Research Article

Exotic gastropods for sale: an assessment of land and aquatic snails in the South African pet trade

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Abstract

Gastropods are amongst the most popular of the Mollusca in the pet trade, with globalisation being the main contributing factor facilitating their establishment globally. Although it is known that gastropods are kept as pets in South Africa, relatively little has been documented on the trade for this group. Physical pet stores selling gastropod species were surveyed seasonally in South Africa, aiming to determine 1) the types of species sold, including their trade popularity, trade volume, and the biogeographic realms they originated from, and 2) seasonal variations in gastropod species traded. Six gastropod species were recorded in the South African pet stores with three known invasives (*Achatina fulica*, *A. immaculata*, and *Pomacea canaliculata*). Of these species, the African giant snail *A. fulica* and the channeled golden apple snail *P. canaliculata* were the species with higher trade popularity throughout the year. The trade of the other species fluctuated with seasons among pet stores and provinces. Gastropod species sampled in this study originated from four biogeographic realms, with two species from the Afrotropical and Neotropical realms, and one each from the Indomalayan and the Palaearctic. The number of gastropod individuals observed in this study was relatively large; as a result, they may pose a potential risk of invasion should they be released or escape captivity. The pet trade industry at a national level needs to be regularly monitored and the policies on selling invasive non-native species should be implemented to avoid the introduction and establishment of potential invaders.

Key words: invasive species, management, ornamental trade, policy implementation, Republic of South Africa

Introduction

Gastropods are amongst the most popular of the Mollusca taxa in the pet trade globally (Ng et al. 2016a; Darrigran et al. 2020; Yanygina 2020). Globalisation has been the main contributor to the introduction of the gastropod species through the pet trade and has facilitated their movement both intra and intercontinentally (Patoka et al. 2017; Yanai et al. 2017). Gastropods have also been associated with ornamentation (Barker 2001), biological control of pests (Cowie 2001), medicinal values (Thiengo et al. 2007), and used for food (often referred to as escargot) in restaurants in many countries, including Israel (Bar 1977), Australia (Ab Lah et al. 2017),...
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various South American countries (Darrigran et al. 2020) and Spain (Serrano et al. 2004). These are some of the factors that have facilitated the increased demand for gastropod species around the world (Yanai et al. 2017). Online and physical pet stores have been the mode of trade for gastropods species (Gong et al. 2009; Ng et al. 2016a, b; Yanai et al. 2017; Yanygina 2020). They are also offered for sale in both indoor tanks and outdoor ponds (Patoka et al. 2016a).

Although most of these gastropods remain in captivity, many individuals are intentionally released or accidentally escape confinement (Joshi 2007; Martin et al. 2012). For example, the African giant snail *Achatina fulica* (Férussac, 1821) established self-sustaining populations in Brazil because of pet release (Thiengo et al. 2007). Its impact has been associated with damage to ca. 28 plant species through flower and leaf consumption (Thiengo et al. 2007; Sarma et al. 2015). This species and the channeled apple snail *Pomacea canaliculata* (Lamarck, 1822) have also been implicated in an outbreak of Eosinophilic meningitis which is detrimental to human and animal health in various countries (Tsai et al. 2001; Lv et al. 2009a; Thiengo et al. 2010). Lowe et al. (2000) considered three gastropod species, including one aquatic snail *P. canaliculata* and two land snails, *A. fulica* and the rosy wolf snail *Euglandina rosea* (Férussac, 1821) amongst the 100 worst invasive species in the world.

Several management programs have been implemented aiming to eradicate invasive gastropods introduced through the pet trade, including the island apple snail *Pomacea insularum* (Orbigny, 1835) in Alabama, USA (Martin et al. 2012). However, the sale of these and other gastropod species remains questionable with large quantities traded across the globe, e.g. Singapore (Ng et al. 2016a, b), North America (Bogan and Hanneman 2013), Pakistan (Baloch et al. 2012), Netherlands (Soes et al. 2011), and in South Africa (Picker and Griffiths 2013). Although some gastropod species have been reported as being traded elsewhere (Ng et al. 2016a, b; Yanygina et al. 2019) in South Africa relatively little has been documented on the sale of these taxa in the pet trade (Appleton 2003; Nelufule et al. 2020).

In South Africa, the National Environmental Management: Biodiversity Act (NEMBA) aims at preventing the introduction of non-native invasive species which can be harmful to biodiversity (NEMBA 2016). This law prohibits, for example, the sale of *A. fulica* in the country. Despite this, the African giant snail *A. fulica*, is reportedly traded and kept as pets (Nelufule et al. 2020). The trade volume of gastropods is largely understudied, and the factors that determine their trade popularity are not known. In this study, physical pet stores were surveyed seasonally across South Africa aiming to determine 1) which gastropod species were sold in the South African pet trade, including their trade popularity, trade volume, and the biogeographical realms from which these species originated, and 2) the seasonal variation of gastropod species traded. Assessment of gastropods in
the pet trade is pivotal in highlighting those species with a high risk of becoming invasive should they be released or escape captivity.

Materials and methods

Study areas

In this study, sampling was conducted in physical pet and aquarium stores (defined as those stores selling varieties of live species that one could visit directly and purchase as a pet) around South Africa (Figure 1). The settings of pet stores were mainly around the shopping centres in urban landscapes and peri-urban populated areas (Figure 1). In total, 117 pet stores selling, or advertising different pet gastropods were surveyed. Most of these pet stores were found online through Google maps with the rest from the South African Pet Traders Association website (SAPTA: http://www.sapettraders.co.za/membership-2016/).

Data sampling

The physical pet stores in the provinces of South Africa were visited four times seasonally to monitor gastropod species available for sale. The study was conducted from September 2018 until September 2019, covering the austral spring, summer, autumn, and winter. The number of individuals of
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Figure 2. Examples of gastropod species, a – channeled golden apple snail *Pomacea canaliculata*, b – assassin snail *Clea helena* (Busch, 1847), c – African giant snail *Achatina fulica*, and d – land snail *Achatina immaculata* (Lamarck, 1822) advertised for sale in the South African pet trade during the present study. Photos by TC Shivambu.

Each species and their prices were recorded. The term “trade popularity” used was defined as the number of times that each species was sampled in a particular pet store. The number of individuals of each species was recorded following previous studies indicating that the number of introduced species for sale is related to propagule pressure (Kikillus et al. 2012; Lockwood et al. 2019). The species-specific price per individual is also an important factor as it has been reported as one of the contributing factors affecting propagule pressure (Dehnen-Schmutz et al. 2007; Lockwood et al. 2019). The provided names for each gastropod sold were verified using the Global Biodiversity Information Facility (GBIF Secretariat 2020) and the Integrated Taxonomic Information System (ITIS: www.itis.gov). We are aware of identification issues associated with cryptic species such as apple snails (Ramachandra Rao et al. 2018). For this study, identification was based on morphological characteristics of gastropods. Pet stores owners who are expert breeders were asked to provide the identity of each gastropod species they sell. The photographs for each gastropod were also taken (Figure 2) and identified using books and online platforms to verify the identity of each species (Mackie and Claudi 2000; Picker and Griffiths 2013; ADW 2020; GBIF Secretariat 2020; https://www.applesnail.net/; https://idtools.org/id/mollusc/index.php).

Statistical analyses

All statistical analyses were performed using R (version 3.6.1, R Core Team 2018) and Past (version 3.14, Hammer et al. 2001). Species trade popularity
Table 1. Mean (± SD) number of individuals of the respective gastropod species sold seasonally in the physical pet stores sampled from September 2018 to September 2019. (Different symbols indicate species status – * invasive, ∆ non-native, and ⸸⸸ protected species. The native ranges are included in terms of continents as their range covers most of the countries within the continent).

<table>
<thead>
<tr>
<th>Species</th>
<th>Common names</th>
<th>Native range</th>
<th>Biogeographic realms</th>
<th>Terrestrial/ Freshwater</th>
<th>Number of pet stores (n)</th>
<th>Mean (± SD) no. of individuals of each species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achatina fulica *</td>
<td>Giant African snail</td>
<td>Africa</td>
<td>Afrotropical</td>
<td>Terrestrial</td>
<td>50</td>
<td>7 ± 29 15 ± 29 16 ± 29 12 ± 28</td>
</tr>
<tr>
<td>Achatina immaculata *</td>
<td>Giant snail</td>
<td>Africa</td>
<td>Afrotropical</td>
<td>Terrestrial</td>
<td>30</td>
<td>6 ± 8 14 ± 8 6 ± 8 4 ± 8</td>
</tr>
<tr>
<td>Clea helena ∆</td>
<td>Assassin snail</td>
<td>Asia</td>
<td>Indomalayan</td>
<td>Freshwater</td>
<td>72</td>
<td>9 ± 48 13 ± 11 4 ± 8 5 ± 8</td>
</tr>
<tr>
<td>Helix pomatia †</td>
<td>Burgundy snail</td>
<td>Europe</td>
<td>Palaearctic</td>
<td>Terrestrial</td>
<td>44</td>
<td>5 ± 14 19 ± 11 5 ± 16 4 ± 9</td>
</tr>
<tr>
<td>Pomacea diffusa ∆</td>
<td>Spiked-top apple snail</td>
<td>South America</td>
<td>Neotropical</td>
<td>Freshwater</td>
<td>80</td>
<td>9 ± 20 19 ± 13 6 ± 12 4 ± 15</td>
</tr>
<tr>
<td>Pomacea canaliculata *</td>
<td>Channeled golden apple snail</td>
<td>South America</td>
<td>Neotropical</td>
<td>Freshwater</td>
<td>74</td>
<td>8 ± 14 15 ± 12 7 ± 10 4 ± 11</td>
</tr>
</tbody>
</table>

among the physical pet stores and the accumulated numbers of gastropod species per season were determined. This was later calculated and represented as the mean and standard deviation (± SD). The mean number of individuals per gastropod species sampled per season for each Province of South Africa was also computed using R. Repeated Measures Analysis of Variance (RMANOVA) was used to determine if there were seasonal variations in the trade of the gastropod species. In this study, the accumulated seasonal trade popularity index obtained from physical pet stores with species biogeographical realms were compared.

Results

Six gastropod species were recorded in 80 pet stores in South Africa. Of these species, three were invasive species (*Achatina fulica*, *A. immaculata* (Lamarck, 1822), and *Pomacea canaliculata*), two were non-native (*Clea helena* (Busch, 1847) and *Pomacea diffusa* (Blume, 1957)), and one was a protected non-native species (*Helix pomatia* (Linnaeus, 1758)) (Table 1). Two types of gastropods, terrestrial (50%) and freshwater (50%), were found advertised for sale (Table 1). *Achatina fulica* was the most commonly sold species in autumn (16.1 ± 29.2; number of samples (n) = 34), summer (15.4 ± 29.2; n = 34), and winter (12.2 ± 28.3; n = 34), followed by *P. diffusa* with a large number of individuals available in summer (19.2 ± 13.2; n = 66) (Table 1, Figure 3). A large number of individual gastropods were available for sale in summer (39% of total) followed by spring (22% of total) and autumn (22% of total) (Table 1, Figure 3). There was a significant variation in the number of gastropod individuals advertised for sale among the four seasons (RMANOVA: $F_{3,920} = 13.37, P = 0.001$).

Amongst the recorded six species, three species, namely *P. diffusa*, *P. canaliculata* and *C. helena*, were sold in more than 70 (80.7%) physical pet stores (Table 1). Most of the pet stores were in the urban city centres of Gauteng Province (Johannesburg and Pretoria, n = 30 pet stores), KwaZulu-Natal (Durban and Pietermaritzburg, n = 18 pet stores), the Western Cape (Cape Town, n = 11 pet stores), and the Eastern Cape (Port Elizabeth, n = 10
pet stores; Figure 1). Few were scattered on the outskirts of small cities and towns of the Free State (n = 5 pet stores), North West (n = 4 pet stores), Mpumalanga (n = 3 pet stores), and Limpopo provinces (n = 2 pet stores; Figure 1).

Gastropod species recorded in the present study were sampled from only eight out of nine provinces of South Africa. The Northern Cape Province had no physical pet stores selling gastropod species during the present study (Figure 4a). Of the eight provinces trading gastropod species, Mpumalanga Province recorded the highest number of traded species (11.02 ± 8.4; n = 87) (Figure 4a). However, there were no significant differences between the number of gastropod species traded across the seasons among the provinces (RMANOVA: F7, 821 = 6.213, P = 0.140). The six gastropod species for sale in the South African pet trade originated from only four of the seven biogeographic realms (Afrotropical, Indomalayan, Neotropical, and Palearctic). There were no significant differences in the number of gastropods for sale from the different biogeographic realms recorded in the physical pet stores (RMANOVA: F6, 518 = 12.143, P = 0.183; Figure 4b). The prices for these gastropods ranged from ZAR50.00 (US$3.5) to ZAR90.00 (US$6.2).

Discussion

Of the six gastropod species advertised for sale in the South African pet trade, the African giant snail *A. fulica* was the most popular traded species sold in the surveyed physical pet stores followed by the spiked-top apple snail *P. diffusa*. Bohatá and Patoka (2019) recorded a total of 55 gastropod species in the pet trade in the Czech Republic, of which *A. fulica* was also
amongst the most common. Of the six gastropod species reported in this study, *C. helena*, and *P. canaliculata* were also recorded in the Czech pet trade (Patoka et al. 2017). It was also found that species trade popularity fluctuated across the seasons. The trade popularity of these species may likely pose impacts, particularly for those species with invasion history elsewhere. Consequently, the more these species are introduced as part of the pet trade, the more likely they are to be released or escape (propagule pressure), colonise and become invasive (Lockwood et al. 2009, 2019). The African giant snail and the channeled golden apple snail are examples of

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**Figure 4.** Mean (± SD) number of (a) gastropod species for sale in South African physical pet stores in the respective provinces, and b) gastropod individuals representing their biogeographic realms.
species with invasion records and impacts elsewhere (Halwart 1994; Wada 2006; Graeff-Teixeira 2007; Meyer et al. 2008). The pet trade has played a role in the introduction of these invasive gastropods to most continents (Appleton 2003; Baloch et al. 2012; Ng et al. 2016a). Moreover, most gastropod species were sold throughout the seasons, indicating that they are bred in large numbers.

An increase in the number of African giant snails in Hawaii (Meyer et al. 2008), Havana, Cuba (Vázquez and Sánchez 2015), India (Sarma et al. 2015), and South American countries such as Brazil (Thiengo et al. 2007; Darrigran et al. 2020) has led to an increase in the population of this species in the wild. As a result, this species has been associated with impacts on native species through predation (Meyer et al. 2008) and as carriers of the parasite Angiostrongylus cantonensis (Chen, 1935), which causes human Eosinophilic encephalitis (Alicata 1966; Vázquez and Sánchez 2015). In addition, it is a pest of ornamental and vegetable gardens and small-scale agriculture (Thiengo et al. 2007).

The channeled golden apple snail Pomacea canaliculata occurs in large numbers in Japan (Wada 2006), United States (Lach et al. 1999; Rawlings et al. 2007), Thailand (Chaichana and Sumpan 2014) and other countries in Southeast Asia such as Indonesia (Schneider et al. 1998; Ranamukhaarachchi and Wickramasinghe 2006). This snail has been implicated in the decline of native Asian freshwater snails (Halwart 1994). It is also a pest to rice and taro (Halwart 1994; Wada 2006), competes with the native Thai snail Pila scutata (Mousson, 1848) (Chaichana and Sumpan 2014), and carries parasites of A. cantonensis which are mainly acquired through consumption (Lv et al. 2009b).

The two invasive species found in the present study, the African giant and channeled golden apple snails were targeted for eradication in several countries as their population numbers were great and they were causing large impacts, – e.g. the African giant snail in Brazil (Albuquerque et al. 2008), Hawaii (Davis and Butler 1964), and Maldives (Muniappan 1987), and the channeled golden apple snail in China (Yang et al. 2013), Japan (Wada 2006), and Taiwan (Teo 2001).

The assassin snail Clea helena was traded in most pet stores, which might be explained by its ability to clean tanks. This species is also known to prey on other gastropod species and was reported establishing in the wild in Kranji Reservoir, Singapore (Ng et al. 2016b). The species is sold in large numbers in the South African pet trade, and so it is likely that this predator will be introduced in the wild either deliberately or accidentally.

Variation in the number of gastropod species sold among seasons generally differs for different species between sources and countries (Schloegel et al. 2009; Faulkes 2015). In the present study, there was a seasonal variation in the number of gastropod species for sale in physical pet stores. But for provinces, the number of species did not differ across
the seasons, and several gastropod species were recorded more from Mpumalanga Province when compared to other provinces. Several studies on pet trade also found seasonal variation in species types and numbers of imported pet amphibians and marbled crayfish *Procambarus virginalis* (Lyko, 2017) sold in the USA (Schloegel et al. 2009; Faulkes 2015). This is because most of the species are affected by season for reproduction, and most of the pet breeders and keepers tend to favour species with high reproductive capacity throughout the seasons and those that can generally survive harsh environmental conditions such as disturbance, pollution, and low oxygen levels, e.g. the two commonly advertised species for sale, the African giant snail in Brazil (Thiengo et al. 2007) and the channeled golden apple snail in Asia (Baloch et al. 2012). The channeled golden apple snail in Hawaii reaches maturity within 10 months, and in some parts of Asia it matures in as little as two months. This is less than time to maturity in its native range (Argentina) where it takes two years. This quick maturation has led to a rapid increase in species population in many countries (Lach et al. 2000). This may potentially increase the likelihood of invasion of these ornamental gastropods should the species spill-over into the wild intentionally or unintentionally.

In general, several factors have been reported to affect species availability in the pet trade, including the sale price, species size and colour (Su et al. 2015, 2016; Patoka et al. 2015; Lockwood et al. 2019). In this study, low price ranging between ZAR50.00 (US$3.5) and ZAR90.00 (US$6.2), and summer season were the two factors that contributed to the trade popularity of the six gastropod species sold in the South African pet trade. Similarly, these factors were reported to contribute the most to the availability of other species in the pet trade (Chucholl and Wandler 2017; Stringham and Lockwood 2018; Lockwood et al. 2019). Generally, in the pet trade, price is related to the size of species, with smaller body-sized species sold in higher volumes at relatively low prices (Maceda-Veiga et al. 2019). Such species are more likely to be released into the wild and become problematic (Stringham and Lockwood 2018; Maceda-Veiga et al. 2019). This was evident in several taxa including small-sized amphibians, reptiles, birds, and marine fishes which were traded in relatively high volumes and at low prices (Rhyne et al. 2012; Holmberg et al. 2015; Stringham and Lockwood 2018). Consequently, many were released because they were difficult to maintain (Holmberg et al. 2015; Stringham and Lockwood 2018). This shows that gastropods with smaller body sizes, sold at high volumes and low prices may have the potential likelihood of establishing wild populations.

**Recommendations**

We recommend that physical pet stores be regularly monitored given that the gastropod species sold are already invasive elsewhere, and the number of species sold fluctuates among seasons and provinces. The fish and plant
trade should be monitored as most of these gastropods are also introduced with traded fish species (for decoration and cleaning tanks) and ornamental plants as hitchhikers (Ng et al. 2016a; Patoka et al. 2016b, 2017; Yanai et al. 2017; Darrigran et al. 2020). A thorough biosecurity monitoring is needed at a national level to disclose which species are introduced in the country as this may reduce the number of potentially harmful species traded in South Africa. Although Appleton and Miranda (2015) and Nelufule et al. (2020) did some molecular work (DNA Barcoding) to confirm the identities of pet invertebrates, including the African giant snail, there is a need to build a DNA Barcoding database of non-native gastropod species sold in the country. We recommend performing risk assessment of potentially imported gastropods to identify potential risk associated with these species. Gastropods care-sheets may need to be provided either by physical pet stores or online selling platforms so that the public could be informed of the risks associated with the species they are purchasing. Customers should also be educated about the risk of releasing exotic gastropod pets into natural water bodies. The government should also restrict giving permits for selling harmful exotic gastropods because a relatively large number of the legal and illegal traded pets pose a high risk of becoming invasive. In addition, customers should also apply for permits to keep an exotic pet as this may reduce the number of intentional pet releases into the environment. The e-discussions such as those in Darrigran et al. (2020) which involves experts sharing information on which gastropod species they have in their countries may help to guide in future samplings and predict where such species exist or could invade.

Conclusions

South Africa trades a variety of ornamental gastropods known to be invasive elsewhere (e.g., African giant snail and channeled golden apple snail), which pose significant impacts to biodiversity. Gastropod species in the pet trade fluctuated in numbers over the seasons, and among the stores across the provinces. Assessing the trade of gastropod species in South Africa may lead to public awareness, policy implementation, regulation, and management. This may help reduce the import of invasive species into the country.

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Author’s contributions

CTS, CTD, and NS conceptualise the research. CTS and NS collected and analysed the data. CTD edited the manuscript prior to submission.
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