indicated that there were similar numbers of live and dead *A. fulica* in George Hill and South Hill (Fig. 2).

Further, with reference to habitat association, the survey indicated that shrublands recorded the highest mean number of *A. fulica* per quadrat from the sampled population, while the woodland habitats had the least number of this invasive mollusc (Fig.3). A higher biomass of *A. fulica* was recorded in the shrubs at Stoney Ground, while Caul's Bottom had the least in this habitat. The data also indicated that *A.fulica* was more prevalent in the woodland habitats of Caul's Bottom and George Hill, whereas Little Harbour recorded the least amount of snails in this habitat. The results revealed that there were a fairly even distribution of *A. fulica* among the woodland and grassland habitats of South Hill and Stoney Ground (Fig.3).

The survey also indicated that among the three topographical structures under investigation, grasslands were associated with a higher proportion of dead snails when compared to shrublands and woodlands habitat. Alternatively, shrublands were associated with a higher proportion of live snails, while woodland habitats recorded the lowest number of *A. fulica* snails for this study (see Figs.8 a,b,c).

This study also evaluated the physical location/microhabitat of *Achatina fulica*. Most of the snails were located on the vegetation during the sampling of habitats (Fig.4). With the exception of Stoney Ground, the data showed that there were very few snails located under the rocks or fallen wood. Meanwhile, there were inconsistencies in terms of the amount of snails located in the leaf litter and on rocks/stony ground for each of the sampled villages. However, the results indicated that the amount of snails found on the tree trunks of the sampled villages were more evenly distributed when compared to the other microhabitats (Fig.4). Additionally, the results also indicated that more live specimens of *A. fulica* were recorded on wet days compared to dry (Fig. 8 d).

Other Species of Snails

The survey yielded a total of 5, 358 specimens of other mollusc species on Anguilla. These terrestrial molluscs are further classified into six species, namely: Species 1) *Drymaeus* species- *D. virgulatus* (family *Bulimulidae*); species 2) *Bulimulus guadalupensis* (family *Bulimulida);* species 3) *Chondropoma (Chondropomorus)* (family *Annulariidae/Licinidae)*; species 4) *Macroceramus* (family *Urocoptidae*; species 5) *Drymaeus* species- (family *Bulimulidi)*striped*;* species 6) *Subulinidae* species (see Fig. 5). Species 1 and 3 were found in all sampled villages. Species 2 was recorded in all villages except Stoney Ground. The data also indicated that specimens of species 4 were only found in George Hill and Little Harbour. Species 5 and 6 were only found in little harbour- and were exclusively associated with the woodland habitats (table 1). The data also indicated that the density of *A.fulica* was relatively close to the most common snail found in the island (table 2).

Although not recorded in the quadrat sampling, 2 other species of invasive molluscs- Zachrysia Species Z. *provisoria* or Z. *auricoma havenensis* (family *Pleurodontidae*), (Fig.6) and a number of veronicellid slugs were found in some villages during the period when the initial rapid assessment survey for the presence/absence of *A. fulica* was conducted.

Perception of the Public

Results from the residential survey indicate that 42% of the respondents considered the Giant African Snail to be a major/significant problem while 37% of them viewed it as a pest. (Fig. 7a). I performed a regression test to ascertain whether there was a relationship between the amount of snails in the respondents' yard and their perception of the molluscs. The results (r square=0.026, F=3.27, d.f =1,121, P=0.07) indicated that there were no significant relationship with the amount of snails and the perception of residents toward *A. fulica*. Again this test was performed to ascertain whether the financial loss they experienced as a result of the snails had any bearing on their perception of the mollusc. The results, r square =0.710, F=223.45, d.f =1, 90, $p < 0.05$, indicated that there is significant relationship between financial losses and perception of snails. Similarly, a regression test suggested that there is significant relationship (r square=0.787, F = 497.91, d.f = 1, 35, $p < 0.05$) with reference to the respondents age and their perception of the introduced snail.

Further, most respondents (44%) stated that the snails have also caused significant damage to their plants/crops (Fig. 7b). In terms of mitigation methods, the majority of the respondents (50%) utilized household salt as a mean of controlling A. *fulica* while 15% used metaldehyde bait to combat these herbivorous snails (Fig. 7l). With reference to the geographic origin of *A. fulica*, 90% of the respondents indicated that they were unaware of the area from which this species originated. (Fig 7d).

Only 2% of the sampled population indicated that they had seen the snail on the island from as early as 1999, while 52% became aware of the snail's existence in 2005 (Fig 7e). The results also indicated that most residents (44%) shared a view that the snail was introduced through the importation of plants (Fig. 7c). In terms of eradication of the mollusc, 50% of the respondents stated that the Government of Anguilla should take measures to eradicate *A. fulica*, while 37% believed that the authorities should resort to using chemicals as a means of controlling them (Fig.7f). Only 2% of the respondents were supportive of the idea of using the snail as a source of food.

Data from the questionnaire also indicated that 50% of the respondents believed that a special task force should be created to combat *A. fulica*, while 35% were of the opinion that it is the responsibility of the Department of Agriculture (Fig.7g). In relation to the question about the *A . fulica* as a potential disease carrier, 46% of the respondents stated that they were aware that the mollusc may be a risk to their health (Fig. 7h).

Interestingly, the questionnaire also revealed that most of the respondents (78%) were not only willing to actively participate in an eradication programme, but were also willing to make a financial contribution (83%) towards the eradication of *A. fulica* (Figs. 7i and 7j). To examine this further, I performed a 2x2 chi square test to ascertain whether the respondents' willingness to physically participate in an eradication programme were influenced by them having snails in their yard. The results, χ square = -0.03, p=1 shows that there is no significant relationship between respondents willingness to participate in an eradication programme and having/not having *A. fulica* in their yards. Again, this same test was performed to evaluate whether the respondents willingness to pay a contribution towards eradication of the mollusc were related to them having/not having the snail in their yard. The results, χ square = -0.02, p = 1, shows that there is no difference between persons willingness to pay and the presence or absence of snails in their yard. As to the issue of who held the ultimate responsibility for eradication of the snails, the results indicated that the prevailing view was that it was the responsibility of all stakeholders (Fig. 7k).

Discussion

This study has indicated that *Achitina fulica* has successfully manifested and established itself within Anguilla's ecological community. With the exception of the villages to the eastern end of the island (Fig. 1), this introduced mollusc has invaded all other communities throughout the island. It must be noted, however, that during the search for study sites the distribution of *A.fulica* seems somewhat sporadic within the villages. The landscape that was modified had a tendency to be affiliated with an abundance of the snails, while the more undisturbed areas were free of the introduced mollusc. This suggests that *A.fulica* has a high affinity towards modified habitats. Although With (2002) states that satellite population of newly invasive species is common, this observation has been documented in several other studies on the invasive mollusc, which showed that *A. fulica* was more prevalent in anthropogenic and disturbed habitats such as gardens, roadsides, wastelands (Cowie, 1998; Meyers and Picot 2001; Raut and Barker, 2002).

The trend and rapid dispersal of *A. fulica* on Anguilla is of great interest. Tomiyama and Nikane (1993) in their radio transmitter experiment to monitor the movement of the species observed that the snails moved in a straight line and that their movement is within limited areas. Perhaps this is the reason why the adjoining villages in the island are gradually being infested with these invasive snails. Singh (1980) also observed a similar pattern of movement in his study of *A. fulica* in the Bihar States. Another striking point about the migration of these snails is that they seem to be following a westward movement throughout the island. This pattern of movement is quite interesting as most of the tourism related facilities, which employ a significant amount of Anguilla's labour force, are located on the western end of the island. This movement may suggest humans are aiding in the dispersal of *A. fulica* (most likely attached to their vehicles). Kierans et al (2005) observed a similar pattern of dispersal with their study on another invasive mollusc.

The abundance of *A. fulica* on the study sites, although not surprising, is also of great concern to conservation managers and residents on Anguilla, as it indicates the high level of fecundity and easy dispersal that is often associated with these pestiferous snails (Raut and Barker, 2002). Meyers and Picot (2001) states that the snails have reached extremely high densities and biomass (up to 770kg/ha) in New Caledonia. Similarly, the Caribbean island of Martinique has experienced the rapid spread of *A. fulica*, as its infested area grew from 90 to 310 hectares within one year (Civeyrell and Simberloff, 1996). By contrast, the sampled village of South Hill recorded the highest density of live snails ($0.66m^2$). Therefore, with the average weight of *A. fulica* listed by the GISP at 32g, this suggests that Anguilla's *A.fulica* population is likely to be 221 kg/ha.

This study also revealed that there were variations in the number of *A. fulica* among the sampled villages, habitat types, and microhabitats (Fig. 2; Fig. 8a,b,c). As illustrated in the results, I expected Stoney Ground to have a higher biomass of the mollusc. My rationale for this statement is based on reports from the Department of Agriculture that the first known specimens of *A fulica* were documented in that village (Christopher, 2006 as per. Comm.). This suggests that *A.fulica's* biomass in each of the sampled villages may be related to the time of its initial invasion. In terms of *A. fulica*'s microhabitat, the abundance of snails on the vegetation suggests that most of the mollusc were foraging during the time the study was conducted; therefore, this study suggests that assessing *A.fulica's* microhabitat may be dependent on time of sampling.

With reference to habitat association of *A. fulica*, I expected to see higher density within the woodland habitats, as the snails have a preference for dense vegetation (Thangavelu and Singh, 1983; Craze and Mauremotoo, 2002). That the results showed higher densities were associated with shublands and grasslands (Fig. 8b,c) suggests that the low biomass in woodland may be due to *A. fulica*'s recent colonisation of this type of habitat. Alternatively, the study revealed that apart from physically being on the vegetation, most specimens of the mollusc were located in the leaf litter, which is another common microhabitat of this species (Craze and Mauremotoo, 2002; Prasad, 2004). This indicates that *A. fulica* may have a preference for this type of environment.

The data also revealed that there are a high percentage of dead *A. fulica* (66%) in Anguilla's sampled population. Most literature states the *A. fulica*'s population reaches high densities and then the population drastically declines (Civeyrell and Simberloff, 1996; Meyers and Picot, 2001; Craze and Mauremooto, 2002; Gervin, 2005). As mentioned by Cowie (1998) and Gerlach (2001), this phenomenon (mortality rate) seems to be a common trend on islands that *A. fulica* had invaded. Other sources have suggested that this drastic decline may be associated with epizootic diseases and lesions (Mead, 1961; Mead and Palcy, 1992), lack of genetic diversity (Civeyell and Simberloff 1996) and the species reaching its carrying capacity (Simberloff and Gibbons 2004). Certainly, the death of the snails at the study sites is not associated with the metaldehyde-baiting programme that was initiated by the Agriculture Department, as those areas were not treated.

Interestingly, Mead (1961) argues that the radiation from the sun also plays a role in dehydrating and subsequently killing *A. fulica*. In this study, I observed that the highest density of empty shells of this mollusc was mainly distributed throughout the grassland habitats that were sampled. Therefore, I postulate that with reference to the three topographical structures under investigation, the sun was better able to penetrate the thin grasslands, thereby causing a higher percentage of snails to die in this habitat. Apart from this, I observed that a high density of dead *A. fulica* was recorded in the grasslands in George Hill (Fig. 8c). Coincidentally, the said area is low lying and was observed flooded on two occasions during the study. Since it takes less that 12 hours for mollusc to drown, I postulate that the high number of snails found dead in this grassland habitat may have been influenced by flooding. It is interesting to note that one beneficiary of the invasive snail is the Caribbean Hermit Crab (*Coenobita clypeatus*), as it has been observed utilizing the shells of *A.fulica* on several occasions during the study (see appendix 2). Sant'Anna et al. (2005) have reported a similar pattern of behaviour in *A. fulica* infested Brazil.

With regards to the other species of mollusc found in Anguilla, I observed that it was very rare to find live specimens in the sampled quadrats. Some invasive organisms are known to have deleterious effects on endemic species (Gurevitch and Padilla, 2004). For example, the mud snail (*Ilyanassa obsoleta)* has been known to cause niche displacement on other species of snails (Mooney 2001) while the rosy wolf snail (*Euglandina rosea)* has been associated with the extinction of Hawaii's endemic snails (Cowie, 1998; Gerlarch, 2001; Simberloof, 2003). Although *A. fulica* is not associated with carnivorous activities, its vigorous and aggressive behaviour is associated with competition and even replacement of native snail species (Craze and Mauremootoo, 2002; Mead and Palcy, 2002). This suggests that the invasive *A. fulica* has potential implications for Anguilla's native malacofauna. However, since the population data of the island's snails are not available this warrants further research.

Results from the household survey indicate that the invasion of *A. fulica* in Anguilla is posing a major challenge to residents and authorities. On several occasions during the study residents were observed removing, baiting, and in some instances burning shrubs from their surroundings to destroy these pestiferous snails (see appendix 3). Most residents resort to salt as a means of controlling the invasive mollusc, but they also believe that the snail bait would be the most effective method of management. Thangavelu and Singh (1993) states that a combination of both methods was most effective in the management of the polyphagous snails. However, the residents and the authorities must be cautioned that most molluscicides are not host specific, (Panigrahi and Raut, 2002; Prasad et al., 2004; Gervin, 2005) and therefore have the potential to implicate other molluscs or non- target species.

The survey also indicated that most residents did not view hand picking and destroying the snails as a viable and practical method of control. Gerlach (2001) argues that manual collection of *A. fulica* in the Seychelles (a particular area) was followed by a 98.3% decline of the said species. Similarly, other sources (Mead, 1961; Raut and Barker, 2002) also reported that some populations of *A.fulica* almost reached to the point of local extinction when this practice was initiated. Although manual collection is quite a tedious and laborious task, and may be more effective with small and incipient populations of *A. fulica*, authorities in Anguilla may want to consider this option as a means of managing and controlling the spread of the invasive mollusc.

Further, the study also revealed that residents on the island of Anguilla are eager to launch a collaborative effort to combat, and subsequently eradicate *A. fulica*. However, it is well known that the longevity of such willingness and enthusiasm expressed by volunteers is short lived. Mead (1961) states that in Southern China, residents were given free bait by the authorities to help control the prolific dispersal of *A.fulica,* but the authorities had to subsequently halt the programme after some residents expressed their views that it was the government's responsibility for controlling the snails. Interestingly, although the respondents indicated a strong sense of willingness for collaboration with the authorities, similar attitudes and sentiments have been expressed throughout the Anguillian community. This suggests that the authorities should be cautious when distributing mollusc bait, and soliciting the help of the wider community.

It is well established that *A. fulica* is an agricultural and horticultural pest (Thaguvelu and Singh, 1983; Prasad, 2004; Gervin, 2005). Therefore, it is not surprising to note that most respondents have suffered significant damage to their crops/plants. However, a potential concern for conservation managers is the likely impact *A. fulica* will have on Anguilla's only endemic plant *(Rondeletia anguillensis*). Sharp spines and small leaves characterize this small stiff shrub-like plant, which is mainly distributed in the northern and eastern end of the island (Walker et al.2005). It is interesting to note that the molluscs are already present in one of the villages (North Side) where this plant is found. Although the snails have not spread to *R. anguillensis* habitat (limestone holes) in the said village, the mollusc has been sampled in the woodlands of South Hill, which is a similar habitat of this plant, and has been observed foraging on similar plant with thorns. This suggests that *A. fulica* has the potential to invade and possibly threaten *R. anguillensis'* ecological community. Perhaps conservation managers in Anguilla may want to know that the authorities in La Reunion Island and Ile Aux Aigrettes have already taken protective and eradicative measures to safeguard their rare and endemic plants from *A. fulica* (Meyers and Picot, 2001; Craze and Mauremootoo, 2002). However, the likely impact of *A. fulica* on Anguilla's endemic plant remains speculative, and therefore warrants further research.

This survey indicates that invasive species can have serious implications for both biological ecosystems and its inhabitants. It also indicates that *Achatina fulica* has spread throughout the various topographical features within Anguilla. Additionally, with its high rate of recruitment, compounded by the absence of its usual competitors, predators and other associates, *A. fulica*'s population is not only capable of sustaining itself, but it is also destined to manifest itself throughout the entire island within a relatively short period. The study also demonstrated that feedback from the public is an integral "tool" when addressing ways of managing and controlling invasive species, and also indicated that the residents throughout the island are not only concerned, but are willing to collaborate with the authorities and play their role in controlling the introduced mollusc. Additionally, since this is the first known malacofauna study to be conducted on the island, the information gathered in this study will be beneficial to any individual who wants to investigate invasive species and other studies on the terrestrial snails of Anguilla and the Caribbean Region. Most importantly, however, this study provides decision makers on the island with empirical data to help them facilitate strategic plans when addressing the issue of the invasive *Achatina fulica*.

Conclusion and Recommendations

This study has shown that *A. fulica* has rapidly dispersed throughout the Caribbean island of Anguilla, and is likely to have serious implications for the island's environmental managers. It is obvious that *A. fulica*'s population is well established throughout the island, and the initial phase of its containment has been greatly missed. Therefore any thoughts of eradicating this invasive mollusc are most likely to be futile. This is based on reports that although Florida (USA) and Queensland (Australia) have successfully eradicated *Achatina fulica*, all others attempts throughout the Pacific have completely failed. Thus, the authorities on the island should focus on public awareness and education, and devise strategies to manage and control *A. fulica*'s population. This in itself is quite a major task, but proactive, practical and effective strategies must be implemented urgently. It's important to note that both mechanical and chemical means of controlling this species have been effective in the past, but they are associated with high costs. Certainly, whatever means of control the authorities initiate, they must be cautioned against the introduction of biological controls or predatory snails. This method has been associated with the extinction of many endemic snails in Hawaii and The Society Islands. It should be noted however that the authorities in the island of Anguilla must now review and upgrade existing legislation on the importation of goods entering the territory. The introduction of strict quarantine measures must also be implemented and enforced to prevent other forms of invasive species from entering the island.

Acknowledgements

I wish to thank my supervisor Dr. Tom Tregenza for his feedback and guidance with this project; to my mentor Dr. Floyd Homer (Conservation Biodiversity Inc.) who provided valuable suggestions for the manuscript. Special appreciation also goes to Farah Mukhida of the Anguilla National Trust who willingly assisted with the data entry and offered suggestions for the study. Also thank you to Antonio Christopher and William Vanterpool of the Department of Agriculture, Karim Hodge of the Department of the Environment, Oliver Hodge of the Environmental Health Unit, and Guy Mathurin (St. Lucia Ministry of Agriculture) for their resources and valuable information towards this project. My appreciation is also extended to my wife Jackie Connor, Doyle Hughes, Asif Niles, and Alan Mills for their contributions. I am particularly thankful to Dr. David Robinson (USDA APHIS) who identified the snail species found in the study. A special thank you to all the respondents who willingly took part in the survey, and most importantly my gratitude is extended to the Overseas Territories Environmental Programme (OTEP) and the Government of Anguilla for their funding of my studentship…for without them this project would not have been possible.

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Figure legends

Figure 1: Map showing the distribution of the Giant African Snails in Anguilla before and after March 2006.

Figure 2: Density (per m2) of Live and Dead *A. fulica* at each survey site.

Figure 3: Mean Number (se) of live/dead snails per quadrat according to habitat type (N=40 quadrats per habitat type)

Figure 4: The number of live *A.fulica* according to micro habitat/physical location

Figure 5: Specimens of Anguillas terrestrial malacofauna.

Figure 6: Specimen of another invasive species of snail found in Anguilla.

Figure 7: Graphs showing respondents views in relation to *A. fulica (Figures a-l)*

Figure 8: Graphs showing the mean density (snails m^{-2}) of dead snails from 40 (4m^{2} quadrats/habitats) in relation to its habitats within each village; and the mean density of snails on wet and dry days.

Table 1: Table showing the villages and number of species of other snails from sampled sites.

Table 2: Density of Giant African Snails (based on all survey sites) compared to densities of other snail species (also found within the survey sites).

Appendix

1 Giant African Snail Questionnaire
2 Hermit Crab using *A. fulica* shell
3 *A. fulica shells collected by a resident*

Figure 1

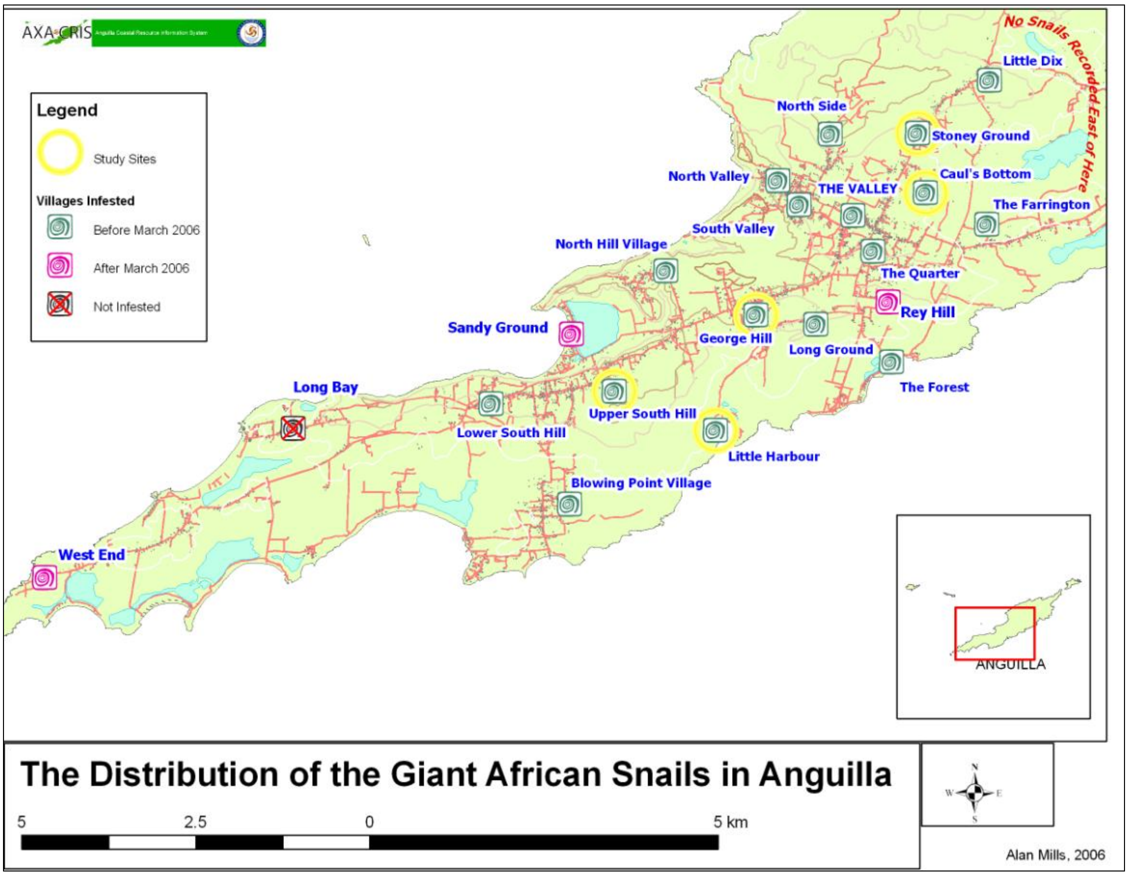
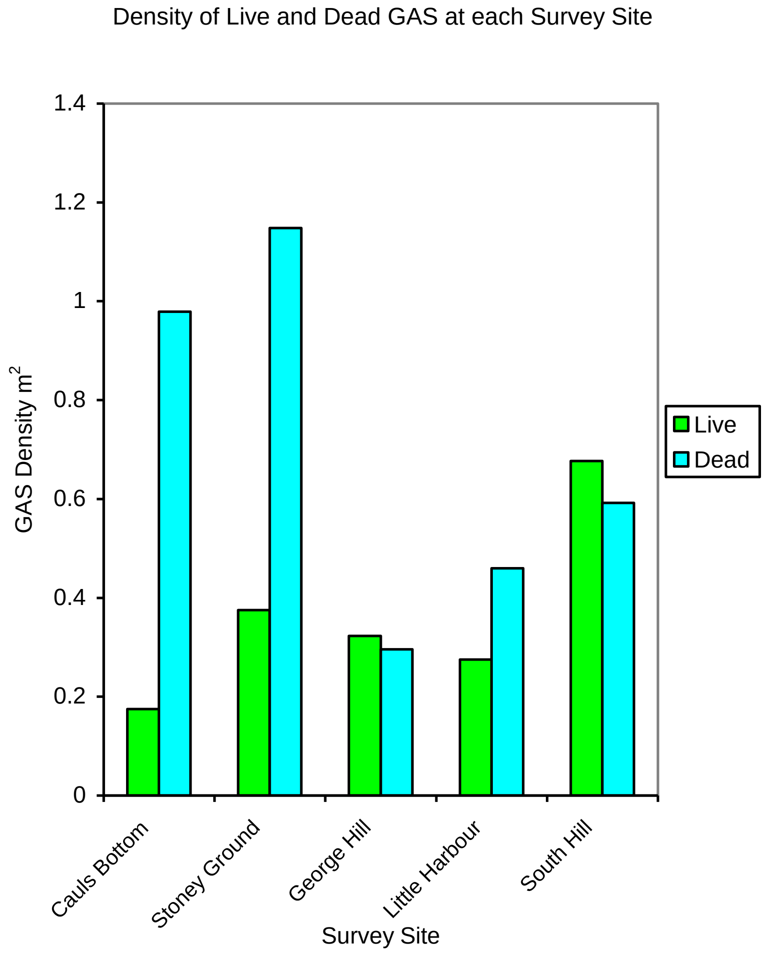
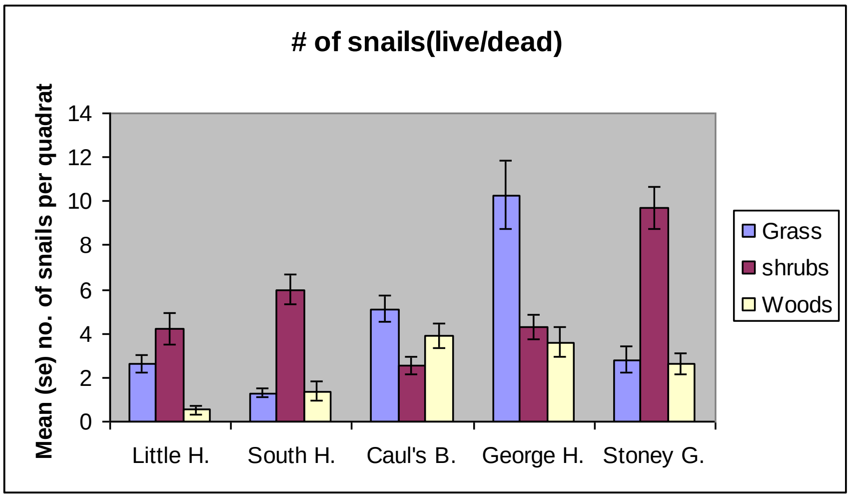

AXA-CRIS
Legend
Study Sites
Villages Infested
Before March 2006
After March 2006
Not Infested
No Snails Recorded East of Here
Little Dix
North Side
Stoney Ground
Caul's Bottom
North Valley
THE VALLEY
The Farrington
South Valley
North Hill Village
The Quarter
Rey Hill
Sandy Ground
George Hill
Long Ground
The Forest
Long Bay
Upper South Hill
Lower South Hill
Little Harbour
Blowing Point Village
West End
ANGUILLA
The Distribution of the Giant African Snails in Anguilla
5
2.5
0
5 km
N
W
E
S
Alan Mills, 2006

Figure 2



Density of Live and Dead GAS at each Survey Site
GAS Density m2
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Cauls Bottom
Stoney Ground
George Hill
Little Harbour
South Hill
Survey Site
Live
Dead

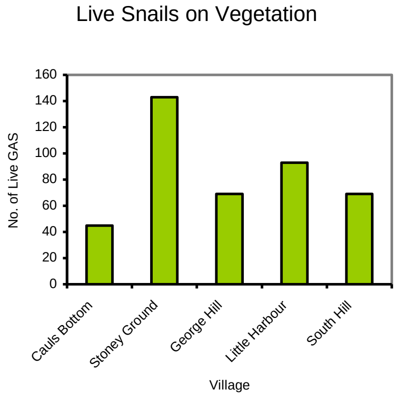
Figure 3



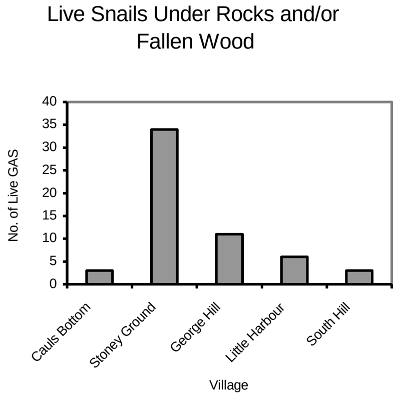
# of snails(live/dead)
Mean (se) no. of snails per quadrat
0
2
4
6
8
10
12
14
Little H.
South H.
Caul's B.
George H.
Stoney G.
Grass
shrubs
Woods

Figure 4

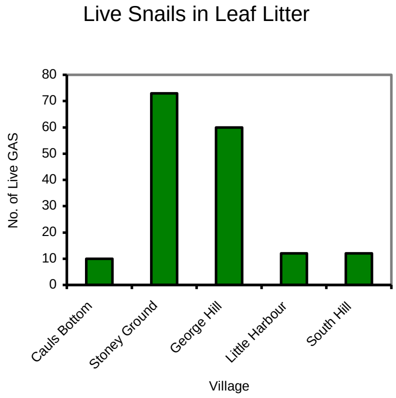
a) On vegetation



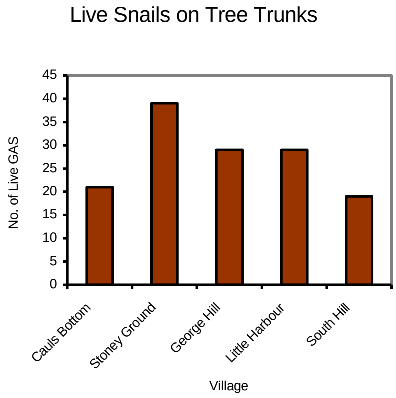
b) Under rocks and/or fallen wood



c) In leaf litter



d) on tree trunks



e) On rocks and/or stony ground.

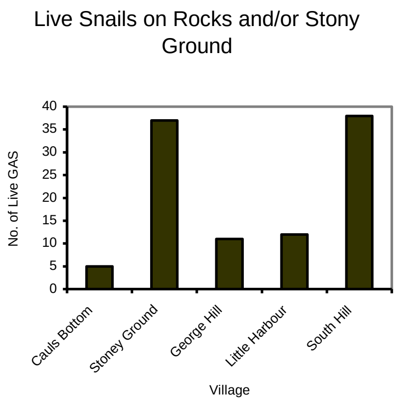


Figure 5:

a); *Drymaeus* species- *D. virgulatus* (family *Bulimulida*e)

b)*Bulimulus guadalupensis* (family *Bulimulidae)*

c) Chondropoma (Chondropomorus) (family *Annulariidae/Licinidae*;

d) *Macroceramus* (family *Urocoptidae*)

e) *Drymaeus* Species- (family *Bulimulidae*)

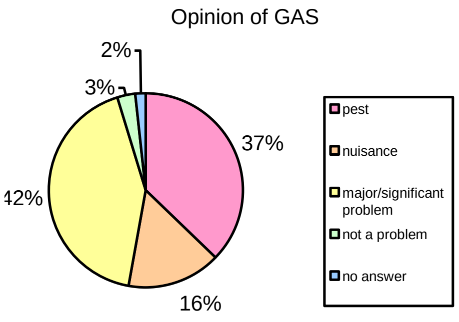
f) Species *Subulinidae*

Figure 6

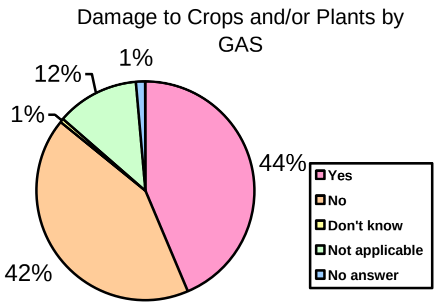
Z. auricoma havenensis (family *Pleurodontidae)*

Figure 7

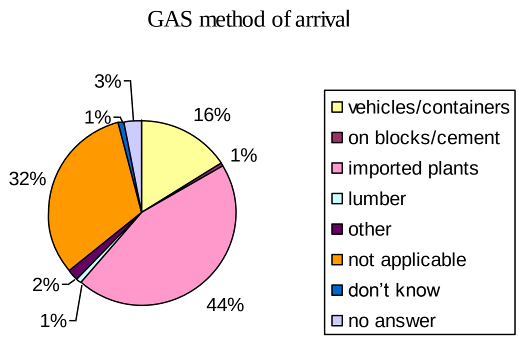
a



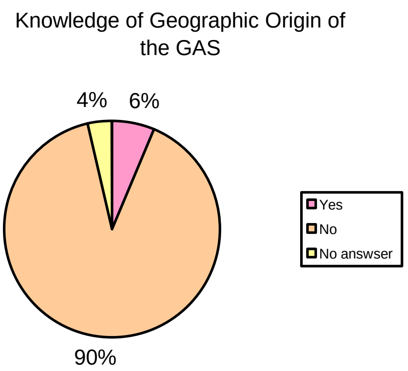
b



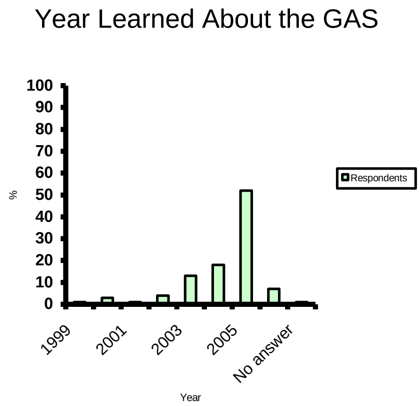
c



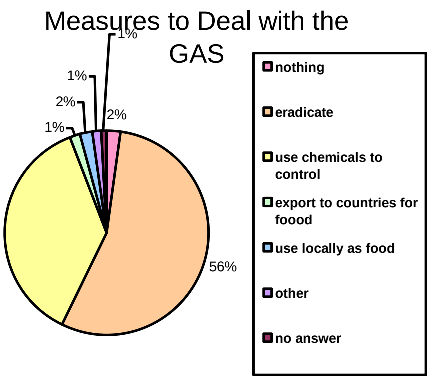
d



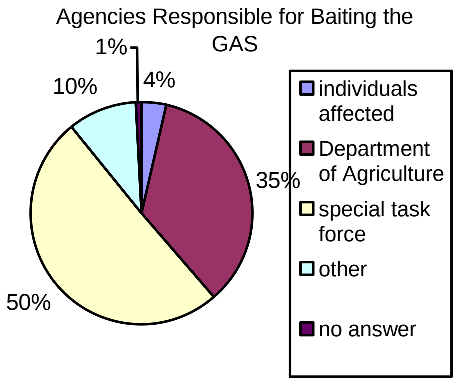
e



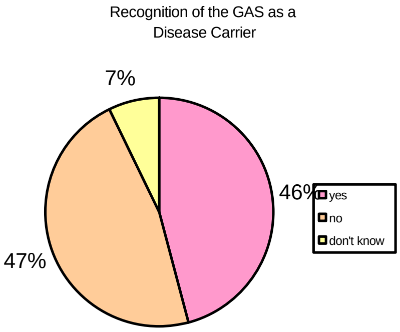
f



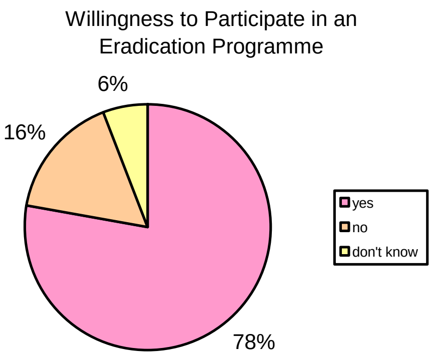
g


Agencies Responsible for Baiting the GAS
1%
4%
10%
35%
50%
individuals affected
Department of Agriculture
special task force
other
no answer

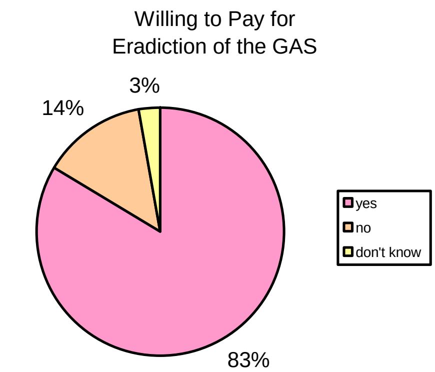
h


Recognition of the GAS as a Disease Carrier
7%
46%
47%
yes
no
don't know

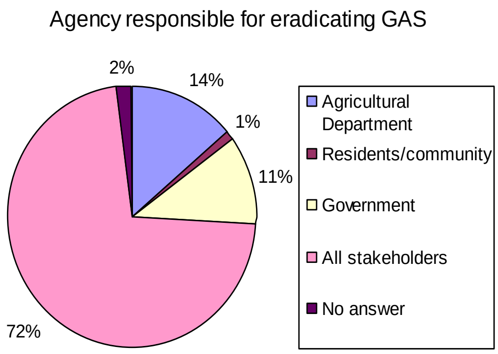
i


Willingness to Participate in an Eradication Programme
6%
16%
78%
yes
no
don't know

j


Willing to Pay for Eradiction of the GAS
3%
14%
83%
yes
no
don't know

k


Agency responsible for eradicating GAS
2%
14%
1%
11%
72%
Agricultural Department
Residents/community
Government
All stakeholders
No answer

l

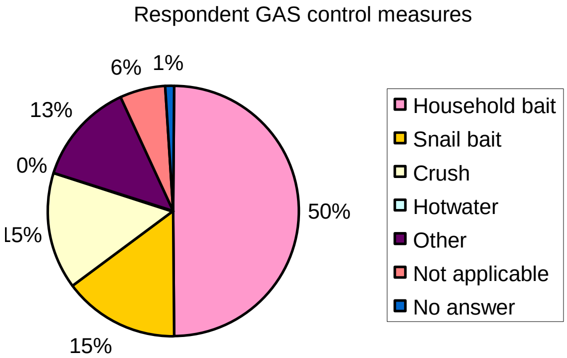
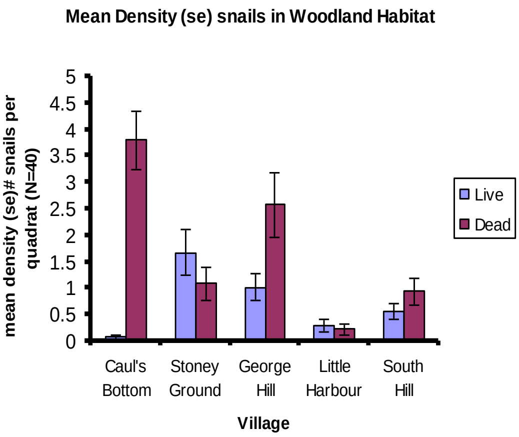
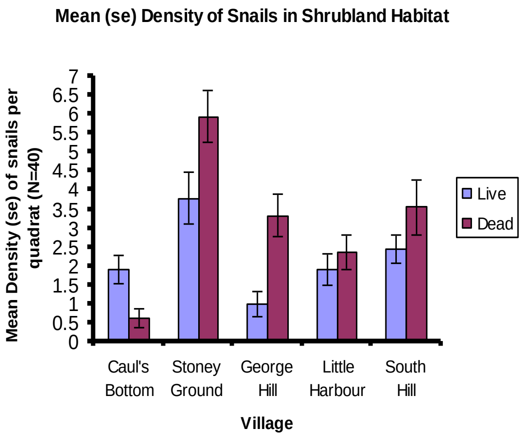

Respondent GAS control measures
6%
1%
13%
0%
15%
50%
15%
Household bait
Snail bait
Crush
Hotwater
Other
Not applicable
No answer

Figure 8

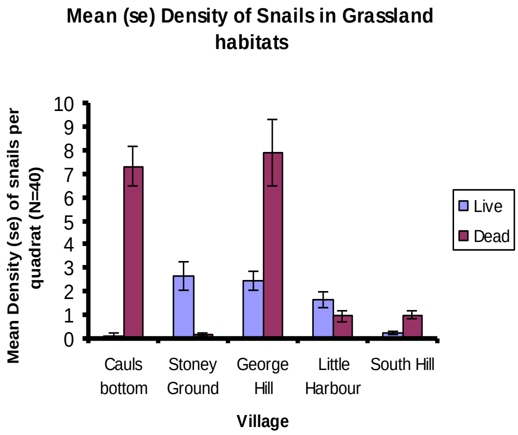
a)



b)



c)



d)

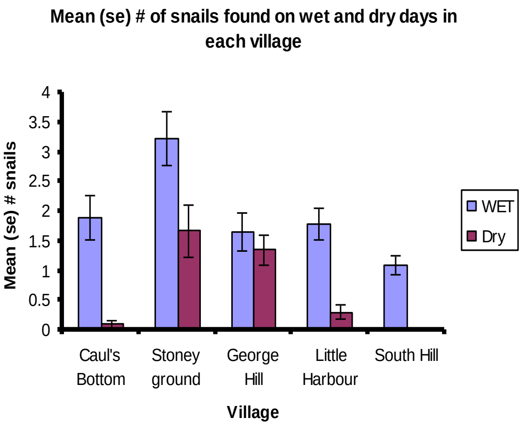


Table 1:

Species	Cauls Bottom	Stoney Ground	George Hill	Little Harbour	South Hill
Drymaeus species- *D. virgulatus* (family *Bulimulida*e)	304	1284	1204	1097	209
Bulimulus guadalupensis (family *Bulimulidae)*	2	0	55	54	3
Chondropoma (Chondropomorus) Family *annulariidae/Licinidae*	107	67	264	400	67
Macroceramus (family *Urocoptidae*)	0	0	47	171	0
Drymaeus Species- (family *Bulimulidae*) (striped)	0	0	0	11	0
Species *Subulinidae*	0	0	0	3	0
Total individuals	**413**	**1351**	**1570**	**1736**	**288**
Total species	**3**	**2**	**4**	**6**	**3**

Table 2

Snail Species	Density
Drymaeus species- *D. virgulatus* (family *Bulimulida*e)	1.708
Bulimulus guadalupensis (family *Bulimulidae)*	0.0475
Chondropoma (Chondropomorus) Family *annulariidae/Licinidae*	0.381
Macroceramus (family *Urocoptidae*)	0.091
Drymaeus Species- (family *Bulimulidae*) (striped)	0.00458
Species *Subulinidae*	0.00125
Giant African Snail	1.0575

Appendix 1

Giant African Snail Questionnaire

Village ________________

Gender: Male ___ Female ___

Age group: 18-25; 26-40: 41-55: 56-70: 70+

How long have you lived in this area?

Less than one year, 1-2 years 3-4 years Over 4 years

Are there Giant African Snails (GAS) within 100 m of this area? Y / N (**if no Q 4**)

Do you find GAS in your yard? Yes / No (**if yes Q 5**)

Are you worried that the GAS will invade your premises? Yes / No (**skip 5 go to 6**)

Approx. how many do you find in your yard at any given time (with dew / rain)?

Less than 50 50 – 100 100-150 150-200 over 200

Do you think that the population of GAS is **Increasing** or **decreasing**?

Which of the following best describes your opinion of the GAS?

A pest a nuisance a major/significant problem its not a problem

If the GAS has caused you financial losses, which of the following estimates (USD)best describes your loss within the past year?

under $50 50-100 100-150 150-200 over 200

What measures do you take to control it?

Household salt snail bait crush them use of hot water other

Does the GAS cause significant damage to your crops/plants? Yes / No / Don’t know

What type of plants are mostly affected? Horticultural / Agricultural /Both

Do you know the geographic origin of the snails? Yes / No

How did you first learn of the invasion of the GAS?

Agricultural Dept. Anguilla Nat’t Trust Family/friend other

Around what year you first heard of these snails in Anguilla?

’99 ’01 ’02 ’03 ’04 ’05 06

Do you think that they (GAS) were intentionally brought to Anguilla? Yes / No / don’t know (don’t know Q17)
If yes, for what purpose? Food, Pets, Attractions, other
If no, which of these methods mostly assist in their arrival?
attached to vehicles/containers; on blocks/cement; imported plants, lumber, other

What measures do you think should be taken to deal with the GAS?
Nothing (allow them to remain in isle): eradicate them; use chemicals to control them: export them to countries (food): use them as source of food (locally).

Have you seen them in other neighbouring islands? Yes / No

Have your area been treated (baited) by the Agriculture department? Yes / No / Don't know

Do you believe that the chemical is effective? Yes No Don't Know

Do you believe that the authorities are doing enough to educate the public about the GAS? Yes / No / Don't know

Do you believe that the authorities are doing enough to educate the public about the GAS? Yes / No / Don't know

Were you given clear guidelines about how to handle the GAS ? Yes / No

Who do you believe is responsible for the baiting of snails?

Individuals affected; Agri. Department; Special task force other

Who is responsible for the eradication of these snails?

Agri. Dept. Residents/Community Government All Stakeholders

Which of these measures do you believe is the most effective in controlling the GAS?

Handpicking and destroying using cooking salt use of snail bait other methods

Which of the following agencies have you reported sightings of the GAS?

Agri. Dept. Env. Dept. Anguilla National Trust None (did not report it)

Do you know the GAS can carry a potentially serious human disease?

Yes / No / Don’t Know

Will you be willing to participate in an eradication programme? Yes / No / Don’t Know

Will you be willing to pay a fee towards the eradiction of the GAS? Yes/No/Don’t Know