Snails used for human consumption

The case of meat and slime

Executive summary

The number of snails produced for human consumption increases gradually every year. Still, there is very little awareness about the details of snail production or how serious an ethical problem it might be. In this report[1], I assess snail production and farming, the global snail market, specific welfare concerns, and discuss some scale, neglectedness, and tractability considerations. Some of our main findings are:

- **Production and demand**: The five major producers of snails worldwide are Morocco, Spain, Indonesia, China, and Romania. Worldwide, the top consumer of snails is Spain.
- **Welfare concerns**:
  - In the farm: High density, movement restrictions, and different kinds of diseases result in high mortality rates.
  - Processing: Commonly traded alive, and again with virtually no space to move.
  - Slaughter: Typically boiled to death.
- **Scope**: It can be estimated that between 2.9B to 7.7B[2] snails were slaughtered for their meat worldwide in 2016.
- **Neglectedness:** invertebrate welfare is an issue that has not gained much attention within the effective altruism community and the animal welfare movement. Even in academia, there is a general lack of concern for studying welfare-related issues about snails.
- **Tractability**: The most prevalent snail pathologies and their possible treatments need to be identified. We know of no large-scale initiatives to improve the situation of snails used for human purposes.

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[1] I am especially grateful to zoologist-malacologist Dr. Joseph Heller, Professor Emeritus at the Department of Ecology, Evolution and Behavior at the Hebrew University of Jerusalem, and academic curator of the National Molluscs Collection at the same university, for reviewing this work and providing helpful feedback. Nevertheless, Dr. Heller’s assistance should not be in any way construed as endorsement of any views expressed in this report. Any possible factual errors and all value judgments are entirely my own.

[2] For brevity, I use *B* for a billion.

Although the snail market looks strong, a sharp increase in production is not expected. All things considered, I conclude that investing specific efforts on behalf of snails used as food may not be cost-effective. Still, further research may uncover specific welfare measures and new forms of intervention on behalf of these animals.

Introduction

For the last while, Rethink Priorities has been studying invertebrate sentience, invertebrate welfare, and more recently, the lives of farmed invertebrates. All our work on invertebrates is available here. Currently, we are focusing our efforts on farmed invertebrates because ameliorating their suffering is likely to be more tractable than intervening in nature on behalf of wild invertebrates. Additionally, the number of farmed invertebrates for different purposes stands to increase in the future, while that is unclear regarding invertebrates living in the wild.

In order to improve the lives of invertebrates, we must first know what those lives are like. In this regard, understanding the situation of farmed snails seems relevant since these animals are consumed by humans in many cultures. Presumably, the problem is of considerable magnitude, given that snails are especially small animals compared to other vertebrates or invertebrates used as food. More precisely, the meat generated per snail is usually equivalent to a mouthful[3]. Therefore, a snail-based dish affects far more individuals than a meat-based dish of, let's say, chicken. That probably results in high numbers of snails killed, even if people who eat snails do it only occasionally and in modest quantities.

According to FAO (2019a) data[4], the tonnes of snails produced for human consumption (e.g., 18,331 tonnes in 2017) rises gradually every year (see also FEAGAS, 2015). Still, FAO figures are an underestimate because no country provides FAO snail production data (I. Kovrova, personal communication, 29 August 2019). Furthermore, the growing demand for beauty slime-based products is boosting a renewed interest in snail farming. Some claim that "over the last 20 years, snail breeding has taken off and the number of farms has trebled" (Mitzman, 2017; data unverified by the author). All in all, we hypothesize that the number of snails used for different purposes may account for a significant and increasing amount.

Still, not much is known about these animals' quality of life and the conditions in which they are raised. While different species, different farming systems, and different farming purposes involve different welfare challenges, it is known that these animals are extremely sensitive to environmental variations. Thus, snails die massively from inadequate control of abiotic factors that are crucial for their well-being. Additionally, images of snail farms suggest that stock density is a common problem. Lastly, it is known that snails used for their meat face prolonged deaths without prior stunning: they are typically slaughtered by boiling. If snails have valenced experiences, it is probably an extremely painful way to die.

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[3] For *Helicidae* snails.

[4] Parameters: *Livestock Primary; World + (Total); Production quantity; Snails, not sea; All years*. The complete FAO data is available here.

While snails are used for different purposes –e.g., for their meat or their mucin–, this report focuses on what appears to be, nowadays, the main driver of snail farming: snail meat consumption. Since the use of snails in cosmetics is rapidly growing in popularity, where possible, relevant aspects about snails exploited for extracting their slime are addressed.

This report is organized as follows: First, the primary uses of land snails are briefly described. Second, snail production is assessed, including a list of the typical snail species consumed, a discussion of the prevalence of the tradition of collecting 'edible' snails from the wild, and a description of snail farming methods. Third, I tackle the global snail market, identifying which countries are the main producers and consumers. Fourth, some welfare issues associated with snail production and consumption are raised. Fifth, I discuss some scale, neglectedness, and tractability considerations. Sixth, I suggest key issues that further research should attend to, in order to improve our current understanding of snail sentience and welfare. Lastly, I conclude by emphasising some directions for future work on snails used for human purposes.

Still, this work has some inescapable limitations. Although snails are consumed in several parts of the world, this report focuses on Europe, because it is the main center of global snail consumption. For the same reason, most of its findings refer to *Helicidae* snails, that is, to the snail species that are typically produced or consumed in Europe. Therefore, it should be borne in mind that some of these conclusions are not generalizable to snail farming in other regions of the world[5] or to snail species belonging to a family different from *Helicidae* snails.

Furthermore, scientific literature and official data on snail farming and collection are remarkably scarce. This may be due to the fact that, historically, these two activities have been predominantly domestic and informal, when not associated with subsistence economics. Hence, accurate detailed information is in short supply. Consistent with the above, most of the relevant literature is in the languages of the countries where snail production is a relatively important activity –mostly, Mediterranean countries. Given the above, this report was prepared on the basis of surveying literature in English, Spanish, French, and to a lesser extent, Portuguese, Italian, and Catalan[6]. However, because of time constraints, research for this report relied exclusively on an exhaustive study of sources in English and Spanish only. Thus, it is likely that relevant literature in other languages was missed.

Finally, it should be noted that some fairly common optimistic prospects for the snail market are not backed up by reliable sources. These appear to be interested forecasts seemingly produced by the snail lobby itself (Elmslie, 2005: 105). Therefore, these sources were not included in this report.

[5] In particular, the findings here presented mostly refer to countries where the rain falls in a moderate summer, and the winter is severe. Hence, our findings do not necessarily apply to dry regions, where the rain falls in a moderate winter and the summer is hot and dry. I thank Dr. Joseph Heller for this point.

[6] This review was based on my knowledge of these languages.

Uses of land snails

Land snails (from now on, 'snails') are either raised or caught from the wild for at least three primary uses: to eat their meat, to eat their eggs as a type of caviar, and to obtain snail slime for use in cosmetics and other parapharmaceutical products.

While snails have been used for food since ancient times, eating their eggs and using their slime appear to be much more modern practices. In what follows, each of these uses is described in turn.

Snail meat

Snails are regarded as a delicacy in several European countries (i.e., France, Spain, Greece, Portugal, and Germany) and the United States (Snail-World, 2016). However, at the same time, several sources (Burgos & Halcón, 2001; da Costa, 2007; Decool, 2013; Duhart, 2009; Fonte, 2018; Gallo, 1998; Generalitat de Catalunya, 2010; Molle, 2017), and visits to Spanish restaurants and informal interviews of European citizens[7], point out that at least some Mediterranean countries (e.g., Italy, Spain, Portugal, France) consider snails of less culinary quality as a popular meal. In Catalonia (Spain), a celebration of snail consumption, 'l'Aplec del Caragol,' takes place each May, drawing more than 200,000 visitors. It is estimated that between around 12 tonnes of snails are consumed during this festival (Generalitat de Catalunya, 2010) –which would be roughly equivalent to 520K to 3.3M animals.

Hence, in these countries, two main general consumer habits are identified: snails of better quality in size, texture, and flavor are prepared in restaurants and considered a delicacy, while cheaper snails are used for traditional and direct consumption. In addition, in France, snails are traditionally served during festive family meals and on Christmas Eve (Bianchi, 2017; Planetoscope, 2012). For these consumers, snails are not an everyday dish, but not necessarily an exclusive delicacy.

Beyond Europe, snails are an important part of the gastronomy of Morocco[8] (Bouaziz, 2017), and of some Western and Central African countries. In particular, Côte d'Ivoire, Ghana, Benin,

[7] The six restaurants and bars visited are located in the center of the city of Barcelona, Spain. These establishments were selected by a convenience sampling method, attempting to cover restaurants and bars with different price ranges. Snail consumers (n = 5) were also chosen by convenience sampling. One of them was from Portugal, and the remaining four interviewees were from Spain.

[8] Strikingly, according to the Islam, it is not permissible to eat snails. I thank Dr. Joseph Heller for highlighting this.

Cameroon, and Nigeria are major consumers of giant snails (Blay et al., 2004 in Ngenwi et al., 2010; Hardouin et al., 1995). Similar to what was found for some Mediterranean countries, there appear to be two very different markets. First, snails are part of the menu of restaurants frequented by affluent African and European customers. For this public, African snails are commonly prepared and presented using European culinary techniques. Additionally, snails are also sold in retail stores or supermarkets, often frozen (Hardouin et al., 1995). Second, snails are prepared as a popular dish, mostly consumed by rural and urban poor households (Adedoyin, 2013 in Osunsina et al., 2016; Bouaziz, 2017; Christian et al., 2019; Ojelade et al., 2013 in Osunsina et al., 2016). In these cases, small roadside restaurants, near schools or factories, or busy locations of some African cities offer prepared snails ready for consumption (Bouaziz, 2017; Hardouin et al., 1995).

The way snails are prepared varies in different contexts. In France, snails are commonly served as an appetizer. Usually, a plate of "escargots"[9] (*escargots à la Bourguignonne* or *escargots de Bourgogne*[10]) consists of 6 to 12 snails in their shells. These snails have actually been removed from their shells, cleaned, cooked (with garlic butter and herbs), and then placed back into their shells (Escargot World, 2016-17a; France Travel Tips, 2017). In other regions, snails are boiled with different ingredients, and served as a snack, in brochettes (Spain) or in their own sauce (Morocco) (Bouaziz, 2017; Generalitat de Catalunya, 2010; Safa, 2018).

As can be observed, snail consumption is not merely determined by economic factors, but mostly due to cultural reasons. While the meat of the same animal is considered a delicacy in some contexts, it is a staple of popular dishes in others. Even within the same country, some people are accustomed to consuming snails, whereas other people have an aversion to eating them.

Overall, it is argued that snail meat is a nutritious and high-quality food for humans, rich in protein, low in fats, and a good source of iron and other micronutrients (Adegoke et al., 2010; Çağıltay et al., 2011; Elmslie, 2005: 102-103; Udofia, 2009). Still, some health risks are associated with eating wild snails, since they habitually eat plants and fungi that are poisonous for humans (Elmslie, 2005: 102-103). As will be detailed below, snails should, therefore, be "purged" before eating.

Snail caviar

[9] '*Escargot*' is the French word for 'snails', and the term used in France for the meat of snails of the *Helicidae* family. The meat of snails of the family *Achatinidae*, when exported from Africa to France or other European countries, is sometimes sold as '*escargot achatine*' (Cobbinah et al., 2008: 12).

[10] The name *Escargots à la Bourguignonne* refers to the traditional way of preparing snails, typical from the Burgundy region in France. *Escargots de bourgogne*, for its part, is another name for this popular dish, which refers to "escargot prepared with herbs and garlic butter" (Escargot World, 2016-17).

During the past years, there has been a growing interest in snail caviar or *escargot* caviar as a luxury food item across Europe (Generalitat de Catalunya, 2010; Randle et al., 2017). This caviar consists in fresh or processed eggs of land snails, typically from the species *Helix aspersa maxima*[11] (Escargot World, 2016-17b).

Snail eggs in their natural state have no color. Once the eggs are processed, they may become pinkish, white, or cream-colored (Escargot World, 2016-17b). For this reason, snail caviar is also known as "white caviar" (Bronzi & Rosenthal, 2014).

Snail caviar is considered a substitute for the traditional fish caviar. However, this product fetches a price comparable to that of caviar from some fish species –such as the sterlet and the Siberian sturgeon (Bronzi & Rosenthal, 2014)[12].

In Europe, snail eggs are mainly produced by snail farms, rather than collected from the wild. In particular, snail caviar production currently supplements the snail meat production of farmers (see, e.g., Generalitat de Catalunya, 2010; Randle et al., 2017; Winter, 2013).

Snail slime

Snail slime is a kind of external mucus that is secreted by some salivary epidermal glands (pedal glands) located at the snail's "belly" (the snail's foot) (Greistorfer et al., 2017). This secretion enables snails to adhere to and glide over all types of surfaces including rough or potentially hostile terrain, even if they are completely vertical (Denny, 1983; Lei et al., 2010). Besides adherence and locomotion, this mucus performs other functions for these animals, having emollient, moisturizing, lubricating, and reparative properties. Snails, like other gastropods, also use their slime for feeding and mating (Denny, 1983; Greistorfer et al., 2017; Newar & Ghatak, 2015; Trapella et al., 2018). Mucin is a defensive substance, also secreted by snails when they are perturbed, threatened or attacked (Denny, 1983; Greistorfer et al., 2017; Newar & Ghatak, 2015).

The use of snail mucus for treating burns, abscesses and other wounds in humans may not be new. According to Bonnemain (2005 in Greistorfer et al., 2017), snail slime was already mentioned as a skin treatment in Ancient Greece[13]. Surprisingly, there is no evidence of later

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[11] *Helix aspersa Maxima* ('gros gris') is a snail species of the *Helicidae* family, different from *Helix aspersa* –also known as *Cornu aspersum*.

[12] Escargot World (2016-17b) claims that snail caviar in Europe is priced at around €2,000 ($2,188) per kilogram. Randle et al., 2017 estimate that snail caviar can be sold for even €65 ($72) per 30 grams –that is, €1,857.14 (or $2,031.17) per kilogram.

[13] However, it should be noted that Bonnemain's (2005) work is published in *Evidence Based Complementary and Alternative Medicine*. This academic journal has been openly disavowed by one of its co-founders, Edzard Ernst. Ernst (2016) states that the peer-review system of the journal is "farcical", and "most of the articles that currently get published on alternative medicine are useless rubbish".

use of snail mucus until about 30 years ago. According to several sources (Del Valle, 2018; Knibbs, 2018; Thomas, 2013), the Chilean skincare brand Elicina was among the first ones to produce snail cream.

Today, snail slime is used in the cosmetics sector or as a parpharmacautic product, either directly or as a component of commercial creams. These snail-derived products are advertised under commercial slogans that promise a skin anti-aging effect, skin regeneration, improving wound healing, or an acne solution (Daily Mail, 2013; Greistorfer et al., 2017; see e.g., 'Oedo' snail cream; 'Bio Beauty' snail cream; Russo, 2018). Several studies support these potential benefits (e.g., Brieva et al., 2008; Harti et al., 2016; Kim et al., 2015; Tsoutsos et al., 2009). However, the chemical composition and biological effects of snail slime are not altogether clear (Greistorfer et al., 2017; Trapella et al., 2018). Apparently, snail mucus is a complex mix of proteins, glycolic acids, elastin, vitamins, and collagen, as well as other compounds (Alogna, 2017; Greistorfer et al., 2017; Trapella et al., 2018).

Currently, the use of snails in cosmetics is rapidly growing in popularity (Greistorfer et al., 2017; Indexbox, 2018 in Food Dive, 2018). According to Arthur (2016), snail mucin is one of the products at the forefront of the "latest big trend in global skin care and cosmetics industry".

Additionally, given the high presence of polymers in snail slime, scientists are studying the possibility of using this substance for stitching up injuries and surgical wounds. In this sense, snail slime could overcome the current limitations of conventional medical adhesives –mostly suitable for fairly straight, clean and not too deep cuts (Shoemaker, 2013).

Other uses

In Africa, unmarketable snails for human consumption (white skin, shell too small for the volume of flesh) are sometimes used as sources of protein for farmed animals, like pigs (Hardouin et al., 1995). Additionally, other authors have investigated the potential use of *Achatinidae* snails to feed farmed chickens (Creswell & Habibie, 1981; Creswell & Kompiang, 1981; El-Deek et al., 2002; Houndonougbo et al., 2012; Reglain et al., n.d.). FAO (n.d.; 2019b) has also recommended the use of land snails to feed catfish or common carp.

Other authors have studied the use of golden or apple snails (*Pomacea canaliculata*) to feed chickens, pigs, fish, and other farmed animals (Heuzé & Tran, 2017; Kaensombath & Ogle, 2005; Serra, 1997; Visca Jr et al., 2018). Golden apple snails are freshwater snails; thus, these animals are beyond the scope of this report. However, it is worth mentioning that these snails are used as feed for crustaceans and some fish species such as black carp, especially in Southeast Asia, where they are considered a "pest." It has been shown that golden apple snail meal can replace 100% of the dietary fishmeal component of commercial feeds (Phonekhampheng et al., 2009 in FAO, 2019b). According to Ali (2013: 82-83), snail-based feed has already shown good results in tilapia farming. However, the intensification of aquaculture makes the use of snail-based feed unsustainable, along with the high costs of manufacturing snail-based meals. Both factors have severely limited the use of these snails as fodder for fish and other marine animals (Hasan et al., 2007). No further evidence suggesting that the use of land or aquatic snails for producing feed for other animals is a widespread practice, or that it will be in the near future, was found.

Furthermore, land snails are occasionally used as household pets. Some internet sites offer very comprehensive information on snail habits, and how to keep them as companion animals (e.g., MotherNatured.com, 2019; Nordsieck, n.d.; wikiHow, 2019). However, this practice is specially controlled in countries where some snail species are considered "pests”[14].

Finally, snails are also sometimes used as an 'animal model' in school classrooms for teaching purposes (e.g., Education.com, 2006-2019; National Association of Biology Teachers, n.d.; Lee, 2017).

Given the scope of the different ways snails are used, this report will focus on what appears to be, nowadays, the main driver of snail exploitation: snail meat consumption. However, given the rising popularity of snail-slime-based products, where possible, specific aspects concerning this activity are identified.

Snail production

Which snail species are caught or reared for human consumption?

Snails are members of the class *Gastropoda*, which, in turn, belongs to the phylum *Mollusca*. *Mollusca* is the second most diverse largest phylum of the animal kingdom (measured by number of species). Gastropoda, for its part, is the only class of mollusks that have successfully invaded land (Ip et al., 2018; Sallam & El-Wakeil, 2012). Terrestrial snails (subclass: *Pulmonata*) are one of the most numerous groups of gastropods, comprising around 35,000 described species (Sallam & El-Wakeil, 2012).

[14] In the United States, for example, a permit is required to import snails into the country, and also to move the animals from one state to another. Moreover, the interstate movement and importation of exotic snails (i.e., snails of the *Achatinidae* family, also known as African snails) is expressly prohibited (USDA, 2019). Similarly, in Canada, the European brown garden snail (i.e., *Cornu aspersum*) is classified as a plant pest, and national authorities have established measures for preventing the importation of these snails in plant and soil matter (Canadian Food Inspection Agency, 2010).

Though not all land snails are considered "food", different sources estimate there are dozens of edible species (e.g., Cobbinah et al., 2008: 12). The breeding and harvesting of snails of specific species mostly results from environmental conditions and the availability of different snail species.

Broadly, two main groups of snail species, the European and African ones, are used for human consumption. Most of the European species (e.g., *Cornu aspersum*, *Helix pomatia*) belong to the *Helicidae* family. The snails usually farmed or gathered in other non-tropical regions (e.g., in North America) belong to this family as well (e.g., *Helix lucorum*). African species (e.g., *Achatina achatina*, *Archachatina marginata* or *Achatina fulica*), for their part, belong to the *Achatinidae* family (Cobbinah et al., 2008: 10-21; Elmslie, 2005: 97-101). For further details about *Helicidae* and *Achatinidae* snails, see *Appendix 1*.

Snails collected from the wild

Traditionally, snails were not farmed, but directly collected from the wild during the rainy season, either for sale or for domestic consumption (Cañas, 2018; Christian et al., 2019; MAPAMA, 2019; Ngenwi et al., 2010). In fact, heliciculture (i.e., rearing snails) is still considered a 'new farming venture' –at least in some Western countries (Pearce, 2015).

Snail gathering is a relevant source of livelihood for rural dwellers in the humid forest and derived savanna zones of West and Central Africa (Hardouin et al., 1995; Ngenwi et al., 2010). In countries like Cameroon and Ghana, snail collectors are mostly women and children from rural areas, with limited alternative sources of livelihood. Usually, this activity is combined with the backyard rearing of these animals (Ngenwi et al., 2010). In West Africa, snail collection is predominantly a subsistence activity, carried out by women and children as well (Ntiamoa-Baidu, 1997). Hardouin et al. (1995) also highlight the role of rural women in the snail trade in African countries in general.

According to a report by FAO from 1997 (Ntiamoa-Baidu, 1997), governmental controls do generally not apply to the collection of snails in these countries. However, in many African communities, the collection of these wild animals is governed by traditional rules. For example, a traditional norm in the southern forest areas of Ghana establishes closed seasons for the giant African snail (*A. achatina*), i.e., when snails are laying their eggs. This unwritten regulation was highly respected in the past and effectively guided the exploitation of these animals.

In European countries, the situation is quite different. Although picking snails from the wild has been a traditional and ancestral activity, common in several regions of France or Spain (Duhart, 2009), this has changed over the last century.

Formerly, in European countries like France, Switzerland and Germany, snails were taken from the wild and then fattened in pens (Agence Wallonne pour la Promotion d'une Agriculture de Qualité, n.d.; Duhart, 2009). However, during the twentieth century, the overcollection of these animals and other factors depleted snail populations in the wild (Conte, 2015; Gheoca, 2013a). As a reaction, since 1979, *H. pomatia* snails are subject to special protection, starting in France and then in other Western European countries. In France, for example, the collection of *C. aspersum* and *H. pomatia* snails during the period of reproduction is banned. During the rest of the year, snail harvesting is authorized only for animals with a shell diameter over three centimetres (*Arrêté du 24 avril 1979 fixant la liste des escargots dont le ramassage et la cession à titre gratuit ou onéreux peuvent être interdits ou autorisés*). Other countries like Spain have adopted a similar regulation for *H. pomatia* (see *Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad*). Moreover, the Council of Europe listed *H. pomatia* in the *Convention on the Conservation of European Wildlife and Natural Habitats* as a protected species (Annex III). Later, the European Union included the same snail species in the *Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora*. According to this classification, *H. pomatia* is considered a vulnerable species, whose harvesting from the wild must be "subject to management measures."

As a result, throughout the European Union, snail collection of specific species is done only under express authorization. These permits stipulate the amount of snails, the species, and the area where the animals can be harvested (Gheoca, 2013a). As expected, these measures led to a severe decline in the number of snails gathered from the wild. In 1999, for example, those who collected snails in France were mostly amateurs and did so for occasional domestic consumption (Fortier, 1999). In Spain, snail picking (mostly, of *C. aspersum*) evolved along with the development of heliciculture and imports. Snail harvesting still prevails in some regions of the country, but it is a limited practice, and it often complements other agricultural activities –such as wine-growing (Duhart, 2009). Concomitantly, the tradition of collecting and eating wild snails has declined over time also because people prefer to spend their time in other activities (Elmslie, 2005: 93-94).

On the other hand, in Eastern Europe, snail harvesting of other Helicidae species–different from *H. pomatia*– is an economically significant activity due to export trade (Gheoca, 2013a).

Snail farming

Snail farming is an old activity in several European countries (Agence Wallonne pour la Promotion d'une Agriculture de Qualité, n.d.; Duhart, 2009). However, the revitalized interest in heliciculture during the past years mostly results from the shortfall in production in France and even in Eastern Europe. As previously suggested, the elevated consumption of snails caused overexploitation that, added to the degradation of suitable habitats due to land use and pesticides, caused a decline of the natural snail populations in some European countries

(Conte, 2015; Gheoca, 2013a). Thus, snail farming is considered necessary “to prevent overexploitation [of snails living in the wild]” and ensure a “sustainable production” (Çelik et al., 2018: 189).

This renewed development of heliciculture started in Western European countries (i.e., France, Italy, Belgium), and more recently, it expanded to Eastern European countries, such as Romania, Bulgaria, and Greece (Gheoca, 2013a). Especially in Eastern Europe, heliciculture is a real possibility of investment. In this context, this activity is not only stimulated by the demand for snail meat, but also by the use of snails’ slime (Conte, 2015).

Similarly, indiscriminate snail harvesting in West Africa encouraged the development of small-scale production systems in that region (Hardouin et al., 1995). More recently, declining snail populations due to habitat loss through deforestation and climate change have fostered the development of snail farming in some African countries (Ngenwi et al., 2010).

In Africa, snails have been raised in small pens in many areas of Western Africa for decades (Ntiamoa-Baidu, 1997). More recently, countries like Nigeria and Ghana have been promoting the development of snail farming not only as a backyard practice to supplement household income and protein supply, but also as large scale commercial activity (Africa News, 2017; Cobbinah et al., 2008; Ngenwi et al., 2010; Ntiamoa-Baidu, 1997).

In general, commercial snail farming is described as a profitable activity (e.g., Katende, 2019; Pearce, 2015). Capital, technical, and labor inputs in simple snail farming are relatively low compared to those necessary for farming other animals, like chickens, pigs, goats, sheep, or cows. However, proper infrastructure and technical capacity is necessary for commercial farms to succeed (FAO, 2013). In particular, snails require specific conditions and are especially sensitive to environmental variations (ANCEC, 2018; Çelik et al., 2018; Padilla & Cuesta, 2003: 94-102). Even if the right conditions are met (e.g., high humidity and temperature), pathogenic microorganisms can proliferate, creating severe sanitary problems, and causing low yields and mortality (ANCEC, 2018; FAO, 2013). Moreover, snails are relatively slow-growing animals. Their consumable meat makes up no more than 40% of the snail's total live weight. Consequently, snail farming is not a way to make money quickly (FAO, 2013).

Systems of production

As far as housing is concerned, at least three types of snail farms are identified. In increasing order of complexity, management, and financial inputs, these farming systems are: extensive, semi-intensive or mixed, and intensive (FAO, 2013; Iglesias & Castillejo, n.d.; Thompson & Cheney, 2008; see also Padilla & Cuesta, 2003: 94-102).

- **Extensive system**: Also known as the free-range system. This is an outdoor farming method that replicates the snails' natural habitat. In these farms, the entire life cycle of the snail develops within the open pen: mating, egg-laying, hatchling development, and growth of the snails to maturity. Hence, environmental conditions are not controlled.
  The animals feed on the plants they are provided with in the pen; thereby, the farmer's maintenance work is relatively reduced. In some extensive systems, there may be different divisions by zones (troughs, drinking troughs, shelters, and a breeding area), more like a semi-intensive system (Padilla & Cuesta, 2003: 94-102). In this farming method, animal density is low. It is practiced mostly by small-scale farmers and subsistence farmers (mainly for consumption, not for commercial purposes).

- **Semi-intensive or mixed system**: In these cases, snails are reared part indoors, part outdoors. First, egg-laying and hatching occur in a controlled indoor environment. After 6-8 weeks, snails are removed to outside pens until they grow to maturity.

- **Intensive system**: The entire production cycle is carried out in a controlled indoor environment. These closed systems may be plastic tunnel houses, greenhouses, or other buildings with a controlled climate such as industrial units. More specifically, animal husbandry can be carried out on horizontally stacked trays or in "tables" that group several vertically inclined surfaces ("curtain method"). Unlike the previous systems, the temperature, humidity, and hours of light are strictly controlled throughout the entire life cycle of snails. Furthermore, snails are not fed with plants, but with compound feeds. Thus, these closed enclosures require a robust economic investment and a high demand for labor.

These different production systems give rise to different models, which, in turn, have evolved and can also be combined. Thus, depending on the model adopted, two extensive farms–although classified under the same production system–can present visible differences in terms of fencing or zoning complexity, for example. In general, the adoption of one model or another seems to depend on the technical capacity of the farmer and, more importantly, on economic investment. Describing all farming models and their possible combinations is beyond the scope of this report. For a complete description, see Padilla & Cuesta (2003: 94-102) and Cuéllar et al. (1986: 59-105). For images of different types of snail farms see Iglesias & Castillejo (n.d.) (in Spanish).

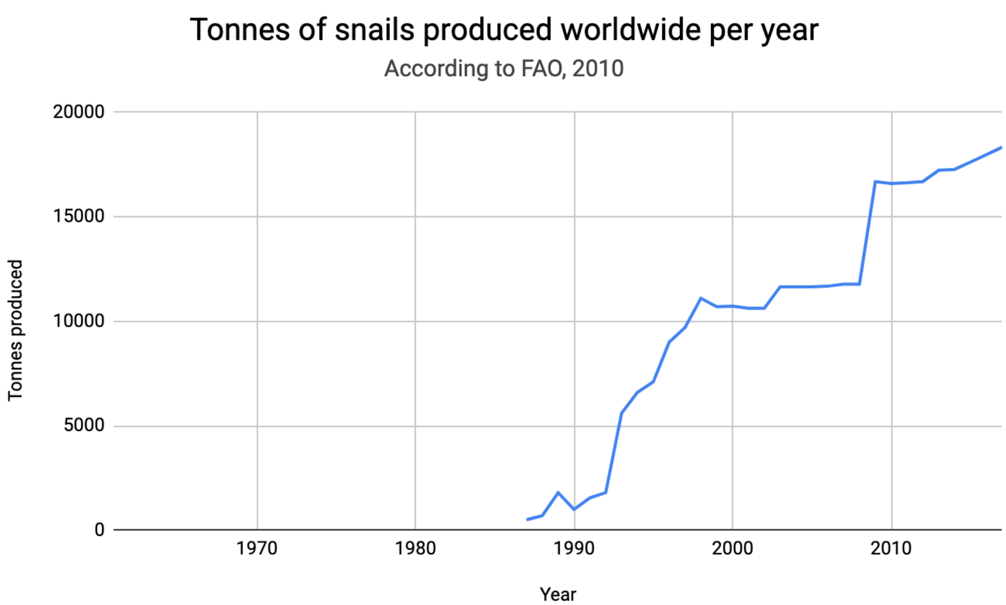
Lastly, at least until 2005, there were no 'large' snail farms. All the successful ones were small and depended for commercial success on selling above the going market price on the basis of a local reputation for quality (Elmslie, 2005: 118-119).

Demand for snails

Snail production estimates and top worldwide producers

According to different sources, it is almost impossible to get reliable production and consumption numbers of snails, since a large percentage of them are collected from the wild (Cuttelod et al., 2011; MAPAMA, 2019; Touchstone Snail, 2015a). According to Touchstone Snail (2015a), only 15% of the global consumption comes from snail breeding units, while the remaining 85% comes from snails collected from nature. However, the source and grounds of this estimation are not specified.

FAO (2019a) estimated that 18,331 tonnes of snails were produced worldwide in 2017 (see fig. 1)[15]. However, according to Irina Kovrova (personal communication, 29 August 2019), statistician of the Crop, Livestock, and Food Statistics Team at FAO, “since *no country provides us the snail production data* [emphasis added], our snail production data are underestimated.”[16]



[15] Parameters: *Livestock Primary; World + (Total); Production quantity; Snails, not sea; All years*. The complete FAO dataset is available here.

[16] FAO snail production data are based on the annual agricultural production questionnaires which the organization sends to countries. Several of these estimates were done in the framework of the Food Balance Sheet compilation for the countries net exporters of snails (I. Kovrova, personal communication, 29 August 2019).

Fig. 1. Tonnes of snails produced worldwide per year, from 1987 to 2017. No data for previous years was found. Own elaboration based on data from [FAO (2019a)](17).

If the tonnes of snails produced annually are higher than the numbers provided by FAO, the question that now arises is *by how much*. Without official statistics on the matter, answering this question is especially tricky. This lack of official data led us, then, to consider other sources, as it is discussed in *Appendix 3*. Out of all of them, and after contrasting further evidence, it was concluded that the data provided by Indexbox (2018 in Food Dive, 2018) was worth taking into account.

Indexbox (2018 in Food Dive, 2018), a market research company, states that in 2016, the global snail market amounted to 43,000 tonnes (between 2.9B to 7.7B snails, see *Appendix 4*)[18]. The same source claims that the five major producers of snails worldwide are Morocco (15,000 tonnes in 2016), Spain (6,500 tonnes), Indonesia (5,900 tonnes), China (2,900 tonnes), and Romania (2,000 tonnes). These five countries represent around 75% of global snail production, as illustrated in the graph (fig. 2) below:

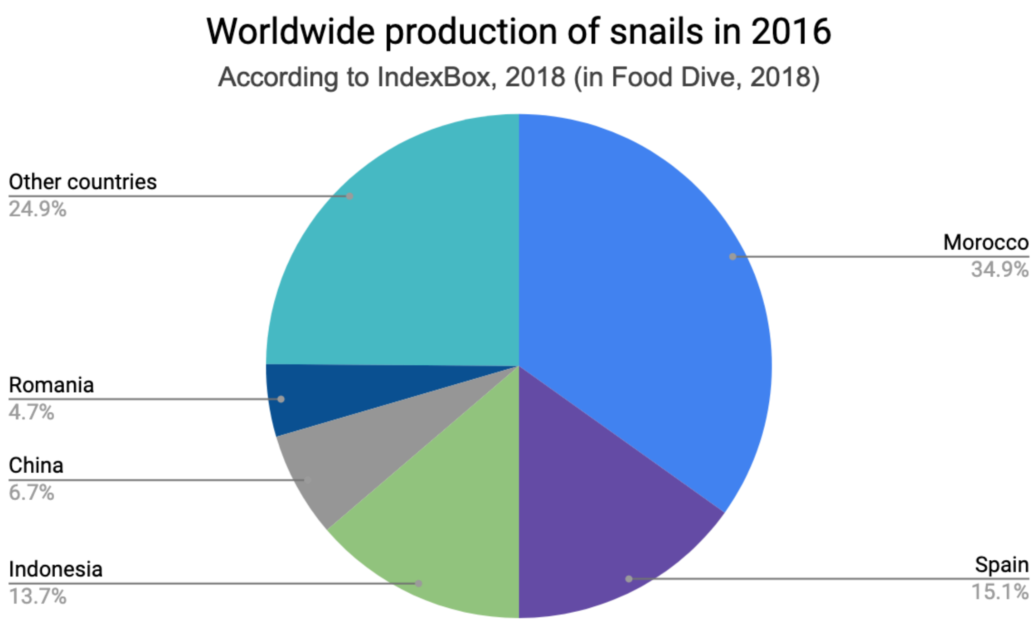


Fig. 2. Worldwide production of snails in 2016. Own elaboration based on data from IndexBox (2018 in Food Dive, 2018).

[17] Parameters: *Livestock Primary; World + (Total); Production quantity; Snails, not sea; All years*.
[18] Indexbox's estimates refer to the product classed under the HS code 030760 'Snails, live, fresh, chilled, frozen, salted, dried or in brine, even smoked, with or without shell (excluding sea snails)'. The figures are based on the production of snails which is available for statistical observation. Therefore, despite it is not defined clearly, it is assumed that the figures most probably apply to farmed snails because farms are likely to have more established reporting as compared with wild snail collectors (S. Avramenko, personal communication, 13 January 2020).

Particularly noteworthy is the case of Morocco. This country is the world's largest producer, according to IndexBox (2018 in Food Dive, 2018) and FAO (2019a). Apparently, Morocco accounts for more than a third of the global production of snails, and at the same time, the country's output has increased by +4.8% annually from 2007 to 2016 (IndexBox, 2018 in Food Dive, 2018).

Some European countries, like Italy or Spain, subsidize or otherwise encourage snail farming. According to Elmslie (2005), "in all countries except perhaps France, this has proved a serious mistake" (118). Frequently, this has resulted in escaped snails spreading in nature, becoming "pests." In other cases, it merely proved to be a commercial failure, mostly because of inexperienced farmers (Elmslie, 2005: 117-118).

Top worldwide snail consumers

Following IndexBox (2018 in Food Dive, 2018), in 2016 the countries with the highest consumption levels were Spain (16,500 tonnes), Morocco (6,000 tonnes), France (5,300 tonnes), and Italy (2,100 tonnes). As can be observed in the following graph (fig. 3) just four Mediterranean countries comprise nearly 69% of global snail consumption:

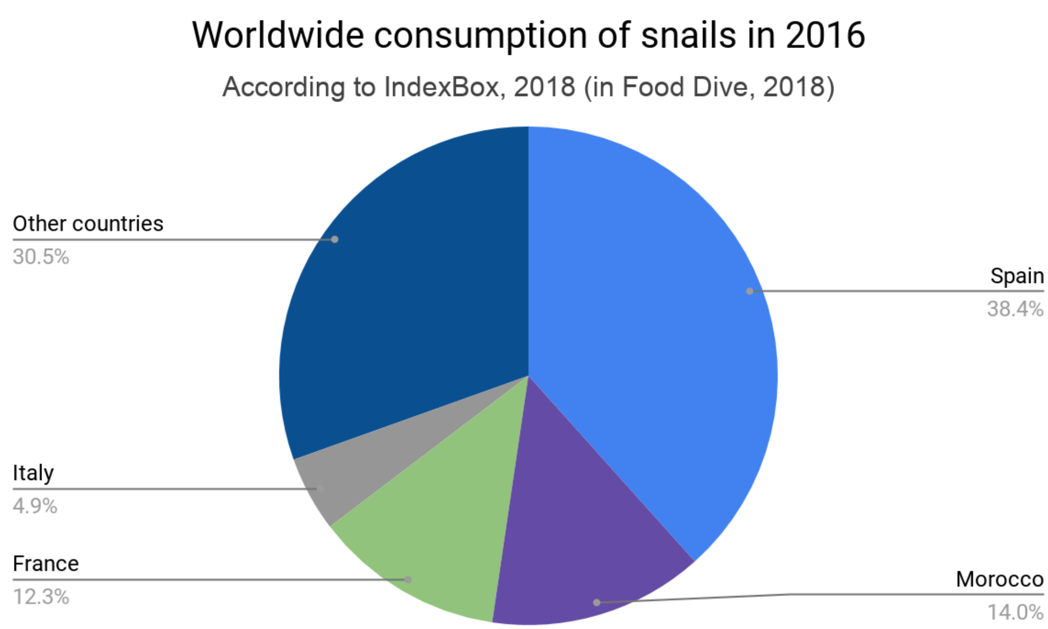


Fig. 3. Worldwide consumption of snails in 2016. Own elaboration based on data from IndexBox (2018 in Food Dive, 2018).

According to IndexBox (2018 in Food Dive, 2018), the highest total annual growth rates of snail consumption from 2007 to 2016 were recorded in Morocco, with +21.6% growth, and France, with +5.9% growth.

Considering *per capita* consumption, in 2016 the countries with the highest levels of consumption were:

- Spain (358 g/year), which is close to 400 grams per person, the figure estimated by the Spanish government in 2017 (La Vanguardia, 2017; MAPAMA, 2019),
- Bosnia and Herzegovina (197 g/year),
- Morocco (174 g/year),
- Portugal (155 g/year),
- France (82 g/year), and
- Tunisia (82 g/year).

Note that all these figures far exceed the average world consumption of snails per capita, estimated at 5.9 grams. This is illustrated in the following graph (fig. 4):

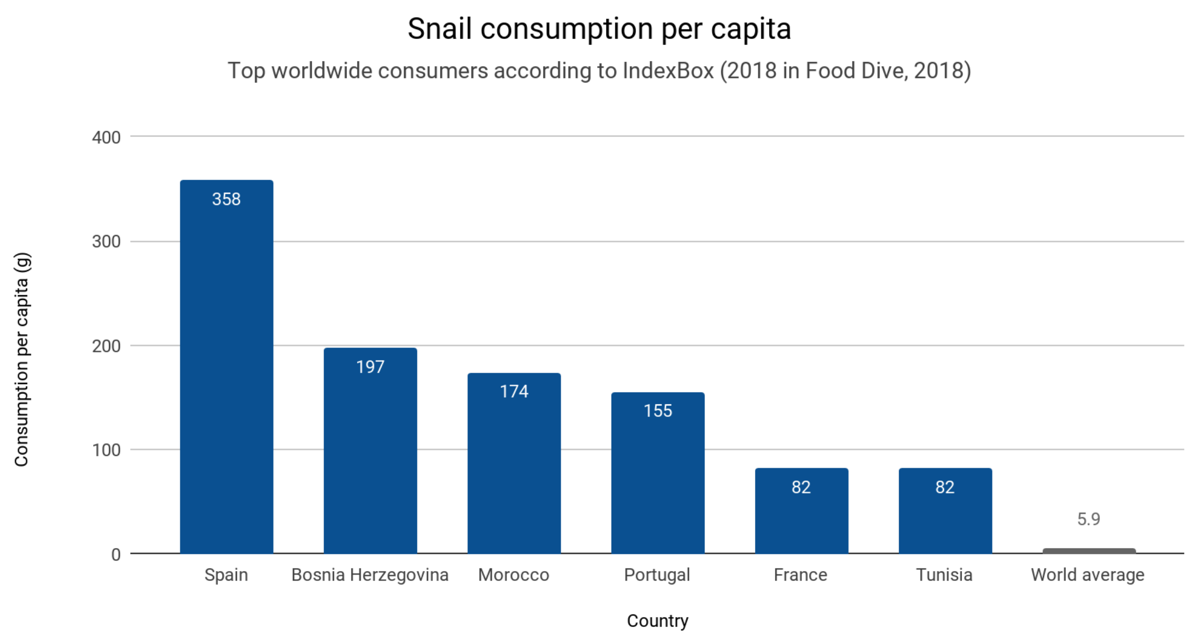


Fig. 4. Snail consumption per capita. Top consumers worldwide according to IndexBox (2018 in Food Dive, 2018).

However, given the disparity in data on snail production, all consumption estimates should be considered with caution.

Welfare concerns[19]

Production of farmed snails and snails living in the wild

Nowadays, most snails used for human consumption seem to be gathered from the wild. If these animals are conscious, we still do not know whether their lives in nature are net-positive or net-negative. However, it is worth briefly describing the **reproductive strategy** of these mollusks.

Snails–as all pulmonate terrestrial gastropods–are hermaphroditic (i.e., they have male and female reproductive organs). However, in most species, the individuals mate with each other before laying eggs (Barker, 2001: 10-20; Cobbinah et al., 2008: 10-11). Typically, they deposit their eggs in excavations, which they dig in moist soil. Embryo development occurs after oviposition. All farmed snail species are iteroparous species, that is to say, they can have offspring many times over the course of their lives (Barker, 2001: 10-20; Baur, 1994).

During the reproductive season, *H. pomatia* snails, for example, mate five to six times per year (Heller, 2001: 413-445). Typically, they lay from 30 to 50 eggs per reproductive season (FAO, 1986). The common snail (*C. aspersum*), for its part, lays eggs two or three times, for at least two years (CABI, 2018; Heller, 2001: 413-445). In this case, egg numbers per clutch range from 40 to more than 200 eggs (Colgan, 1918; FAO, 1986; Madec et al., 1998; Madec et al., 2000). According to the work of Basinger (1931 in CABI, 2018) on a population of *C. aspersum*, each individual would lay around 86 eggs each time, five times a year, resulting in approximately 430 eggs laid annually per snail. Overall, the number of eggs in a clutch and their size vary greatly within, as well as between species (Elmslie, 2005: 95).

However, these estimates of the number of eggs do not correspond to the number of snails that actually hatch from a clutch. Due to egg cannibalism, a large proportion of eggs do not hatch: around 70% of newborn snails will ingest a sibling egg during their first days of life, while they remain in the soil cavity (Elmslie, 1988 in CABI, 2018). This a common phenomenon since not all eggs hatch at once, and this asynchrony increases under unfavorable environmental conditions, providing a few of the hatchlings with the opportunity for eating sibling eggs (Barker & Efford, 2004: 362). According to observations in land snails of other species, egg cannibalism is a genetically determined trait (Baur, 1987, 1994; Heller, 2001: 413-445).

[19] I thank Dr. Pavel Balaban, professor and researcher in snail biology at the Institute of Higher Nervous Activity and Neurophysiology, for answering some questions on snail sentience and welfare. I also thank Dr. Joseph Heller for carefully reviewing this section and solving my doubts.

The consequences of this reproductive strategy for the suffering of animals are uncertain. First, it is unknown whether snails are sentient individuals, and less is known about the odds that unborn snails can have valenced experiences. If unborn snails are conscious, being eaten alive is a painful way to die. Moreover, since they are very young, they do not have enough time to have any significant positive experience in their lives. However, there is not enough evidence to confirm the claim that egg cannibalism is harmful for the unhatched 'snails' so eaten.

Second, since eggs are rich in energy and nutrients, egg cannibalism is hugely advantageous for the newborn snail –it favors the snail's growth rate and its chances to survive (Baur, 1994; Heller, 2001: 413-445). Therefore, it is difficult to gauge whether or not this phenomenon, and snail reproductive strategy as a whole, results in net suffering.

Still, parental care of younglings has not been observed in snails –just as it has not been found in any terrestrial gastropod species either (Baur, 1994). Therefore, of the snails that are born, at least 20% of them die within a few days[20] (Padilla & Cuesta, 2003: 99). The surviving snails will face various threats, including diseases and parasites (see Barker, 2004), along with death by predation (see Barker, 2004; Heller & Ittiel, 1990).

In addition, changes in environmental conditions often result in wide fluctuations in the successive stages of snails' life cycle. However, after **reproduction** and **hatching**, surviving snails may go through the following phases (Padilla & Cuesta, 2003: 94)[21]:

- **Newborn snails**: this stage goes from birth until the animal (*C. aspersum*) reaches around 0.2 - 0.5 g. During this phase snails grow rapidly. It may last 1 to 2 months in *C. aspersum* snails.

- **Growing (juvenile snails)**: during this stage snails reach their maximum weight –around 10g for *C. aspersum* snails. In this species, the growing phase lasts around 6 - 7 months.

- **Fattening**: in which snails reach sexual maturity. In the case of *C. aspersum* snails, the animals used for breeding are kept active for two reproductive periods, with a resting phase that corresponds to hibernation.

[20] 20% of newborn snails die shortly after birth in extensive farms (Padilla & Cuesta, 2003: 99). I did not find specific data for snails that live in nature. Given the similarity of the conditions of an extensive farm with the life of snails in the wild, it may seem reasonable to think that the mortality rate of newborns is similar. Even so, because of the protection from predators offered by a farm and the relative control of certain hygienic conditions that prevent diseases, it is also likely that the mortality rate of snails living in nature is higher than 20%.

[21] The classification and names of the snail life cycle stages may vary according to different authors.

All the above descriptions apply to snails that live under optimal conditions. That typically is *not* the case of animals living in nature, but it ordinarily is of snails bred in captivity (Padilla & Cuesta, 2003: 94)[22].

Nevertheless, the overexploitation of wild snails, together with demand, and the fact that heliciculture does not require a substantial investment (Conte, 2015; Cordópolis, 2013; FEAGAS, 2015), suggest that, in the future, production will progressively depend on snail farming. In addition, snail slime production is usually based on farmed snails, and this activity is one of the major causes of positive trends in the snail farming industry and its future growth. In light of the foregoing, this section is mostly based on farmed snails. Where relevant, aspects that may refer to snails living in nature are identified.

Furthermore, it should be noted that–unless otherwise indicated–this section focuses on *Helicidae* snails because (i) most of the available information relates to this group of snails, and (ii) more importantly, most of the snails used by humans belong to this family. Lastly, two main aspects of snail welfare are addressed: first, factors associated with habitat and environmental conditions; and, second, health indicators.

Habitat and environmental conditions

Temperature, humidity, and light

As ectothermic animals, snails are especially sensitive to various environmental variations –indeed, drought, cold, and changes in weather conditions can kill a substantial proportion of a snail population (ANCEC, 2018; Çelik et al., 2018; Padilla & Cuesta, 2003: 94-102). In general, humidity, temperature, and light are the most critical environmental characteristics that affect snail welfare (Padilla & Cuesta, 2003: 90-92).

All these three abiotic factors influence snail reproduction (mating and oviposition), snail growth rate, and the trade-off of age versus size at maturity (CABI, 2018; Dan & Bailey, 1982). Thus, long days stimulate snail growth and egg-laying, whereas short days inhibit them (Bailey, 1981; CABI, 2018; Lazaridou-Dimitriadou & Saunders, 1986). Similarly, warm, damp weather increases oviposition frequency[23]. These factors also affect the level of activity of snails and the duration of hibernation (or estivation[24]). Generally, low temperature and low humidity inhibit snail

[22] Additionally, it should be noted that these stages vary in duration according to the species. For *Achatinidae* snails, see Cobbinah et al. (2008: 14-21).

[23] It should be noted that that occurs only in regions where the rain falls in a moderate summer, and the winter is severe. In dry countries, where the rain falls in a moderate winter and the summer is hot and dry, this is not so. I thank Dr. Joseph Heller for this point.

[24] Estivation or aestivation or summer sleep, is a state of animal dormancy, similar to hibernation, although taking place in periods of heat or drought in warm latitudes. In countries with a moderate winter

activity, while these animals become most active in long days (Bailey, 1981; CABI, 2018; Lazaridou-Dimitriadou & Saunders, 1986).

Furthermore, since snail breeding takes place in conditions with environmental parameters of high humidity and temperatures, pathogenic microorganisms can also reproduce quickly. That can cause serious health problems for snails, including high mortality rates (ANCEC, 2018). This issue is discussed later.

Density and restrictions on movement

In rearing facilities, crowding is an additional condition that can affect snail welfare. According to FAO (2013), snails reared in farms may suffer from overcrowding, which inhibits snail growth and maturity even when food is abundant (see also Cobbinah et al., 2008; Daguzan et al., 1981). Snails in a densely populated area become smaller adults who lay fewer clutches of eggs, have fewer eggs per clutch, and whose eggs have a lower hatch rate (Thompson & Cheney, 2008).

Moreover, high population densities increase the risk of diseases (Cobbinah et al., 2008; Daguzan et al., 1981; FAO, 2013), and hence, snail mortality raises (Daguzan et al., 1981; Daguzan et al., 1985; Dan & Bailey, 1982; Jess & Marks, 1995; Thompson & Cheney, 2008)[25]. On the contrary, at low densities (less than 100 individuals per m2), snails eat more, increase their activity, grow bigger, and more of them become adults (Cameron & Carter, 1979; Dan & Bailey, 1982; Dupont-Nivet et al., 2000).

The above seems to suggest that extensive breeding (i.e., where there is a lower density of animals) is more efficient than an intensive one. However, at higher densities, the total amount of biomass produced is more significant. Hence, for *C. aspersum* snails the gross margin is maximal at a density of 250 animals per m2–that is, 40 cm2 per individual (Dupont-Nivet et al., 2000)[26].

In intensive facilities, the density of animals may reach up to 700 juvenile individuals per m^2, according to Daguzan et al. (1985). Images from these farms suggest that snails have limited

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and a hot, dry summer, snails undergo a period of aestivation rather than hibernation. I thank Dr. Joseph Heller for this point.

[25] In particular, it has been observed that adverse population density effects increase progressively after the first weeks of a snail's life (Blanc & Attia, 1992; Jess & Marks, 1995). However, it should be noted that Dupont-Nivet et al. (2000) did not find significant differences in mortality rates in snails bred at different densities.

[26] In case the breeder merely fattens the snails. If the breeder also processes the animals, the value of non-adult snails may be increased, and the density of 500 individuals per m2 is more profitable (Dupont-Nivet et al., 2000). However, such a measure reduces the area available to each individual by half –i.e., 20 cm2 (4,5 x 4,5 cm) per snail. Considering that a *C. aspersum* snail measures between 3 and 4,5 cm (FAO, 1986), in conditions of 500 individuals per m2, these animals can hardly move.

space to move around (see e.g., Cañas, 2018; Iglesias & Castillejo, n.d.). However, given the disadvantages of very high densities for snail development and health, it is suggested to moderate the number of snails per square meter (FAO, 2013).

Finally, dwarfing–ie., snails that are much smaller than the usual size for their kind–is quite common in snail farming. In the market, smaller adult snails sell for less. Hence, snail farmers have an economic incentive to avoid this alteration in snail development–which is attributable to rearing conditions rather than heredity factors (Thompson & Cheney, 2008).

Feeding

Snails are described as general herbivores, meaning they eat a variety of plants, including grass, crops, and various vegetables (Dimitriadis, 2001: 237-256; Speiser, 2001: 259-288). In extensive facilities, vegetables such as cabbage, strawberries (leaves and fruit), spinach, parsley, nettles, thyme, poppy, cabbage, radish or lettuce are usually grown to feed the animals. Intensive farms, on the other hand, typically feed snails with specialized feed.

In addition, intensive facilities have specialized areas for snail fattening, where they remain until they reach their commercial weight. Fattening may take around four months, and it can be carried out in indoor breeder pens, outdoors, in greenhouses, or plastic tunnels (Padilla & Cuesta, 2003: 94-102).

Nevertheless, it should be noted that the nutritional needs of snails are not fully known. Hence, some nutrition-related problems may arise (Cuéllar et al., 1986: 56; Padilla & Cuesta, 2003: 102-103). Additionally, within the same species, snail diets may vary widely, as animals take advantage of and adapt to the foods that are available within crawling distance. Genetically determined physiological differences, different learning abilities, different feeding experience, and subtle differences in the diet may all cause individual variability in feeding behavior (Speiser, 2001: 259-288). This should be especially taken into account in the case of snails that are directly collected from nature to be bred in captivity.

Finally, access to quality feed is a matter of greater importance for snails living in the wild, including those who inhabit crop areas–where snails for human consumption are usually collected. In monocultural landscapes, crops constitute a superabundant source of potential food, but with very little diversity in their nutritional composition (Speiser, 2001: 259-288). Similarly, snails that live in other natural environments do not seem to be particularly 'food limited'–that is to say, that their population growth is limited by the amount of available food in nature (Speiser, 2001: 259-288; see also Butler, 1976; Wolda et al., 1971). However, high-quality foods are typically scarcer than low-quality foods. It is hypothesized that in a situation of 'relative shortage' of food, the total amount of food is not limiting. However, high-quality food is rare and limits population growth (Speiser, 2001: 259-288).

Maintenance

In extensive installations, snail management is simple, while the necessary maintenance for intensive farms is usually somewhat more complicated and demanding. An intensive farm requires daily control and inspection of the husbandry systems and the state of the animals. Feed consumption must be controlled, and the containers must be cleaned every 24 or 48 hours. In addition, once a week, it is necessary to check the laying containers and the eggs in incubation. Finally, general cleaning of the installation must be carried out every fortnight, which includes replacing the breeding substrate (Padilla & Cuesta, 2003: 102).

Inadequate snail management and lack of cleanliness can stress the animals and negatively affect their immune system (Padilla & Cuesta, 2003: 102-103). Indeed, the lowest mortality rates of farmed snails are observed at lower population densities, in containers that are frequently cleaned (Jess & Marks, 1995).

Nevertheless, frequent handling can place significant stress on the animals, especially on juvenile individuals. Moreover, if snail shells are damaged during handling, repairing them demands a great amount of energy, in particular for young animals. If a snail cannot fix its shell, the individual eventually dies (Çelik et al., 2018). Before maturity, *C. aspersum* snail shells are especially fragile (Thompson & Cheney, 2008).

Health indicators

Some of the main threats affecting snails are infectious diseases, parasitic pathologies, and predation (Padilla & Cuesta, 2003: 102). All of these factors can affect the well-being of snails to varying degrees, whether they live in nature or are bred for human use. In what follows, I briefly describe the primary diseases and predators that affect snails. For a complete survey on natural snail enemies, see Barker (2004).

Diseases and parasites

Infectious diseases

Snails can suffer various infectious diseases, but probably the most harmful are *epizootic*[27] diseases. These pathologies are usually related to bacterial agents. However, the specific pathogens responsible for epizootics in snails are not well known (Padilla & Cuesta, 2003: 102; Raut, 2004: 599-611). So far, most of the epizootic diseases identified in *Helicidae* snails are caused by bacteria of the genus *pseudomonas* (Padilla & Cuesta, 2003: 102; CABI, 2018; Vera García, 2016). In general, these diseases can quickly appear and decimate farmed snail

[27] An epizootic disease is analogous to an epidemic in humans, though occurring in a nonhuman animal population.

populations–around 70-80% of individuals (Padilla & Cuesta, 2003: 102). In France, epizootic diseases are responsible for the massive mortality of *Helicidae* snails that occurs periodically in farms (Raut, 2004: 599-611).

In the case of *C. aspersum*, epizootic diseases regularly appear in rearing farms during the dry season. *Pseudomonas aeruginosa*, for example, causes an infection that leads to septicemia and, finally, the death of *C. aspersum* snails. In a short time–48 hours, in the worst cases–, this bacterium can kill around 60% of a farm's snails (Martínez, 2001). Similarly, pathogenic strains of the bacteria *Aeromonas hydrophila* are responsible for the so-called "snail summer disease." This disease can also result in high population losses (Kiebre-Toe et al., 2005; Raut, 2004: 599-611).

Yellow fluorescence, for its part, is another infectious disease that has been identified in *H. aspersa* and *A. fulica*. Its more visible symptom is the copious release of yellow fluid and mucoid materials and generally results in the death of the infected animal within a few days. The pigment-forming bacteria of the genus *Pseudomonas Migula* are usually the causing agents of this disease (Raut, 2004: 599-611).

In breeding conditions, snails are early, intensely, and permanently colonized with multiple species of bacteria (Kiebre-Toe et al., 2003). In fact, *A. hydrophila*, *P. aeruginosa*, *P. Migula*, and other bacteria are part of the normal microbiota of the animal–at least, of those reared in farms (Kiebre-Toe et al., 2003; Martínez, 2001; Raut, 2004: 599-611). However, these diseases are often caused by poor farm maintenance (i.e., lack of hygiene) or abrupt environmental changes (i.e., in humidity or temperature) (Cuéllar & Cuéllar, 2002; Cuéllar et al., 1986; Vera García, 2016). At least *P. aeruginosa* can be controlled through the administration of antibiotics or sulfonamides (Cuéllar & Cuéllar, 2002). However, Padilla and Cuesta (2003) argue that in the face of a bacterial disease, the only treatment is extreme care and cleanliness (103).

In general, infectious diseases are more common in intensive farms than in other rearing systems (Padilla & Cuesta, 2003: 102).

Parasitic diseases

Numerous species of diptera, mites, helminths, protozoa, and fungi are known to affect snails. Additionally, these animals can act as vectors (intermediate hosts) of parasites for other animals in the wild (Padilla & Cuesta, 2003: 102-103).

Regarding fungal pathologies, the most frequently described fungus in *C. aspersum* is a *Fusarium* species, responsible for 'pink clutches', triggering egg degradation (Meynadier et al., 1979 in CABI, 2018). Other fungi of the genus *Aspergillus* infect and intoxicate snails as well (Vera García, 2016). However, of all the parasites that can affect snails, the *Riccardoella limacum* mite is the one that has the highest incidence (Padilla & Cuesta, 2003: 103).

R. limacum[28] is a hematophagous mite that lives in the lung cavity of terrestrial gastropods. It is commonly found in *Helicidae* snails, in Europe and North America. These mites are true "blood-feeders" that obtain their food by producing a feeding tube or 'stylostome' in the tissues of their hosts (Baker, 1970).

Some authors state that *R. limacum* "are often present in considerable numbers with no apparent harm to the host mollusc" (Baker & Ramsay, 1978: 441). However, other sources report that heavy infestations with *R. limacum* reduced the feeding activity and growth rate, and delayed reproductive development of *H. aspersa* snails (Fain, 2004: 516). Moreover, when the mite population is sufficiently high in snail farms, it correlates with high mortality among snails (Padilla & Cuesta, 2003: 103).

For their part, endoparasitic nematodes (*Alloionema appendiculatum*, *Nemhelix bakeri*, *Phasmarhabditis hermaphrodita*, *Rhabditis maupasi*, *Angiostoma aspersae*) can also affect reproduction or cause mortality, particularly in rearing farms (Morand et al., 2004: 525-558).

In general, snails are subject to a range of pathologies caused by bacteria or parasites. These conditions are very variable and depend on whether the animals are reared in outdoor farms or indoor facilities (Padilla & Cuesta, 2003: 102-103). However, very little is known about snails' illnesses and parasites (Raut, 2004: 599-611). Typically, no preventive or curative treatment is applied to farmed snails "due to poor knowledge of snail pathology" (Dupont-Nivet et al., 2000: 454).

While microorganisms mostly affect snails in intensive farms, parasites and predators are more relevant threats for snails in extensive systems (Padilla & Cuesta, 2003: 102-103). Probably, these factors are some of the most relevant health risks for snails living in nature as well. Snail predation is addressed hereunder.

Predators

Besides humans, several other animals prey on snails, as they are small and slow-moving animals. Their predators include mammals (e.g., badgers, foxes, weasels, hedgehogs, rats, dormice, wild boars, mustelids and shrews), birds (e.g., blackbirds, crows, magpies, ducks and thrushes), reptiles (lizards, turtles, snakes), amphibians (frogs, salamanders, newts), myriapods, insects (some *Diptera*, *Carabidae*, *Staphylinidae*, *Lampyridae*, *Silphidae*), planarians, spiders (*Porrhothele antipodiana*), and even other predatory land snails (e.g. *Euglandina rosea*, *Rumina decollata*, used for biological control of *Helicidae* snails) (Padilla & Cuesta, 2003: 103; CABI, 2018; for a more complete description, see Barker, 2004).

[28] Until relatively recently, several authors have confused *R. limacum* and *R. oudemansi* as they thought there was only one valid species, i.e. *R. limacum*. However, in 1986, Fain and van Goethem demonstrated that *R. limacum* and *R. oudemansi* are clearly distinct from each other, not only in their morphology but also in their host preferences. In this regard, the typical hosts of *R. limacum* are, indeed, helicid snails (Fain, 2004: 509).

Mortality rates and lifespan

According to Padilla & Cuesta (2003), in an extensive farm, around 20% of **newborn snails** die during their first few days of life (99). I was unable to find equivalent estimates for other breeding systems.

During the **growing and fattening** phases, the same authors estimate that around 15% of snails in an extensive farm usually die (Padilla & Cuesta, 2003: 99). Cuéllar et al. (1986) also state that "under normal conditions," around 15% and 20% of animals die during the growing stage (123). Another source points out that during the growing period, a mortality rate of up to 10% can be expected (Murphy, 2001). Given the literature reviewed, 10% appears to be the minimum mortality rate for snails in captivity.

Scientific studies provide other estimates of mortality rates, higher than the figures outlined above. Daguzan et al. (1982), for example, studied *C. aspersum* snail growth under controlled environmental conditions. The researchers found that from the juvenile phase onwards, snail mortality rates slowly increase. In particular, after week 14, mortality rates rise to about 28%, and it is higher in small-sized animals (Daguzan et al., 1982). Daguzan et al. (1985) found that, in a mixed farming system, mortality rates can fluctuate between 28% and 69% at different density levels.

Several studies claim that mortality rates increase in overcrowded facilities (Dan & Bailey, 1982; Dupont-Nivet et al., 2000; Jess & Marks, 1995)[29]. Dan & Bailey, (1982), for example, found that many more animals die at medium and high densities–approximately one-third of snails–when compared to snails reared at less crowded environments. According to Dupont-Nivet et al. (2000), the mean mortality of snails reared at different densities was around 21%, and this figure would be similar to that observed in snail farms. It is also close to the estimates by Cuéllar et al. (1986).

Additionally, Daguzan et al. (1981) report exceptionally high mortality rates among **breeding snails**, affecting 39.6% of animals. Cuéllar et al. (1986) state that in intensive farms–where animals are reproducing continuously–, mortality is usually very high: after one year of breeding, 70% of reproductive snails generally die (123). According to Daguzan et al., (1981), this high mortality rate among breeding snails probably results from "normal death" [sic] and the exhaustion of snails placed in intensive breeding (262). Indeed, other researchers point out that high reproductive activity could negatively affect the life history of snails (Çelik et al., 2018).

These and other estimated mortality rates are summarized in the table below (fig. 5):

[29] Nevertheless, it should be noted that Daguzan et al. (1982) found no significant differences in mortality rates in snails bred at different densities.

Animal	Estimated mortality rate	Source
Newborn snails	20% (in extensive farms)	Padilla & Cuesta (2003: 99).
Growing snails	10%	Murphy (2001).
	12%	Daguzan et al. (1985)
	15% (in extensive farms)	Padilla & Cuesta (2003: 99).
	15% - 20%	Cuéllar et al. (1986: 123).
	21% (mean)	Dupont-Nivet et al. (2000).
	28% (mean)	Daguzan et al. (1982).
	28 - 69% (at different density levels, in a mixed system)	Daguzan et al. (1985)
Breeding snails	21%	Daguzan et al. (1985)
	39.6%	Daguzan et al. (1981).
	Up to 70%	Cuéllar et al. (1986: 123).

Fig. 5. Estimated mortality rates of snails reared in captivity, according to different sources.

Furthermore, mortality may have a higher prevalence during months characterized by variations in weather conditions, reaching up to more than 60% among juvenile snails (Çelik et al., 2018).

These high mortality figures do not seem to surprise snail breeders. For example, Novagric (2015), a Spanish snail company, affirms that mortality rates in snail farms are "very high." The company attributes the prevalence of this phenomenon to limited habitat in captivity, to frequent crowded conditions to forced feeding and, generally, to the poor hygienic conditions that these breeding spaces usually have. Similarly, Vera García (2016) states that high mortality rates are also frequently described in farmed snails, even if the cause is not altogether clear.

In farmed snails, these high mortality rates are commonly preceded by a series of symptoms, such as loss of reflexes, incomplete retraction of the animal in the shell, and change of color of the foot–becoming yellowish or greenish in its margins–. Additionally, snails may not retract their ocular tentacles, the head grows, the genital pore dilatiates, or the animals may secrete filamentous mucus from the mouth (Vera García, 2016).

It is not known whether mortality rates are higher or lower for snails living in the wild. However, observations of *C. aspersum* in natural conditions indicate a lifespan of 3-5 years. Yet the species is known to live up to 10 years in artificial conditions (Comfort, 1957 in CABI, 2018;

Taylor, 1914 in CABI, 2018). In the case of *H. pomatia*, adult individuals may live up to 20 and even 35 years, but usually snails die much younger because of unfavorable environmental conditions (Schultes, 2014). In the case of *H. lucorum*, they are sexually mature 3 years after hatching; however, it is estimated that snails of this species may live up to 14 years (Staikou et al., 1988). For its part, *A. fulica* may live up to 9 years in captivity (Mead, 1961: 21), but no clear information was found about its average lifespan in the wild.

In the case of farmed snails, they are typically slaughtered when they reach their maximum or commercial weight. If well-fed, *C. aspersum*, for example, grow to their full size in one year. *H. pomatia*, for their part, can reach their full size in two to three years (FAO, 1986). *Achatina* snails, for their part, are suitable as a food only when young; when older, their flesh becomes leathery (Dr. Joseph Heller, personal communication, 25 January 2020). Hence, they are probably slaughtered well below their maximum lifespan, as it happens with *Helicidae* snails farmed for their meat.

To summarize, the following table (fig. 6) lists the welfare problems described above, and estimate which of them are more prevalent in snails under different farming systems. Based on our literature review, each aspect is ranked from "low," "medium" to "high" importance for each method of exploitation:

Welfare issue		**Systems of snail exploitation**		
		Extensive system	**Semi-intensive system**	**Intensive system**
Habitat and environmental conditions	**Temperature, humidity, and light**	High	Middle	Low-middle[30]
	Density and restrictions of movements	Low	Middle	High
	Feeding	Unclear	Unclear	Unclear
	Maintenance	Low	Middle	High
Health indicators	**Infectious diseases**	Middle	Middle	High
	Parasitic diseases	High	Middle	Middle

[30] In intensive farms, temperature, humidity, and light are strictly controlled. Therefore, in normal conditions, these factors do not constitute a threat to snail welfare. However, it should also be considered that catastrophic failure of control systems is a real risk in these facilities.

	Predators	Middle-high[31]	Middle	Low
	Mortality rates	Middle	Middle-high	High

Fig. 6. Importance of potential snail welfare issues, in different systems of exploitation.

Transportation and sale of snails used as food

Collection and preparation

Typically, only adult snails are harvested, either in farms or when snails are collected from the wild (Iglesias & Castillejo, n.d.). In farms, the animals are gathered when they reach their commercial weight (around 10 g), which usually occurs at 6 months old for *Helicidae* species (Padilla & Cuesta, 2003: 101). Images suggest that snails are collected manually and stored in sacks (see fig. 7).

After collection, snails are purged of anything unhealthy they may have eaten. Traditionally, purging involves a period of fasting of five or six days. Previous to this fasting period, animals may be fed only with cornmeal or bran since it will clean out previously-eaten food (Thompson & Cheney, 2008). During this process, snails are kept in a closed container or box. Then, they are washed in running water and placed into a large container with layers of salt in between them.

Salt is used to make the animals disgorge any substance that may be toxic for human consumption. Since snails have a thin, moist skin, when salt or a saline solution is poured on them the animal's water is very rapidly pulled out of their cells by osmosis. This process causes dehydration, making snails foam. Also, it may be painful. If snails are sentient, this process may feel like salt rubbed in a wound (UCSB ScienceLine, 2017).

Forcing snails to disgorge is an indispensable step when it comes to snails collected from nature. For their part, farm-raised snails may undergo a more straightforward process, being kept away from soil in a grated box and washed daily (Iglesias & Castillejo, n.d.; Snailfarm.org.uk, 2019). In this case, snails are not fed, but they are supplied with water. Pens are also cleaned several times a day to keep mucus and fecal matter out (Thompson & Cheney, 2008).

After being rewashed, snails are examined, cleaned, and sorted by size (Iglesias & Castillejo, n.d.). Each snail should be inspected to ensure it looks healthy. Only active snails must be selected for processing or shipping, since an inactive snail may be sick or dying. Commonly,

[31] Depending on the farm's infrastructure to prevent the presence of predators.

juvenile individuals and small adult snails are discarded, since they are not commercially desirable (Iglesias & Castillejo, n.d.; Thompson & Cheney, 2008).

Fig. 7. Collection and storage of live snails. Source: Touchstone Snail, 2015a.

As noted, snail collection and preparation involves continuous handling of the animals, and access to food is severely limited as well. Snails are packed together and practically impeded of all movement. Probably, all this process is extremely stressful for snails.

Shipping conditions

For shipping–whether for processing or direct commercialization–snails are packed in containers (e.g., into sacks in plastic crates, see fig. 7 and 8). In any case, shipping cartons must have air holes, preferably screened to prevent snails from escaping (Thompson & Cheney, 2008). Several pictures regularly show snails packed in sacks in overcrowded conditions, crushing each other (e.g., fig. 8).

Live animals are transported in refrigerated containers by truck, ship, and also by plane (Touchstone Snail, 2015b). The low temperatures in these containers (around 4º C) should neither kill the animals nor freeze them either, but induce hibernation (Thompson & Cheney, 2008; Touchstone Snail, 2015b). In fact, refrigerating (not freezing) live snails is a recommended practice for storing these animals even for several months (Pearce & Örstan, 2006: 269).

Fig. 8. Live snails packed in sacks. Source: Touchstone Snail, 2015a.

Snails are not fed during shipping. According to Thompson & Cheney (2008), providing them with food "will spoil and may make the snails sick or die".

Long-distance live snail shipping seems to be a common practice. According to the Spanish Interprofessional Heliciculture Federation (FIH, 2017 in Bouaziz, 2017), 80% of the 15,000 tons of snails that Morocco exports annually to Spain are not processed but shipped alive.

Processing and commercialization

In Africa and some European countries (e.g., Spain, Portugal), snails are commonly sold live in markets, packed in sacks or baskets. Snails are crowded together, crushing each other (see e.g. Aloise, 2012). Since –unlike when shipped– animals are not now usually exposed to low temperatures, they remain active. Even so, snails can hardly move at all.

These conditions often result in very high mortality rates (Hardouin et al., 1995). When animals do not die, overcrowding, severe movement restrictions, and frequent handling probably place significant stress on them.

In other cases, snails are processed to be sold blanched, frozen, or canned to be ready for consumption (Escargot World, 2016-17c; Touchstone Snail, 2015a; see fig. 9 and 10).

Fig. 9. Frozen and pre-cooked snails, sold at two different popular supermarket chains in Spain. In both cases, they are Otala lactea *snails, a species also known as the milk snail or Spanish snail (for more information about O. lactea's use, see [Padilla & Cuesta, 2003: 89]).* O. lactea *belongs to the* Helicidae *family, the typical European snails.*

Fig. 10. Blanched snails, ready for consumption. These products are sold at the Spanish supermarket chain 'El Corte Inglés'.

In the case of giant African snails, sometimes fragments of these snails are introduced into snail shells of *H. pomatia* or *H. aspersa maxima* to pass them off as snails of European species (Hardouin et al., 1995). However, it is not known whether this practice is still prevalent, and if so, how widespread it is.

Slaughter conditions

Typically, snails are slaughtered by boiling. First, the animals are rewashed and soaked in water. Then, snails are put in boiling water and cooked to death. Given their size, giant snails must be cooked longer. In any species, boiling the animals makes removal from the shell easier (Snailfarm.org.uk, 2019; Thompson & Cheney. 2008). Discussing to what extent being boiled alive is a painful experience is beyond the scope of this report. However, it is worthwhile to succinctly explore the scientific evidence of snails' responses to heat.

In general, snails and in particular, *Helicidae* snails do display avoidance behavior in response to high temperatures, and other nociceptive reactions to a potentially threatening tactile stimulus (for *Helix* snails see Balaban, 2002, and Ierusalimsky & Balaban, 2007 in Crook & Walters, 2011; about *Cepaea nemoralis*, another *Helicidae* snail, see e.g. Dyakonova et al., 2005). These reactions have also been observed in other land snails as well (i.e., *Megalobulimus sanctipauli*, according to Achaval et al., 2005). Additionally, these responses are reduced by opioids (i.e., morphine), suggesting the participation of endogenous opioid peptides in these reactions (Achaval et al., 2005), as it happens in mammals.

This evidence suggests that fundamental components of painlike information processing in vertebrates might be present in a rudimentary fashion in snails. Additionally, high temperatures seem to be an aversive stimulus to snails, and, consequently, these animals can modify their behavior in order to avoid it. Although these findings are not sufficient to conclude that snails feel pain caused by heat, several sources that provide instructions for cooking snails mention the attempts of snails to escape boiling water (see, e.g., Chilla, 2019; Blog de Cuina de la Dolors, 2011, Urrutia, n.d.). This is why it is repeatedly pointed out that the pot where snails are being cooked must be covered. Additionally, since salt can be deadly to snails, and therefore, they are repelled by it, it is also recommended to spread salt on the edge of the pot as a method of dissuading them from escaping (Asociación de Amas de Casa y Consumidores de Callosa Segura, n.d.; Chilla, 2019; Recetasdecaracoles.com, 2008-2018). This anecdotal evidence reinforces the possibility that coming into contact with salt causes a negative experience for these animals.

Furthermore, in countries like Spain other killing methods are employed, like low-temperature cooking and drowning. In the first case, snails are put in a pot, and cold water is added until it completely covers the animals. Then, the snails are cooked on very low heat, until they are boiled to death. The second technique consists in placing the animals in a plastic bag, or into a large bowl, full of water. The bag must be closed with a firm knot, or if a vessel or container is used, it must also be sealed firmly (see CocinAdictos, 2012). It is not recommended to simply put the snails in a covered pot filled with water, because the animals are usually able to lift the lid off the pot when trying to escape (MiCulinaria, 2013). In this way, the snails are left in water for at least six hours, until all of them have drowned (CocinAdictos, 2012; Recetasdecaracoles.com, 2008-2018).

While the animals are being slowly cooked or while they are drowning, they try to escape, even leaving their shells behind. That is why these two methods are called “deceiving the snails” (‘engañar a los caracoles’ originally in Spanish): while being killed, snails are given plenty of time to try to make a getaway. In their attempts, snails first move around and, after a while, they start to squirm and get out of their shells. Hence, when using these methods, snails typically die out of their shells. That is precisely why these methods are recommended, since they spare the cook the work of manually removing the animals from their shells (Asociación de Amas de Casa y Consumidores de Callosa Segura, n.d.; Blog de Cuina de la Dolors, 2011; Chilla, 2019;

CocinAdictos, 2012; Recetasdecaracoles.com, 2008-2018). Some sources admit that these methods are exceptionally cruel (CocinAdictos, 2012; Urrutia, n.d.).

Thus, after being excessively handled during washing, snails die slowly by boiling or drowning. If these animals are sentient, any of these methods is probably a painful way to die. In particular, drowning and cooking on low fire possibly cause a prolonged period of agony.

Afterward, the dead snails are entirely taken out from their shells. Most often, the hepatopancreas organ, the snails' equivalent of a liver, is removed, and the flesh is soaked in salty water for a half-hour. After one final wash, the meat is ready to be cooked or frozen (Hardouin et al., 1995; Snailfarm.org.uk, 2019; Thompson & Cheney. 2008).

No legislation covering methods or recommendations for snail slaughtering was found. In Europe, for example, the Regulation (EC) No. 1099/2009, on the protection of animals at the time of killing, excludes snails and any invertebrate animal from its scope of application. Specifically, the regulation states that by "animals" is meant "any vertebrate animal, excluding reptiles and amphibians." European law only regulates the handling and processing of snails–i.e., Regulation (EC) No. 853/2004, Section XI.

Other welfare concerns: Production of snail slime

As previously described, snails secrete mucin not only to move but when they are perturbed or threatened (Denny, 1983; Greistorfer et al., 2017; Newar & Ghatak, 2015). Hence, traditionally, slime is obtained from fasting snails, which are physically stressed by different forms of stimulation (Alcalde & del Pozo, 2008). This process is called "milking" snails.

A standard method of "milking" snails involves the use of a delicate utensil, such as a stick, made of wood or plastic. This piece is inserted over the head of the snail into its shell. Once introduced, the animal will start drooling (CriaderoDeCaracoles.com, n.d.; Rebelo, 2016). Another widespread technique consists in stressing the animal by exposing it to substances that a snail tends to repel –vinegar (acetic acid) or salt (Sampò, 2017 in Mitzman, 2017). The noxious substance is poured on them (Bucher, 2007 in Diario Sur, 2007), or snails are dunked in pots of water with those substances (Vogt, 2017)[32]. As previously described, these elements quickly suck the water out of the animals' cells. As the snail dries out, its body secretes slime to protect itself. It also produces bubbling, because of the slime and air being forced out of the snail's body as it shrivels up. If snails are sentient individuals, being immersed in a saline solution would probably feel like being burned alive (UCSB ScienceLine, 2017). Due to the

[32] The 'noxious substance' used is typically an aqueous hyperosmolar solution. That is to say, it is a solution with an elevated concentration of solute per litre, which results in a high osmotic pressure or a solution's capacity to take in pure solvent by osmosis.

severe dehydration it causes, this process kills the animals (Sampò, 2017 in Mitzman, 2017; UCSB ScienceLine, 2017).

For its part, a French company, Maison Royer (2015), states that they place snails in a net, and then the animals are "gently" agitated. In this case, the snails start producing slime as a stress response to the shake. Similarly, according to the klog, a beauty website, South Korean skincare company Cosrx extracts snail mucin by placing the animals "over a mesh net in a dark and quiet room. (...) For about 30 minutes, the snails are left alone to freely roam the net, leaving mucin in their trails. Throughout the process, there is no external stress applied to the snails or the mesh net to force mucin production. (...) After 30 minutes, the snails are transferred back to their homes to rest and regain energy (...) (Cho, 2018)."

Apparently, each manufacturer has its own know-how when it comes to collecting snail mucin, and they seem to be reluctant to give details about their techniques[33]. Overall, the techniques employed and their implications for snail welfare remain obscure or vague. However, some companies or beauty websites–like Maison Royer or Cosrx–insist that snails are not harmed during slime extraction. In contrast, Simone Sampò (2017 in Mitzman, 2017), director of the Istituto Internazionale di Elicicoltura (*International Institute of Heliciculture*) in Cherasco, Italy, states that traditional methods used to produce mass quantities of snail slime do harm the animals.

Scale, neglectedness and tractability considerations

Scale

Estimated number of snails produced

Since it is highly difficult to obtain reliable figures about snail production and consumption, it is even more laborious to get reliable estimations about the number of snails used and killed worldwide. This task becomes more complicated by the fact that this industry employs snails of different species in proportions that are not officially known.

With these constraints in mind, following FAO's (2019a) data on snail production, I estimate that in 2017 between 1.2B to 3.4B snails were killed (see *Appendix 4*). Of this interval, let's consider

[33] In addition to surveying the literature, I contacted two other companies about their methods of snail slime extraction –Elicina, one of the first ones to produce snail cream, and Darvėja, an important European producer. However, I received no response.

the worst-case scenario–that is, the one where the highest number of snails are killed. 3.4B snails is more than twice the recorded number of pigs that were slaughtered in 2017 for meat production (i.e., 1,485,986,756, according to FAO, 2019c[34]). Still, it is a small number (5.1%) compared to the recorded figure of chickens slaughtered for their meat in that same year (i.e., 66,566,725,000 according to FAO, 2019c). These differences can be observed in the following graph (fig. 11):

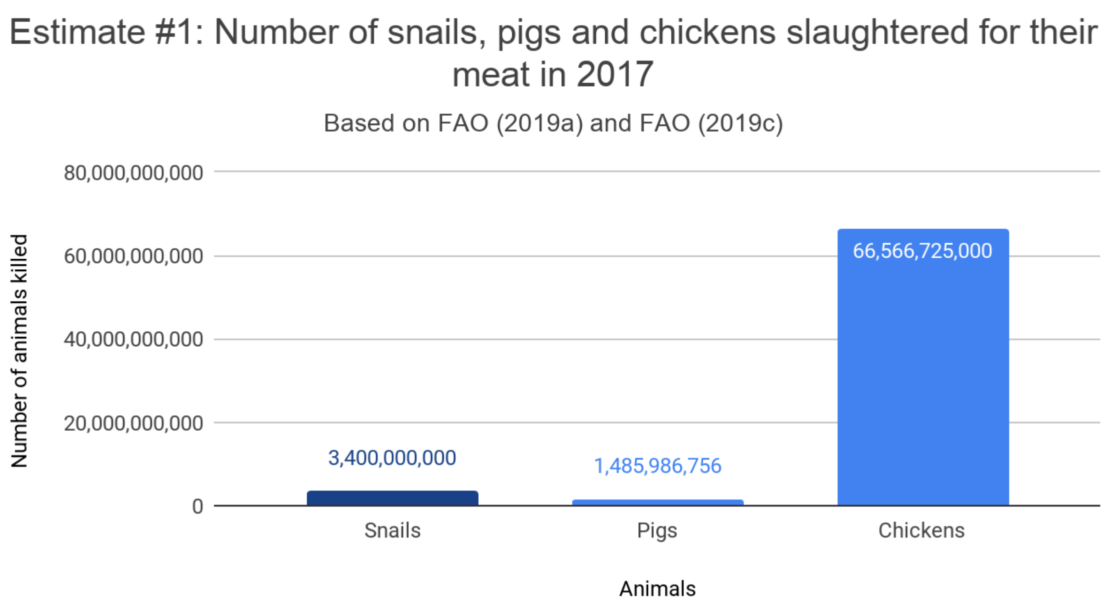

Fig. 11. Estimate #1. Comparison of number of snails, pigs and chickens slaughtered for their meat in 2017, based on FAO (2019a) data.

Nevertheless, given that the FAO snail production data is an underestimate, it is worth considering the production figures provided by Indexbox (2018 in Food Dive, 2018). Based on their data, I estimate that between 2.9B to 7.7B snails were slaughtered worldwide in 2016 for their meat (see *Appendix 4*). Again, let's consider the worst case scenario: in this instance, the highest number of snails killed, 7.7B, equals more than five times the recorded number of pigs slaughtered in 2016 for their meat (i.e., 1,480,741,771 animals, according to FAO, 2019c). Nevertheless, this estimate represents about 11.7% of the recorded figure of chickens slaughtered for their meat in that same year (i.e., 65,787,732,000 animals, according to FAO, 2019c). The following graph (fig. 12) illustrates these differences:

[34] Parameters: *Livestock Primary; World + (Total); Producing Animals/Slaughtered; Meat, pig; Meat, chicken; 2016, 2017*. The complete FAO dataset is available here. However, it should be noted that FAO figures mentioned here do not include animals killed in domestic slaughters, animals that die while transported or in any other circumstances before being slaughtered –e.g., animals that die in the farm before reaching their fattening weight.

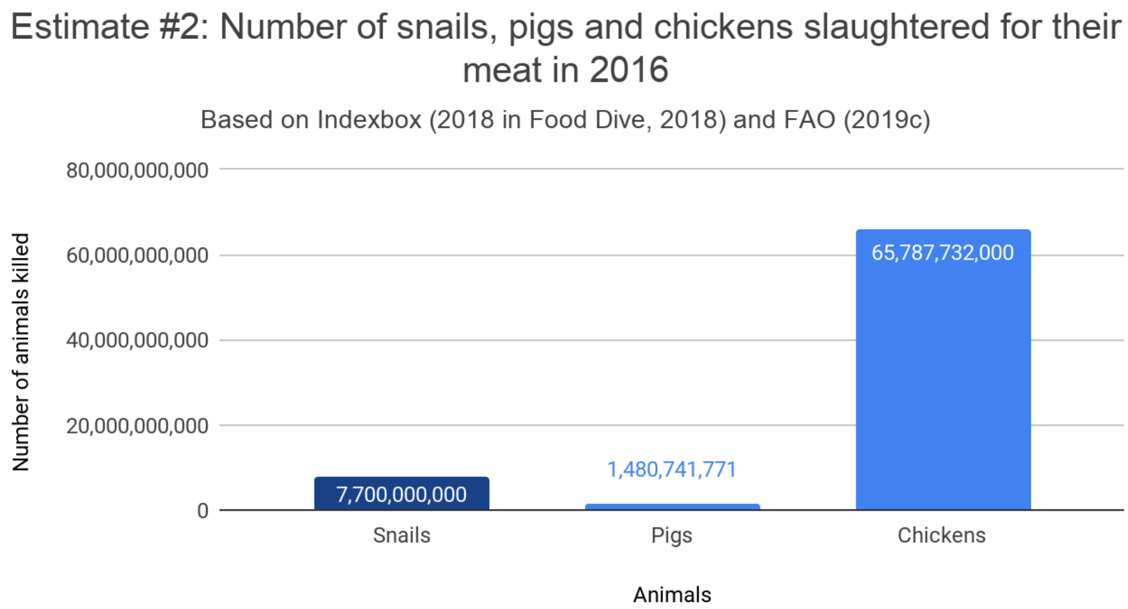

Fig. 12. Estimate #2. Comparison of number of snails, pigs and chickens slaughtered for their meat in 2016, based on [FAO (2019a)]() and [Indexbox (2018 in Food Dive, 2018)]() data.

Since there is no data available about mortality rates during transport, numbers of breeding snails used and breeding snails' mortality rates, these factors could not be included in these estimates[35]. Hence, the real number of snails slaughtered is probably closer to the upper limit than to the lower limit of the interval –i.e., 7.7B individuals.

For a more complete assessment of the scope of the problem it is also necessary to consider how many snails may be alive in the industry at any time. Given the underestimation of the FAO (2019a) figures, I calculated that number based solely on the data provided by Indexbox (2018 in Food Dive, 2018), as detailed in *Appendix 4*. In this case, I estimate that in 2016 between 3.8B to 11B snails were alive at any time, in order to meet the market's annual demand.

How to interpret the magnitude of these figures? Again, comparing them with the number of pigs and chickens alive at any moment can help to better understand the scope of the problem. As previously, let's consider the worst-case scenario–that is, the highest number of the interval, or 12B snails alive at any time. 12B equals more than 12 times the recorded number of pigs alive at any moment in 2016 (i.e., 978,466,142 animals, according to FAO, 2019d[36]). Still, this number is far less than the number of chickens alive at any time that same year (i.e., 22,562,532,000, according to FAO, 2019d). In particular, it is slightly more than half (53.2%) the number of live

[35] Similarly, it should also be noted that FAO figures on the number of chickens or pigs slaughtered for their meat do not include breeding animals or animals that die before reaching the slaughterhouse. On the contrary, our estimates for the number of dead snails partially account for these mortality rates.
[36] Parameters: *Live Animals; World + (Total); Stock; Chickens; Pigs; 2016*. The complete FAO dataset is available here.

chickens in the meat industry in 2016. These differences can be observed in the following graph (fig. 13):

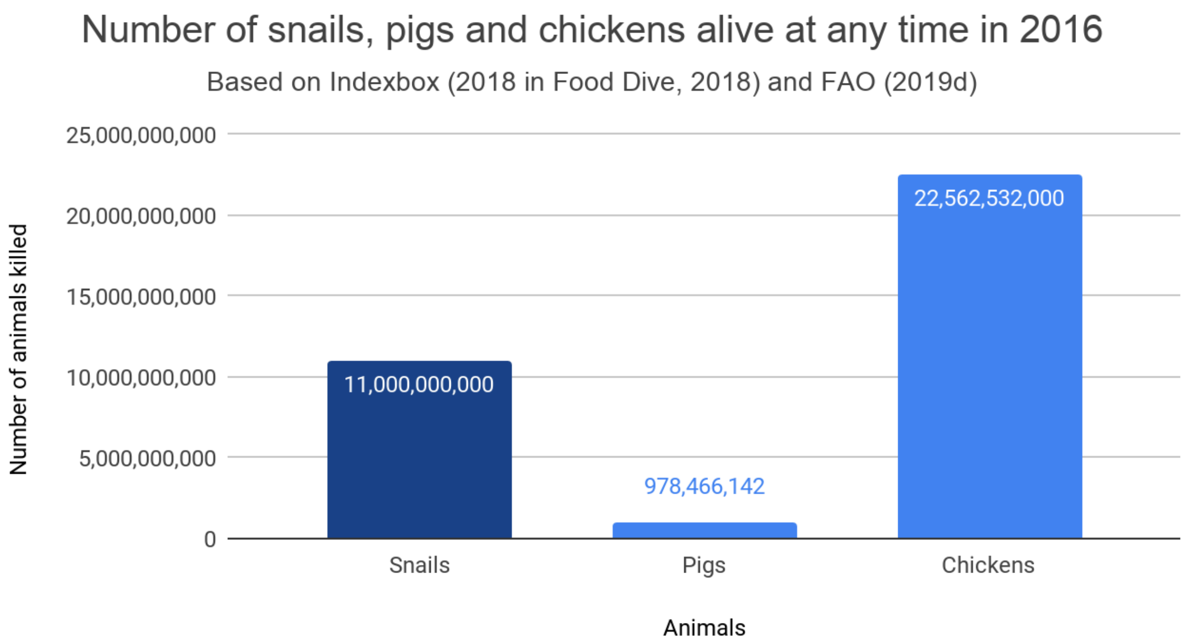

Fig. 13. Comparison of number of snails, pigs and chickens alive at any time in 2016, based on FAO (2019d) and Indexbox (2018 in Food Dive, 2018) data.

However, to make these comparisons more meaningful, ideally, we might also consider the severity of harms inflicted on the animal species here compared. Such a comparison should cover different production systems, and the suffering caused by different slaughter methods and other relevant procedures as well.

In the meantime, we can conclude that, even assuming that snail meat production causes massive suffering, this problem is of much lesser magnitude than the exploitation of some farmed vertebrates like chickens–or fishes caught from the wild (see Fishcount.org.uk, 2019)–both because of the greater number of individuals involved and because there is much more solid evidence that these vertebrates are sentient.

Finally, note that these estimates only refer to snails slaughtered for their meat[37]. For a further description of the methodology behind these calculations, see *Appendix 4*. No data was found to make equivalent estimates of snails used for other purposes.

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[37] The figures provided by Indexbox most probably refer to snails traded for their meat. Theoretically, some live snails intended not for meat but for cultivation might be included. However, "even if such snails exist, it is unfeasible to break them out from the total figures, and their share in terms of total figures should be small" (S. Avramenko, personal communication, 13 January 2020).

How likely is this problem to grow?

As *per capita* consumption in countries like Morocco, France and Portugal went upwards in recent years (2007-2016), according to IndexBox (2018 in Food Dive, 2018), further market growth in these countries is likely to be expected in the medium term.

The same company forecast in 2010 that the market would grow to produce over 51,000 snails by 2016. However, the actual figure (i.e., 43,000 tonnes) is 2,500 tonnes less than the snails produced in 2010 and 8,000 tonnes below forecast (IndexBox, 2018 in Food Dive, 2018; Indexbox, 2019). Similarly, more recent market trends suggest a slowdown in the market, reflected in a gradual reduction of the international trade value of edible snails during the past years (see *Appendix 2*, and ABRAMS World Trade Wiki, 2019; Chatham House, 2019; IndexBox, 2018 in Food Dive, 2018; Indexbox, 2019; Tridge, 2019; United Nations, 2019).

While snails remain at a privative price (e.g., in France, see Bord Bia, 2018; Daoust, 2011), a significant increase in their demand seems unlikely. In Spain, despite being the major snail consumer in the world, snail demand has stagnated in the past years (Generalitat de Catalunya, 2010; Tridge, 2019) and it may progressively diminish throughout the next decades[38]. Furthermore, given the cultural specificity of eating snails (Elmslie, 2005), I consider that existing markets for snail meat are limited and that it is unlikely to expand to new ones.

Except for Morocco, since production estimates for 2016 are very similar to those for 2010, it is reasonable to expect that snail meat production will remain relatively stable in the coming years.

Nevertheless, the situation may be different for snails used for slime production. Seemingly, the boom of snail mucin-based cosmetic products has also boosted the snail farming industry, at least in countries like Italy and Morocco (Kasraoui, 2017; Saner, 2017; Vogt, 2017). In 2016, a BBC article called snail slime one of the South Korean skincare industry's "key ingredients." The exports of such items from that country are "soaring," according to the same article (Arthur, 2016). Given the above, improving the exploitation conditions of snails used for cosmetics could have a more significant impact in the future than affecting the breeding of snails for other purposes.

[38] Anecdotal information provided by local consumers also suggests that eating snails is much more prevalent among older generations than among the youngest population. Furthermore, the sociocultural context that once encouraged snail consumption in a country like Spain has profoundly changed (see Elmslie, 2005: 106-108). If there are no new social norms or incentives that promote snail-eating among the younger generations, consumption of these mollusks is likely set to slowly decrease throughout the next decades.

Neglectedness

As outlined in a previous post, invertebrate welfare is an issue that has not attracted much attention within the effective altruism community and the animal welfare movement. Even though invertebrates comprise more than 99.9% of all animals, there is no single organization in the effective animal activism movement exclusively working to promote invertebrate well-being.

Beyond the effective animal advocacy ecosystem, very few organizations are concerned about snail welfare. In the Anglo-Saxon world, PETA is one of them. This organization has published some content about snail exploitation for slime production (e.g., see here, here, here, and here). However, except for one mention in a book by PETA's president (Newkirk, 2009: 50), apparently no statement has been made on the consumption of snails. I could not identify any other organization in the English-speaking world that has addressed snail consumption.

For its part, in Spain a couple of animal rights blogs have published two short articles about "the cruelty of eating snails" (see here and here). In Portugal, some years ago, an association (Acção Directa[39]) launched a campaign against cooking live snails (see fig. 14).

Fig. 14. "Would you like to be cooked alive? Neither do they"[40]. This is the motto of the awareness campaign launched by Acção Directa in Portugal in 2014. Source: Acção Directa (2014).

Nevertheless, it must be stressed that neglectedness, in itself, is not a sufficient argument for considering snail welfare to be important. We should also examine whether there are good

[39] *Direct Action*, in English.
[40] Own translation of the original text in Portuguese: "*Gostava de ser cozido vivo? Ele também não*".

reasons why effective altruism or animal welfare organizations are *not* investing resources in a given issue. It might be, for example, that the problem–as such–does not exist. That would be the case if we found out that snails are possibly *not* sentient. But even assuming our current uncertainty about snail sentience, we may have other good reasons (e.g., tractability-related reasons) for not prioritizing their welfare. For instance, suppose we concluded that the exploitation of snails for their meat will start declining in the near future. If so, in a few years' time, without any kind of intervention on our part, the problem may disappear or, at least, become much less serious. In this scenario and considering the opportunity cost of helping snails and not other individuals, we may have good reasons for not investing additional resources in this cause.

In this respect, we may have good reasons for not openly promoting snail welfare– or, at least, for not promoting it among the general public. First, because of our uncertainty about snail sentience and snail welfare tractability. Second, because of the psychological barriers that make the moral consideration of animals like snails especially difficult for us (see *Invertebrate welfare: Thinking about directions for future work, Part 3*). Therefore, we must be cautious when assessing to what extent the neglectedness of snail welfare should be considered a strong consideration in favor of working on this issue.

Still, our uncertainty about snail sentience should encourage us to promote further scientific research in this matter. However, even in academia, there is a general lack of concern for studying welfare-related issues about snails. A Google Scholar search with the keywords 'snail welfare', for example, produces only six results, and only a couple of those publications provide some relevant, yet very restricted, information about this issue. A broader search (e.g., 'snail', 'welfare', 'helix', 'pain') produces additional publications with minimal information about particular aspects of snail well-being (i.e., Cooper & Knowler, 1991; Crook & Walters, 2011). That is not surprising, given that snail biology has not been sufficiently researched, and this knowledge is a prerequisite for assessing critical snail welfare issues and ways to address them (Cooper & Knowler, 1991).

Finally, most of the complete descriptions of snail farming conditions are written in different (local) languages. The latter may obstruct scientific communication –in particular, evidence compilation, as well as the exchange and contrast of information between researchers.

Tractability

If there is minimal information about snail welfare, even less knowledge is available about possible interventions on behalf of these animals. A general review of the conditions under which snails are maintained, used, transported, and killed suggests that snails are often managed with minimal care and oversight, in contrast to the concern shown to vertebrates.

Hence, to design cost-effective interventions on behalf of these animals, first, further research about snail treatment at different points in their lifecycle is highly needed.

The above entails that, for the time being, we know very little about specific ways of improving snail welfare. However, ignorance is not necessarily a decisive argument for dismissing a cause, nor for concluding that it is intractable. Having insufficient knowledge should prompt us to learn more so as to maximize our chances of successful interventions. Or, at least, further research should contribute to determining with stronger foundations whether snail welfare is not important or if, for various reasons, it is not cost-effective to address it.

In this section, I explore some specific measures that should be considered to improve snail farming conditions, shipping, slaughter conditions, and an alternative to reduce the potential harms inflicted on snails during the process of slime extraction. Nevertheless, given the current state of knowledge, the scope of these recommendations is limited, especially on a commercial scale.

Additionally, it should be taken into account that tractability does not only depend on the availability of adequate interventions, but also on what at any given time is socially and/or politically possible to implement. In this regard, I must admit that I have severe doubts as to whether there may be any interest in applying several of the specific recommendations here presented. However, this does not rule out the possibility that there will be opportunities to improve certain aspects of snail welfare in the future.

Developing optimal rearing conditions

As described, under extensive or intensive conditions, management methods of farmed snails vary considerably. If these animals are sentient, suboptimal environmental conditions and nutritional deficiencies are known to deteriorate snail welfare, causing or contributing to their mortality.

In general, adequate **humidity, temperature, and light** are usually better guaranteed in controlled environments. Following Padilla & Cuesta (2003: 90-92), humidity should be between 80-90%. Temperature, for its part, should be between 10ºC and 30ºC, with an optimum of 17–25ºC. Regarding light, it is recommended that snails have a photoperiod of at least 8-12 hours of light. Given the relevance of these abiotic factors in snail mortality, snail farmers are usually aware of these recommendations, and they have an economic incentive to ensure them.

Rearing densities, for its part, is another crucial aspect for snail welfare. In this case, there is no explicit agreement on optimal density conditions. The Spanish Ministry of the Environment

(MAPAMA, 2009), for example, states that "the density of animals shall be adequate to ensure animal welfare (...)"[41] (41). However, no specific recommendations are provided.

Giving the effects of overcrowding in the development and health of these animals, rearing snails in very densely populated areas is considered a "false economy" (Thompson & Cheney, 2008). Hence, snail farmers also have an economic incentive to limit population densities. In this regard, Charrier and Daguzan (1978 in Dupont-Nivet et al., 2000), for example, suggest an optimal growth performance density of 133 individuals (*C. aspersum*) per m^2. Therefore, we can assume that density levels above this limit are detrimental to snail welfare.

Surprisingly, optimal **feeding** is a matter of even greater uncertainty (Cuéllar et al., 1986: 56; Padilla & Cuesta, 2003: 102-103). Further research about the specific nutritional needs of snails is highly needed. At the very least, the composition of the food provided must be monitored. In addition, the transport and storage conditions of the feed should be controlled to prevent the proliferation of mycotoxins (Cuéllar et al., 1986: 122).

Furthermore, it is in the interest of producers to maintain their **breeding facilities** in good condition –it is necessary to prevent the proliferation of diseases, reduce mortality rates and, in many cases, comply with existing regulations or market requirements. Countries like Italy or Spain, with a long tradition in snail consumption, have developed official handbooks of good working practices in heliciculture (Micheli et al., 2019; see Spanish Ministry of the Environment, 2009). Disseminating these recommendations, education, and training of both veterinarians and snail keepers could contribute to improving the conditions and maintenance of farmed snails. This is a measure that, in turn, can be supported by the private sector. However, these good practices do not consider health indicators and include no standards to safeguard individual snail welfare.

The main challenge is that further recommendations to ensure snail welfare seem to be unavailable. For example, snail health problems, although a fundamental aspect of their well-being, is a much-neglected topic. Although diseases can cause major economic losses, farmed snails do not receive any treatment simply because those treatments are unknown (Raut, 2004: 599-611). In this regard, a potential intervention that can make a significant difference for snail welfare consists in doing research on the most prevalent snail **pathologies**, whether caused by bacteria or parasites, and their possible solutions.

Finally, physical barriers can minimize the access of **predators** to sheds.

[41] Own translation of the original text in Spanish: "*La densidad de animales será la adecuada para garantizar el bienestar animal* (...)". Besides rearing densities, no other recommendations are given for ensuring snail welfare.

Developing better methods for handling and transportation

For shipping, animals are manipulated continuously and packed together in sacks, crushing each other. The adverse welfare effects of this process can be ameliorated if it is carried out between late fall and before spring begins–in regions where the winter is severe–when snails are naturally “dormant” (hibernating). In dry regions, snails may remain inactive during the hot dry season, which is usually during the summer months (estivation)[42]. Additionally, other sources say not to ship live *H. pomatia* snails from late spring and during summer, as they no longer have good flavor (Thompson & Cheney, 2008).

However, if snails are collected when hibernating, it will be more challenging to ensure that they are active and, thus, healthy (Thompson & Cheney, 2008). It is possible to determine whether the snail in diapause is alive, by detecting its (slow) heartbeat. However, this is hardly practicable on a commercial scale (Elmslie, 2005: 104-105). In addition, if demand for snails is not seasonal or if the flavor is not significantly affected during warm months, farmers may not be willing to limit the snail "harvest" period to fall and winter.

Transportation and sale: Discouraging the sale of live snails for direct consumption

If snails are sentient individuals, the deprivation conditions in which they are sold live probably imply prolonged suffering. Moreover, given the environmental conditions of popular markets themselves, and the fact that snails are highly sensitive to any atmospheric variation, pathogenic microorganisms can quickly proliferate. This is probably the reason behind the elevated mortality rates of snails sold live.

If these environmental conditions are likely to create sanitary problems or threaten food security, this is a good reason for an eventual ban on the sale of live snails for direct consumption. However, it should be noted that in some European countries (e.g., France), most of the snail meat commercialized is already processed, either frozen or blanched (Touchstone Snail, 2015a). If this trend is progressively adopted by other countries–as it seems to be happening in Spain, for example–, direct advocacy for a ban on the sale of live snails may not be a cost-effective initiative.

Developing better methods of killing

[42] I thank Dr. Joseph Heller for this point.

Drowning or simmering snails are perhaps the cruelest ways to kill them. According to Dr. Donald Broom, Cambridge University Professor of animal welfare, "cooling them [snails] right down in the freezer to slow their nervous processes, and making sure that the water you drop them into is already boiling, is the best way to ensure they are killed quickly" (CooksInfo, 2004; Rivera, 2016).

Except for chef Gordon Ramsay (2011 in FoodFirst TV, 2011), no other source recommending this practice was found. It is probably because this method, although simple, implies an additional step to the already cumbersome preparation of snails to be cooked, combined with a generalized disinterest in minimizing possible pain in these animals. Still, given snail physiology, it seems plausible that cooking hibernating animals in already boiling water causes them less suffering than traditional techniques.

Furthermore, a recent investigation suggests dipping snails in beer to sedate the animals before killing them (Gilbertson & Wyatt, 2016). It should be noted that this method was tested in land snails of a family different from that of the snails used for human consumption (i.e., *Succinea putris* spp., *Succineidae* family)[43]. Still, there are reasons to believe that findings for a species of land, air-breathing, pulmonate snails may be relevant for gastropods of similar characteristics. For example, what the researchers describe as 'aversive behaviors' of *S. putris* to various euthanasia solutions are notably analogous to the responses that the literature characterizes for edible snails when dumped into noxious solutions –e.g., retracting into the shell, defecating, and secreting abundant mucus. Notably, Gilbertson and Wyatt (2016) documented that when snails were immersed in beer, the animals did not display the aversive responses that were observed in snails dipped in other solutions. Nevertheless, one may ask whether the absence of these reactions is because the snails were anesthetized or because they were agonizing from a cause other than dehydration –i.e., drowning. In the latter case, the response of excessive mucus secretion, for example, would not be adaptive. On the contrary, a profuse production of slime usually occurs when the animals are exposed to substances that cause dehydration.

No other recommendations were found about how to kill snails causing them as little suffering as possible[44].

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[43] In particular, the main goal of this research was to identify a humane method of euthanasia that could minimize distress and pain in *S. putris* snails used in scientific research. According to their findings, a humane way to end the lives of these animals consists of a two-step method. First, the animals are immersed in a few ounces of beer or a 5% ethyl alcohol solution. This sedates and immobilizes the snails. Afterward, they do not exhibit signs of physical distress during the final step—a terminal dunk in 95% ethyl alcohol. According to the authors, this process is much like that used with companion animals, when dogs or cats are sedated before administering a final dose of a euthanasia drug (Gilbertson & Wyatt, 2016).

[44] Several websites have reported about a new Portuguese bill that would ban boiling snails while they are still conscious. This is a hoax, as stated on this website –which also seems to have been the original source of this fake news.

Similarly, other large-scale interventions on behalf of farmed snails were not found. Thus, I consider that the tractability of snails consumed for their meat is low, or at least, uncertain.

Implementing better methods of slime production

According to S. Sampò, a snail farmer and entrepreneur, stressed snails produce slime of lower quality than “happy” snails (Great Big Story, 2017; Mitzman, 2017). In view of the above, he and his team developed a slime-extracting apparatus designed to cause snails minimal discomfort, known as the Muller One.

The Muller One is a device that consists of a metal base, with two plexiglass domes under which 1,500 snails can be placed (see Lumacheria Italiana, n.d.). First, snails are washed and placed on the metal base of the structure. During the first half-hour, snails are sprayed with ozone to relax and cleanse them of bacteria and mold. Afterward, during the second half-hour, the animals are exposed to a nebulization of a solution of natural (undefined) substances, which stimulate them to produce slime (Lumacheria Italiana, n.d.; Mitzman, 2017).

According to Sampò, snails produce slime not only for locomotion or when threatened but also for pleasure. I could not find any scientific literature in support of this claim. Sampò maintains that the ozone-infused water is pleasant for snails, stimulating them to drool. "We consider this machine as a spa for snails," he argues (Great Big Story, 2017; Mitzman, 2017).

By the same token, one Italian cosmetics brand, Donatella Veroni, has developed a very similar device, called the OzoSnail. According to the company, this device was designed with animal welfare in mind and to get the most slime of each extraction procedure. Unlike what seems to happen with traditional extraction methods, in this case, snails can be placed back into the farm immediately after the extraction process (Vlifestyle, 2017).

Seemingly, both devices offer interesting advantages for the farmers: the slime they produce is supposed to be of better quality, the mucin is immediately sanitized, and they allow several extraction cycles. As the animals do not die during the extraction process, snails can be sold for their meat as well. However, these benefits and to what extent these methods do not harm the animals in a significant way are issues that should be assessed by independent researchers –not by the same companies that promote these devices. In particular, it is necessary to know if it is true that the slime produced by snails using these devices is not a response to stress, as one of the inventors of the Muller One assures. Only one scientific study (a Master’s dissertation) was found on the effect of sucking the slime from the snail foot, while preventing the dehydration of the animal. According to this investigation, adding distilled water during the process causes much less distress when compared with other methods of slime extraction through physical stimulation (Rebelo, 2016). However, the researcher does not conclude that snails produce slime because this is a particularly pleasant experience, as Sampò (in Great Big Story, 2017; Mitzman, 2017) states.

It is not currently known how widespread the use of the Muller One and the OzoSnail are. However, given the high price of the Muller One[45], this device is probably not affordable for a large part of producers and its benefits may not outweigh its economic cost.

To summarize, the following table (fig. 15) lists the different possible interventions, as presented above:

Rearing conditions:
• Limit rearing densities –133 individuals (*C. aspersum*) per m^2. • Research on the most prevalent snail pathologies and their possible solutions.
Handling and transportation:
• When snails are naturally "dormant" (between late fall and before spring in regions where the winter is especially severe; or during summer in dry regions).
Transportation and sale:
• Discouraging the sale of live snails for direct consumption.
Killing:
• Cooking hibernating (cooled) snails in already boiling water. • Dipping snails in beer to sedate the animals before killing them?
Slime production:
• Placing snails in a chamber where they are exposed to ozone and a nebulization of substances that stimulate them to produce slime (i.e., the Muller One or the OzoSnail). • Adding distilled water to the animal while the slime is sucked from its foot (?).

Fig. 15. Different possible interventions on behalf of snails used for human consumption.

Key issues that should be addressed

[45] Starting from 33,000€ (or $36,788), plus additional delivery and training costs (Donatella Pistagna, personal communication, 17 October 2019).

Are snails sentient individuals? If so, how should they be morally considered?

Whether snails have a capacity for valenced experience is still uncertain. In a series of publications by Rethink Priorities, we surveyed the scientific evidence on invertebrate sentience. Although we already studied 18 invertebrate taxa, including a representative of the *Gastropoda* class (i.e., Aplysia), we did not examine pulmonate (air-breathing) snails.

Studying and compiling extant evidence about pulmonate snails will be of interest not only because of the extensive use of these animals, but also to better understand the distribution of sentience within *Mollusca*. *Mollusca* is a very broad phylum with over 100,000 species, encompassing organisms of enormous diversity, with a significant variation in neural and sensory complexity (Crook & Walters, 2011). Thus, albeit snails are part of the *Mollusca* phylum, unlike other members of this group (i.e., bivalves), they are typically motile and active foragers.

However, we are much less confident about whether snails are conscious than we are regarding other *Mollusca* members such as coleoid cephalopods (see *Invertebrate Sentience: Summary of findings, Part 2*). In fact, snails have been considered as an edge case of consciousness in philosophical circles (see Schwitzgebel, 2018). At the same time, we are uncertain to what extent existing findings about a marine opisthobranch (i.e., *Aplysia californica*) are generalizable to pulmonate gastropods like terrestrial snails. Hence, further research is needed about whether these animals are conscious, and if they are, how we should morally consider snails compared to other moral patients. We briefly discussed the issue of moral weight in our invertebrate welfare cause profile. Still, much more research is needed in this regard.

What are people's moral attitudes toward snails? Would they be willing to support a form of intervention on behalf of snails?

Suppose we discovered that snails are conscious in a morally significant way. Suppose, in addition, that we possessed the technical means to aid them. For at least some interventions, we would still have to ascertain the likelihood that they will be socially supported, or supported by key stakeholders, and thereby, adopted. Hence, public attitudes towards snails and interventions on their behalf are a vital element to consider when determining the tractability of snail welfare.

So far, little is known about our attitudes towards invertebrates, and even less about our specific attitudes towards snails. However, there may be several psychological barriers that make the moral consideration of these animals especially challenging. We know, for instance, that categorization changes judgments of moral concern. If, in a given culture, snails are categorized as food, probably, people are motivated to deny mind, humanity and even moral standing to those animals because it is in their interest to do so (see Loughnan & Piazza, 2018 in Gray & Graham, 2018: 165-176). We know, moreover, that cuteness, seeing an animal as an intelligent individual, and perceiving it as similar to humans, are all factors that increase our concern for that animal's well-being (Loughnan & Piazza, 2018 in Gray & Graham, 2018: 165-176).

However, it appears that snails do not meet any of these conditions. If so, we do not even know if there are ways to overcome these psychological obstacles to snail welfare (see *Invertebrate welfare: Thinking about directions for future work, Part 3*). Given the discrepancy between a concern for snail welfare and the current way in which these animals are treated, and our possible psychological barriers to morally consider them, raising awareness about this problem is likely to have limited chance of success. Precisely, most of the social media comments to the campaign against cooking live snails in Portugal are negative (see Acção Directa, 2014), pointing out that many people may have trouble ascribing morally valuable states to these animals. In particular, the ideas that snails might suffer while being cooked alive and that we should do something about it strike some people as "crazy" or "ridiculous". Hence, it is conceivable that, in the short to medium term, initiatives to promote snail welfare may be fruitless or have an effect contrary to what was intended (ie., a backfire effect).

Despite our presumed resistance to morally consider snails, people may not have strong opinions one way or another about specific interventions on behalf of these animals. If there are interventions that could help snails, how these measures are perceived is an issue that merits further investigation. People may still support a specific initiative on behalf of these animals because of reasons different from a welfare perspective. We still have to obtain a better grasp of the arguments that may be used for an indirect promotion of such interventions, assuming there are any.

How can we improve the life of snails under human control?

There is an increasing acceptance of the link between animal health and animal welfare, and even, by extension, between animal health and food safety and food quality. Snail health problems, although an essential aspect of this matter, are a much neglected topic. As already stated, further research on the most prevalent snail pathologies, preventive health care, and treatment of these diseases is highly needed. Similarly, other welfare indicators should be assessed, including adequate feeding and, if relevant, behavior-related indicators specific to these species (e.g., deviations from normal behavior). Further research is also needed to discover the preferences and understand the positive experiences of these animals.

These research findings may unveil useful health, productivity, stress hormone levels, behavior, and preference indicators, along with other welfare-related factors. This empirical data, together with expert validation surveys, may contribute to elaborating a framework for assessing snail welfare, similar to the FOWEL model for hens raised for their eggs. Such a framework can help (i) determine the farming conditions that provide the highest levels of welfare; (ii) identify specific measures for improving snail conditions; (iii) advance in standard farming procedures, as well as (iv) evaluate which killing methods cause less suffering.

Nevertheless, it should be considered that improving farmed snail welfare does not only depend on the availability of adequate measures, but also on whether farmers have an incentive to implement them. While it is true that snail farmers have an economic incentive to maintain the health of their snails, they have little reason to look after the welfare of individual snails. Probably, they will be more willing to prevent diseases or to medically treat snails if those conditions are associated with a significant economic loss (i.e., epizootic diseases), or if associated with specific measures that affect food safety or improve food quality.

Moreover, even if farmers have some incentive, it is necessary to ensure that a given treatment is viable in practice, especially on a commercial scale. Hence, although welfare measures for snails may be developed, if they are not feasible and if they do not bring any benefit to the farmer, it is doubtful that they will be implemented in practice.

How will climate change affect snails and heliciculture?

Snails are highly sensitive to environmental conditions. Variations in humidity, temperature, and light can easily cause the proliferation of pathogenic microorganisms, which, in turn, can result in serious diseases that can kill a substantial proportion of a snail population. Climate change causes fundamental and rapid alterations to the habitats and the specific environmental conditions that snails require for surviving. Probably, climate change poses a great threat to the survival of some snail communities.

In particular, this phenomenon may directly affect the health and mortality rates of snails in those farming systems where environmental conditions are not totally controlled (i.e., extensive and mixed systems). In contexts of low incomes –where extensive farms predominate–, the above may disincentive heliciculture. On the other hand, in conditions where additional investment is available, climate change could encourage non-intensive farms to switch to intensive systems, and/or push farmers to breed snails of species that are better adapted to new climate conditions.

Furthermore, if climate change results in declining snail populations of economically relevant species, this phenomenon will probably encourage heliciculture to meet the demand (e.g., in Europe). I hypothesize this is likely to happen only in contexts where there is a tradition of collecting and commercializing snails, as it has already been happening in some African countries with *Achatinidae* snails (Ngenwi et al., 2010).

Overall, climate change can affect the prospects of the industry, given the potential impact of this phenomenon on the lives of snails. Still, these consequences are not well known (Bezemer & Knight, 2001; Marshall et al., 2015).

Conclusion

This report explores the use of snails for their meat, and to a lesser extent, for extracting their slime. The global snail market, major producing and consuming countries, and prospects for future growth were also described. Additionally, some factors that affect snail welfare, along with scale and tractability considerations were discussed.

As stated, between 2.9B to 7.7B snails were slaughtered for their meat worldwide in 2016. Although snail meat production possibly causes massive suffering if snails are sentient, the scope of the problem is of lesser magnitude than the exploitation of some farmed vertebrates like chickens or fishes. Moreover, it is likely that the scope of the problem will progressively diminish, in line with certain market trends. Additionally, despite the problem's neglectedness, there may be good reasons for not publicly advocating on behalf of snails, especially because we know of no large-scale initiatives to improve their well-being. In this sense, tractability appears as a current and inescapable limiting factor for ameliorating snail suffering, at least in the short to medium term.

All things considered, I conclude that investing specific efforts on behalf of snails used as food may not be cost-effective. Nevertheless, the prospects may be different for snails used for slime production. Recently, the sector of slime-based products seems to have boosted heliciculture. Moreover, this activity has a niche market that is decidedly different from the one of snails consumed for their meat. In this regard, further market research may contribute to a better understanding of how important this industry is, its prospects, and how the scale of the problem is likely to evolve.

Finally, if we eventually aim to design forms of intervention that help both snails farmed for different purposes and those living in nature, future work should primarily assess snail biology. That knowledge is fundamental to determine the likelihood of snails being sentient and to obtain a better understanding of the determinants of their well-being.

Credits

This report is a project of Rethink Priorities.
It was written by Daniela R. Waldhorn. Thanks to David Moss, Eze Paez, Dr. Joseph Heller, Jason Schukraft, Kim Cuddington, Marcus A. Davis, Dr. Pavel Balaban, and Peter Hurford for their contributions.
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Appendix 1: *Helicidae* and *Achatinidae* snails

Two main groups of snail species are used for human consumption: *Helicidae* and *Achatinidae* snails. In what follows, these two snail groups are briefly described.

Helicidae snails

According to Gheoca (2013b), the *Helix* genus, family *Helicidae*, represents over 70% of the world snail market[46]. Within this group, the most popular species are *Cornu aspersum*, *Helix pomatia*, and to a lesser extent, the *escargot turc* or Turkish snail (*Helix lucorum*) (Padilla & Cuesta, 2003: 87-88; Conte, 2015; Gheoca, 2013a; Snail-World, 2016; Yıldırım et al., 2004). This is because of their large size, but also due to their gastronomic qualities –taste, consistency and even color (Gheoca, 2013a).

[46] Gheoca (2013b) includes *C. aspersum* as members of the *Helix* genus, given that this how this species was previously classified.

Cornu aspersum (previously known as *Helix aspersa* [Müller, 1774]) is the common garden snail or more specifically, the European brown garden snail[47]. It is also known as *petit gris*, or "little grey" snail. As these names indicate, it is considered a relatively "small" species: typically, these snails weigh from 4 to 20 grams and measure from 30 to 45 millimetres (FAO, 1986). They have a weak shell that varies in coloring and shade of color, but generally, it has broken stripes which are light brown to black (Padilla & Cuesta, 2003; FAO, 1986).

These animals are native to the Mediterranean area and Western Europe. However, they have spread to different regions worldwide, especially where part of the year is warm and part of the year is cold (Padilla & Cuesta, 2003: 87-88; FAO, 1986). The little grey snails can adapt to different conditions, and some of their most common habitats are woods, fields, and gardens (Padilla & Cuesta, 2003: 87-88). In some regions (e.g., in California, USA), it is considered a widespread crop pest (Kay, 1995: 65).

According to Iglesias and Castillejo (n.d.), the most consumed snail in the world is *C. aspersum*. Other sources add that *C. aspersum* is the most farmed species in Europe (Padilla & Cuesta, 2003; Martínez, n.d.; Touchstone Snail, 2015a). Snail farming is especially economically profitable with that species (Kay, 1995: 27; Elmslie, 1989 in Conte, 2015). That is consistent with *C. aspersum*'s adaptability to different environmental conditions (Escargot World, 2016-17c).

Similarly, ***Helix pomatia*** is another popular edible snail species. They are also known as the Roman snail, Escargot de Bourgogne/Burgundy snail or Gros blanc ('big white'). Originally from Europe, they can also be found in the Americas, Asia, Africa, and Oceania. Some of their typical habitats are vineyards, gardens, valleys, or limestone soils, in places with mild temperature and high humidity (Padilla & Cuesta, 2003; Escargot World, 2016-17c).

Unlike *C. aspersum*, *H. pomatia* snails have a strong shell and are slightly bigger. They can grow up to 50 millimeters and usually weigh from 15 to 25 grams. Their shell is pale brown and off-white (FAO, 1986).

The breeding of *H. pomatia* has met with less success than that of *C. aspersum* (Kay, 1995: 27). However, *H. pomatia* is the snail traditionally used in the exclusive French cuisine (Padilla & Cuesta, 2003: 88).

Helix lucorum or the *escargot turc*, has a brown coloration, with five darker stripes. As H. pomatia, H. lucorum is also larger than the little grey snail –in this case, the shell measures between 40-50 mm in diameter (Padilla & Cuesta, 2003: 88). It is most abundant in low, moist,

[47] The scientific name of *C. aspersum* has long been debated by taxonomists. The oldest name in use is *Helix aspersa* (Müller, 1774) (Chase, 2001: 179; Snail-World, 2017a). Over the last few decades, the snail has also been known as *Cryptomphalus aspersus* (Müller, 1774), *Cantareus aspersus* (Müller, 1774), and most recently *Cornu aspersum* (Müller, 1774). *Cornu aspersum* is currently considered the most accurate name (Canadian Food Inspection Agency, 2010), and that is why this term will be preferred in this report.

riverine grasslands, also in humid forests at moderate altitude, gardens, and orchards. Typically, *H. locurom* snails are found in central Europe, Italy, southern Russia and Turkey (Yıldırım et al., 2004).

Furthermore, there are at least another 17 edible snail species in Europe and North America, but they do not seem to have the economic relevance of the species here described (Cobbinah et al., 2008: 10; Elmslie, 2005: 97-101; see also Snail-World, 2016).

Achatinidae snails

Regarding *Achatinidae* snails, the most popular edible species are the giant snail *Achatina achatina*, and the big black snail, *Archachatina marginata*. In countries like Liberia or Ghana, for example, *A. achatina* is considered the most prized species for eating, followed by *Archachatina marginata* (Cobbinah et al., 2008: 10-21; FAO, 2013).

Both species are common in Sub-saharan regions. While Achatina achatina is the most common species in West Africa (mainly in Benin, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, and Togo), Archachatina marginata is mostly found in the humid African rainforest belt, from Southern Nigeria to Congo (Cobbinah et al., 2008; Hodasi, 1984 in Ntiamoa-Baidu, 1997).

A. achatina is called “giant snail” because it is reputedly the largest land snail in the world. These animals can grow up to 30 cm in body length and 25 cm in shell height. The average adult shell length is 18 cm, with an average diameter of 9 cm. The conically shaped, somewhat pointed shell is brownish with a characteristic stripe pattern –that is why it is also called “tiger snail.” It is considered an adequate candidate for snail farming in most areas of West Africa, although it requires higher humidity than other Achatina species and needs a longer growing time to reach sexual maturity (Cobbinah et al., 2008).

A. marginata, for its part, is also a giant snail, generally growing to about 20 cm. While FAO (1986) states that the big black snail weighs from 150 to 200 grams or more, Cobbinah et al. (2008) claim that this animal reaches a live weight of 500 grams. When compared to other Achatina species, big black snails have a much less pointed shell. Additionally, this species has been the object of a series of stocking and feeding experiments in Nigeria, aimed to promote its productive rearing (Cobbinah et al., 2008).

A third important snail species of the *Achatinidae* family is the garden snail, ***A. fulica*** (Cobbinah et al., 2008: 10-21; FAO, 2013). *A. fulica* is originally from East Africa (i.e., Kenya, Tanzania) (Cobbinah et al., 2008). It is also called “garden snail” or “foolish snail” and has a particularly poor reputation as a pest crop (FAO, 2013). It is a large snail, that reaches 20 cm in length or occasionally more, with a shell length up to 20 cm and a maximum diameter of 12 cm. A mature snail averages 250 grams in weight. This species is highly adaptable to a wide range of environments, modifying its life cycle to suit local conditions (Cobbinah et al., 2008).

In general, these different giant snails are an integral part of the African culinary tradition (Hardouin et al., 1995). All of them are considered suitable tropical snail species for farming (FAO, 2013).

In other regions, other species are more commonly consumed. For instance, in South America, *Bulimulus* snails have been eaten for generations, as has the edible snail *H. pomatia* in Europe (Kay, 1995: 64). However, the species described here appear to be the most economically relevant ones from a global perspective.

Appendix 2: International trade of snails

According to the United Nations (2019), the international trade of edible snails was worth approximately $124M in 2018 and has been experiencing a gradual reduction since 2016. As detailed in the table below (fig. 16), this is due to a fall in both imports and exports. However, the reduction in the latter has been more pronounced than in imports:

Period	Imports	Exports	Total	Interannual variation
2015	$60,964,222	$73,642,467	$134,606,689	n/a
2016	$66,710,321	$80,830,975	$147,541,296	8.77%
2017	$66,174,595	$77,500,194	$143,674,789	-2.69%
2018	$60,260,352	$63,416,957	$123,677,309	-16.17%
Total	$254,109,490	$295,390,593		
Average		$137,375,021		

Fig. 16. International trade value of edible snails, from 2015-2018. Own elaboration based on data from United Nations (2019).

Albeit these figures are a proxy indicator of snail global production, they do not measure internal trade. Therefore, these figures do not account for any kind of domestic production of snails used for their meat –i.e., snails traded between different regions or within the same region in a given country.

According to their importance in the international market, during the past years (2015-2018), the top traders (importers and exporters) of snails have been France, Spain, and Morocco, and to a lesser extent, Bosnia Herzegovina, Romania, Italy, and Indonesia (United Nations, 2019).

Similarly, different sources also indicate that European countries are key players in the international snail market (ABRAMS World Trade Wiki, 2019; Chatham House, 2019; IndexBox, 2018 in Food Dive, 2018; Tridge, 2019). They are not only among the major exporters, but France, Spain, and Romania are the leading destinations of snail imports worldwide (ABRAMS World Trade Wiki, 2019; Chatham House, 2019; Tridge, 2019; United Nations, 2019).

Additionally, several sources indicate that Morocco is the most important exporter of snails worldwide (ABRAMS World Trade Wiki, 2019; Chatham House, 2019; Tridge, 2019).

In sum, snails are a widely traded commodity. United Nations (2019) data shows that, in general, import dynamics are generally in line with exports: these trade flows globally complement each other.

Appendix 3: Discussion about snail production estimates

While FAO (2019a) estimated that 18,331 tonnes of snails were produced worldwide in 2017, some other projections for France only are much higher. This suggests that the FAO dataset is highly incomplete. In particular, France seems to account for 20,000–40,000 tonnes of snail meat consumed annually (Conte, 2015; Cuttelod et al., 2011), which is more than the annual world production estimated by FAO. However, another source claims that France consumes only around 5,300 tonnes annually (Indexbox, 2018 in Food Dive, 2018), while a French website states that approximately 16,000 tonnes are consumed in that country per year (Planetoscope, 2012).

In any case, FAO data does not include figures for any European country,[48] while different sources claim that this region is a relevant consumer and, more importantly, a continent where heliciculture has been rising (e.g., Spain according to Cañas, 2018 and La Vanguardia, 2017; Polonia according to Jakubek, 2013, or Romania, following Gheoca, 2013a). For instance, around 90-95% of the snails consumed in France are imported from Eastern European markets, like Romania (Bord Bia, 2018). In fact, according to the United Nations (2019), Romania and other European countries like France and Bosnia-Herzegovina are among the world's largest exporters of snails. However, these countries are not included in FAO estimates.

Moreover, FAO data does not include figures for African countries other than Morocco, Tunisia, and Côte d'Ivoire (see fig. 17). However, West Africa is a major snail consumption region, where

[48] FAO data only includes estimates of net exporter countries (I. Kovrova, personal communication, 29 August 2019).

snails have been traditionally collected from the forest (Hardouin et al., 1995; Ngenwi et al., 2010). For decades now, snails have also been raised in small pens in many areas within this region. More recently, countries like Nigeria and Ghana have been promoting the development of snail farming as a large-scale commercial activity (Africa News, 2017; Cobbinah et al., 2008; Ngenwi et al., 2010; Ntiamoa-Baidu, 1997). In a recent post by Rethink Priorities, we discussed other examples of inconsistencies in FAO animal data, and further reasons to think that these numbers may sometimes be inaccurate.

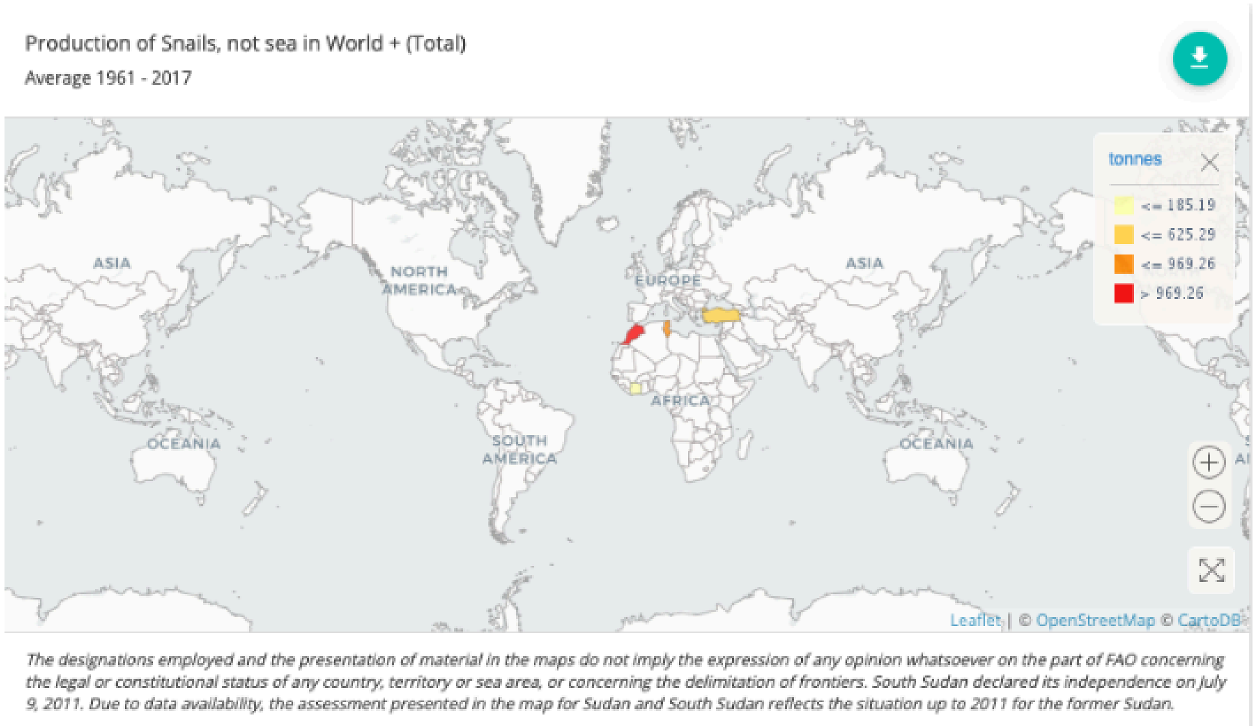

Fig. 17. Countries included in FAO estimations of snail production. Source: FAO, 2019a.

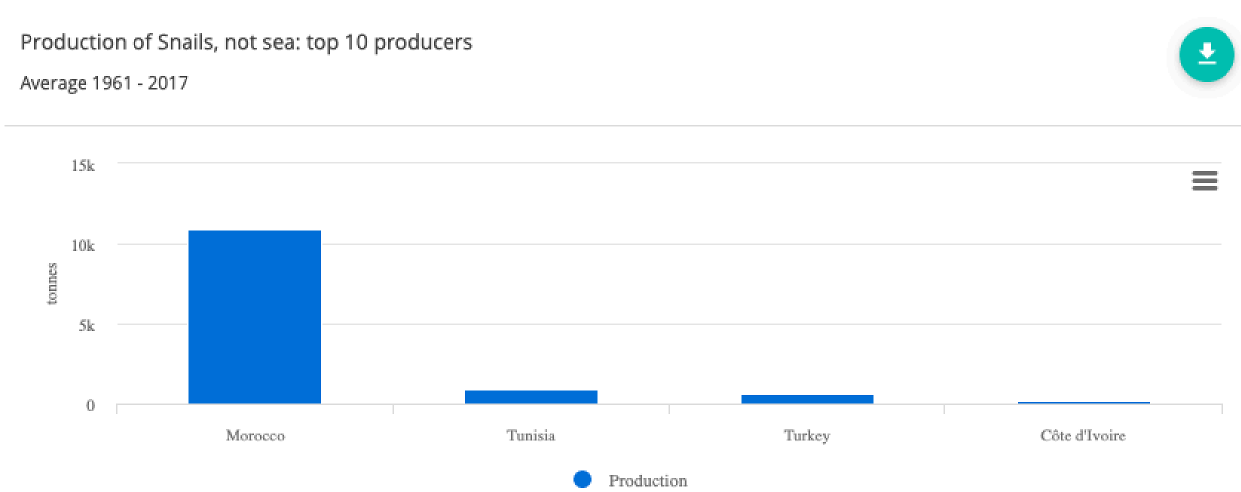

Fig. 18. Top 10 world producers of snails. Source: FAO, 2019a.

Other sources, for their part, give much higher figures on snail production. This is the case of Touchstone Snail, for example, a Cyprus company specialized in snail breeding. Touchstone Snail (2019) claims that the global consumption of snails in 2007 was around 420,000 tonnes. By 2014, this figure rose to 450,000 tonnes, according to the same source. That is more than 26 times the FAO (2019a) estimations for that same year (17,269 tonnes). This inconsistency is illustrated in the following graph (fig. 19):

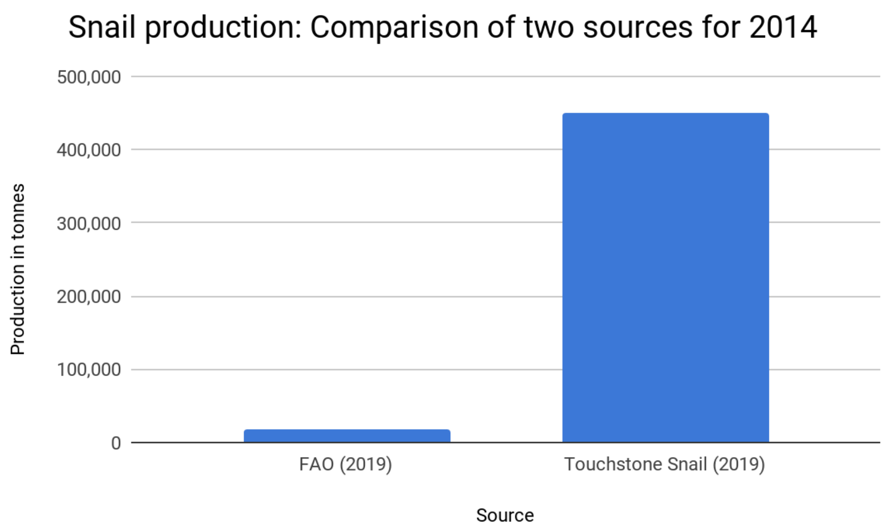

Fig. 19. Comparison of snail production for 2014, according to two different sources: FAO (2019a) and Touchstone Snail (2019).

The company does not provide transparent information about how their estimates were obtained. Given the above and the significant difference with other sources (including FAO and data on snail international trade), these estimates appear unreliable. As Elmslie (2005: 105) already cautioned, some snail-farming promoters produce misleading data on the snail market, usually suggesting that it is significantly broader than it really is.

Similarly, other sources (mainly in Spanish), argue that more than 300,000 tonnes of snails are annually consumed worldwide (e.g., Castellanos, 2007; Martínez, n.d.). However, the original source of this figure is unknown. Therefore, I do not attribute credibility to this estimate.

As mentioned before, Indexbox (2018 in Food Dive, 2018), a market research company, claims that in 2016, the global snail market amounted to 43,000 tonnes –2,4 times the FAO estimation for that same year. This difference is represented in the graph below (fig. 20):

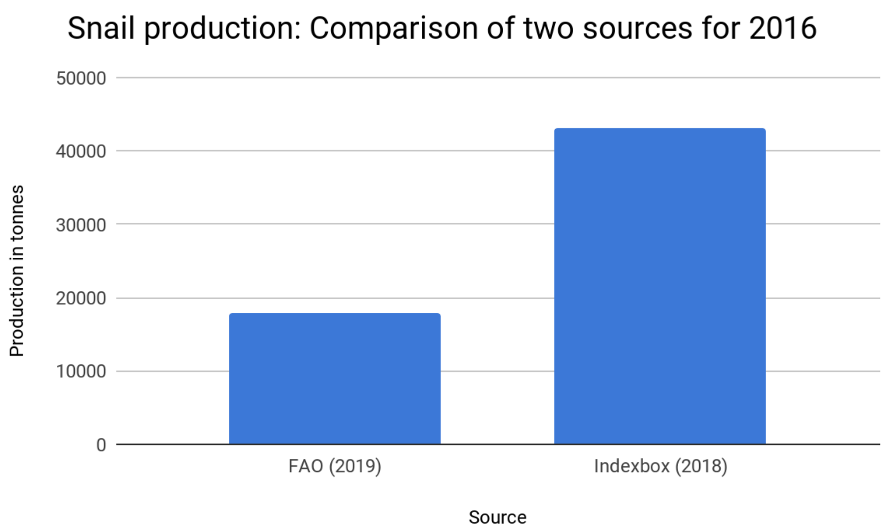

Fig. 20. Comparison of snail production for 2016, according to two different sources: FAO (2019a) and Indexbox (2018 in Food Dive, 2018).

Probably, Indexbox's figures are more reliable than other sources, given that their estimates of the main worldwide producers is consistent with United Nations (2019) data on international snail trade.

Appendix 4: Estimating the number of snails

Number of snails killed

I developed two guesstimate models for estimating the number of snails slaughtered for their meat annually: one of them, using FAO (2019a) data, and the second one, employing Indexbox's (2018 in Food Dive, 2018) figures. Both models (available here and here) are based on the following assumptions:

- *Helicidae* snails represent around 70-85% of the world snail market (based on Gheoca, 2013b and Iglesias & Castillejo, n.d.)[49];

[49] While Gheoca (2013b) states that *Helix* snails represents over 70% of the world snail market, Iglesias and Castillejo (n.d.) claim that only *C. aspersum* accounts for 80% of total demand. However, Iglesias and Castillejo estimates seem to be from well before Gheoca's figure. Additionally, it may exclusively refer to farmed snails, since other sources also assert that *C. aspersum* is the most farmed species in Europe (Padilla & Cuesta, 2003; Martínez, n.d.; Touchstone Snail, 2015a).

- Therefore, *Achatinidae* snails represent around 15-30% of the remaining world snail market;
- The market for *Helicidae* snails is dominated by *C. aspersum* (35-45%), *H. pomatia* (23-33%), and *H. lucorum* (17-27%). Other *Helicidae* species represent around 5-15% of *Helicidae* snails used for human purposes (based on Conte, 2015);
- The market for *Achatinidae* snails is dominated by *A. achatina*, *A. marginata*, and *A. fulica*;
- Snails are harvested when they are adults (Iglesias & Castillejo, n.d.; Padilla & Cuesta, 2003);
- The weight of *Helicidae* and *Achatinidae* snails, as detailed here;
- A mean mortality rate of newborn snails of 15-25% (based on Padilla & Cuesta, 2003: 99);
- A mean mortality rate of growing snails of 16-26% (based on Dupont-Nivet et al., 2000).

I assigned wide intervals to Gheoca's (2013b) and Conte's (2015) original estimates of snail species in the world market, given that their primary sources and the methodology of their estimates are not specified. However, I could not find any other source with more precise information on the proportion of the different snail species used. Regardless, the data provided by these authors is consistent with assertions from other sources about (i) the relevance of *Helicidae* snails in the international market, and (ii) the importance of *C. aspersum* and *H. pomatia* in comparison to snails of other *Helicidae* species.

Note that breeding snails and their mortality rates were not included in these calculations, since (i) there are no estimates of how many breeding snails are used worldwide; (ii) the number of eggs per clutch varies greatly by species, by season, by individual and according to abiotic factors; (iii) I did not find data on egg mortality by species; and, finally, (iv) I found only two estimates of mortality rates among breeding snails (i.e., Daguzan et al., 1981; Cuéllar et al., 1986: 123), but these sources offer very dissimilar data. Moreover, given that I could not find information about mortality during handling and transport, these rates were not included in my calculations.

Furthermore, it is highly likely that small quantities of snails reared in pens or harvested from the wild (e.g., for domestic consumption) were not accounted for, as they may represent quantities that are not economically significant in themselves. However, this does not mean that these quantities, as a whole, are not significant. But since no reliable estimates on domestic breeding or collection of snails were found, it is not possible to estimate the importance of this activity.

Finally, I did not consider figures of snail production provided by Touchstone Snail (2019), Castellanos (2007) or Martínez, (n.d.), given that the original sources for their calculations are unknown and their data is highly inconsistent with other sources. As previously stated, I do not attribute credibility to those estimates.

Number of snails alive at any time

I developed an additional model to estimate the number of snails alive in the industry at any time (available here). Given that the FAO (2019a) snail production data is an underestimate, this model is solely based on the production figures provided by Indexbox (2018 in Food Dive, 2018).

This third model followed the same assumptions as the two previous calculations. In this case, however, I also incorporated the age at which snails of different species are harvested. It should be noted that, in most cases, this information was not directly available. Hence, it was deduced from the age at which snails reach their maximum body weight, or the age at which these mollusks reach sexual maturity –as Iglesias and Castillejo (n.d.), and Padilla and Cuesta (2003) suggest. This information, compiled for *Helicidae* and *Achatinidae* snails, is available here.

Nevertheless, these age estimates vary widely since several factors can significantly influence snail growth, including population density, environmental conditions, food availability and quality, and the breeding system and technology used (Thompson & Cheney, 2008). This variability in growth rates–even from one egg batch–is not exclusive to snails, but a common feature of land mollusks (Blinn, 1963; Wagge, 1952; Wolda 1970 in Pollard, 1975).

In light of the above, I assigned wide intervals (10%) to the estimates of ages provided by different authors. However, I did not apply such an interval for *C. aspersum*, as this species life cycle has been widely studied, and, moreover, these snails are known for their adaptability to different environmental conditions. Hence, in this case, I proposed an age range with a high degree of confidence, supported by contrasting several specialized sources.