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Management Guideline Manual for Invertebrate Live Food Species.

Edited and produced by
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Introduction

This manual has been designed to assist those concerned with the good management of invertebrate species destined as a captive live food resource, especially, but not exclusively, in zoos and aquaria.

These guidelines cover the breeding and rearing methods for twenty three invertebrate species with supplementary information on invertebrate health and nutritional elements. References to further information are also included to assist breeders wishing to develop their protocols beyond the basic care information provided. It is important to note that although these guidelines are for the most part specific to the species in question, valuable guidance on the breeding of other invertebrates can also be drawn from this document.

The Management Guideline Manual for Invertebrate Live Food Species has been compiled under the auspices of the Terrestrial Invertebrate Taxon Advisory Group (TITAG) of the European Association of Zoos and Aquaria (EAZA).
This publication will be updated regularly, in order for new information to be added as soon as possible. Constructive criticism is always welcome and should be addressed to the European Association of Zoos and Aquaria, PO Box 20164, 1000 HD, Amsterdam, The Netherlands. Alternatively email info@eaza.net.

Disclaimer

Although this publication has been produced for use as a guide to the management of invertebrate live food species, no responsibility can be accepted by EAZA for any liability whatsoever arising from such use.

Policy and Ethics

Zoos are committed to excellent animal husbandry, which means in many cases, the use of live invertebrates as food. A given situation may require specific assessment, but in general it is believed that invertebrates will be unaware of being in danger and of any resultant feeling of fear. We cannot be certain that they do not feel pain, but the consensus is that perhaps less so than vertebrates. The important element is to minimise any potential suffering as far as possible, and to recognise that this use although regretful, is necessary for the successful captive care of many animal taxa.

The justification for the use of invertebrates as live food can be demonstrated by the following points:

- The predator is essential for a desired captive breeding programme or other similar project.
- The predator depends on live food for its well being in captivity.
- The live food is an appropriate species and size for the predator.
- The live food is from a sustainable source.
- The process of feeding is made as ‘humane’ as possible.
- The live food receives the very best of care and is also given such when contained with the predator.
- Uneaten live food is removed as soon as it is obvious that it is not required by the predator in order to reduce chances of damage to the predator and of suffering to the prey.

Nutritional Value

The development of standardised breeding guidelines is an extremely useful aid in realising the confident breeding of many useful live food species. It is essentially crucial that live food species are given the best possible care, including the provision of a balanced and appropriate diet at all times. This will ensure that they will in turn provide a nutritionally valuable meal to a predator species.

It is important to appreciate that there are significant differences in the feeding values of larval stages and adults; the main differences being that larvae tend to contain higher levels of fat and protein. To improve a predators' live food diet it is necessary to identify the nutritional value of the live food species used.

Table 1 outlines a list of known nutritional values for a number of species featured in the care guidelines. It is hoped that further nutritional study can establish values for the remainder.

Table 1

Species	***Water %***	***Fat %***	***Protein %***	***Fibre % (ADF)***	***Ash %***	***Energy MJ/kg***
Annelids Earthworm *Lumbricus terrestris*	83.7	4.4 (EE)	60.7	15.0	11.4	(4.93 Kcal/g)
Orthoptera House cricket (adult) *Acheta domesticus*	69	13.8 EE 9.8	64.9 55	9.4	5.7 9.10	5.34
Dictyoptera Deaths head cockroach *Blaberus discoidalis*	71.20	20	78.8	-	4.3	-
Isoptera Damp wood termite *Zootermopsis angusticollis*	70.64	15.04	58.20	25.09	4.11	25.15
Lepidoptera Greater waxmoth (adults and larvae) *Galleria mellonella*	65.90	46.6	42.40	4.80	3.70	7.06 GE
Silkworm (larvae) *Bombyx mori*	82.90	8.09	53.76	6.36	6.36	16.30 ME
Diptera Vestigial winged fruit fly *Drosophila melanogaster*	78.8	29.4	40.3	5.9	9.8	23.31
House fly *Musca domestica*	6.3	20	56.8	18	6.8	25.4
Coleoptera Giant mealworm (larvae) *Zophobas morio*	61	43.08	47.18	6.41	3.08	20.14 ME
Mealworm (larvae) *Tenebrio molitor*	62.40	32.8	52.7	5.7	3.2	6.48 GE

Health

General: Invertebrates are susceptible to many of the pathogens that affect other animal groups, including mites, viruses, bacteria, funguses and protozoans. In many respects these diseases, due to their highly infectious nature, have been successfully used as bio-control agents as an alternative to pesticides. Invertebrates and insects in particular, are typically infected by their food which can be soiled by regurgitated or faecal material. Other means of infection can be through eggs, which can spread disease from one generation to the next via contaminated egg surfaces or damaged tissues where fungal invasions are prone to occur.

It is extremely important to be mindful of the potential effects of overcrowding and how it can exacerbate the vulnerability to disease and mass infection. It is well worth keeping large cultures in smaller distinct units where possible, although each species specific requirements should be taken into account. Another important aspect of invertebrate health is the occurrence of health disorders linked to incorrect environmental parameters. Temperature, humidity, light quality and quantity, photoperiod and substrate should all be carefully considered when setting up a breeding population ensuring that a suitable environment is provided. In essence this is really the most important health related issue and thus an excellent preventative measure.

Disease control: Using sterilized diets and equipment can reduce disease outbreaks to a minimum, therefore giving breeders the ability to raise many generations of invertebrates without problem. There will always be some degree of disease risk when more natural based invertebrate exhibits or cultures are in close proximity. It would be beneficial to develop rearing protocols that adhere to the principles of laboratory-based disease-free conditions.

The following three steps can reduce the prevalence of disease in captive-bred invertebrates:

- Surface sterilization of the eggs.
- The use of un-contaminated or sterilized diets.
- The use of chemotherapy where appropriate.

Disinfection: It is vital that equipment, work surfaces and rooms are disinfected between batches or as frequently as possible to prevent the spread of disease. It is also essential that this disinfection occurs following total cleaning as organic debris may inactivate disinfectants. Similarly any organic materials that may harbour micro-organisms and are not amenable to adequate penetration by disinfectants should be discarded.

A disinfectant should be selected on the basis of:

- Safety to operator and invertebrates.
- Activity against likely pathogens.
- Ease of use.
- Contact time and concentration must be adequate to achieve the expected “kill rate”.
- The disinfectant should be thoroughly removed from the environment before replacing the invertebrates.

Quarantine: It is important to quarantine new specimens until they are confirmed disease-free. It is believed that after three generations of careful observation followed up by a programme of health screening, the culture can be considered as clear. Dead specimens should be sent off for analysis periodically to monitor the disease profile of your culture.

Personal protection: Equipment such as masks and gloves (only non-powdered) should be worn when servicing invertebrates, their housing and other associated equipment. Many invertebrate species and their by-products can cause allergic reactions.

The species most commonly linked to allergies display a hazard symbol on the top right hand corner of their guidelines. Anyone with a known history of high sensitivity should not be assigned to work with these species.

Records

It is crucial that up-to-date animal records on all species are kept. These records should include accurate identification, enclosure location, births, deaths, husbandry/management notes and the most current health information.
Current ISIS databases such as ARKS 4 (Animal Record Keeping System) can be used to monitor your live food population. ZIMS (Zoological Information Management System) which is expected to be ready soon, will provide a greater opportunity to record and manage invertebrate data than ever before.

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Care Guidelines

Annelids

Scientific name: ***Lumbricus rubellus***, ***Eisenia foetida***.
Common name: Earthworm, Red Wrigglers, Redworm.

Complete life cycle: 1 year.

Introduction: Annelida is an important phylum containing about 9,000 species. Both *Lumbricus rubellus* and *Eisenia foetida* belong to the class Oligochaeta which comprises about 3,100 known species of marine, freshwater and terrestrial earthworm. Species belonging to the class Oligochaeta (meaning 'few bristles') can also be distinguished by the presence of a clitelium, an important reproductive structure present in adults. All species play an important role in decomposing organic matter, dispersing nutrients throughout the soil and improving soil structure and texture. Therefore, oligochaetes are considered to be of considerable economic and agricultural importance. Both *L. rubellus* and *E. foetida* are a good nutritious source of food for many species of reptiles, amphibians, fish, birds and mammals.

Description: *Lumbricus rubellus*: body length reaches 12-15cm with a diameter of 5mm. The body is cylindrical in shape, with the tail slightly flattened. The dorsal colouration is brown to red with an iridescent purple sheen. Ventral colouration is a light brown/grey. The clitelium covers the 26^{th}–32^{nd} segments. Two to eight eggs are produced at a time. The cocoon is egg-shaped, yellow-green in colour and is 3-4mm long and 2-2.5mm in diameter. Each worm can lay approximately two cocoons per week. The threadlike hatchlings measure 8-10mm and are whitish in colour.

Eisenia foetida: body length reaches 10-13cm with a diameter of 3-4mm. Colouration is brown-red all around with yellow segmental lines. Up to two cocoons are produced a week, each containing two to eight eggs. The cocoons are similar in colour and size to *L. rubellus* cocoons. The hatchlings are 5-8mm long and have a transparent whitish appearance.

Food: For best results a diet made up of oats, coarsely ground corn and/or other ground grains mixed with honey should be used. In addition, grated vegetables and fruits such as potatoes, carrots and pear can be added to the diet. Food is placed inside an indentation in the substrate and covered again. After four to six days more food can be added, only if the previous food has been consumed. Remove any food which has turned mouldy.

Environmental requirements: Substrate should consist of equal parts of soil and peat moss. Coarse builders' sand and leaf litter can be added to keep the substrate loose. Breeding starts at 12°C. Temperatures above 20°C can only be tolerated for short periods. The substrate must be kept evenly moist at all times; both species are sensitive to standing water and desiccation. A substrate pH value of 5.5-6.5 is recommended; if below 5.5 then limestone or chalk powder can be mixed in. For pH values of over 6.5, moisten the substrate with a weak solution of vinegar and water.

Housing: The housing is dependent on available space. If housing inside, use any form of container at least 25cm deep which can withstand humidity and ideally has a lid. Large plastic trays such as those used in the fishing industry are ideal; these can also be stacked or placed in a rack system. If you can not prevent the accumulation

of standing water at the bottom of the container then small holes can be drilled. Cover the holes with fine mesh held in place with silicon sealant. Fill each tray with approximately 20-25cm of substrate and spread the worms over the surface. Worms which have not burrowed into the substrate after thirty minutes are weak or dead and should be removed in order to prevent spoiling of the substrate. Both species become more active at night, moving to the surface. To avoid loss of individuals from lidless containers, a light can be left on above their housing. To help maintain good moisture levels within the container, hessian sacking or off-cuts of carpet can be placed on the surface of the substrate. This is particularly important if the container does not have a lid to maintain moisture levels.
If outdoor space is available a wooden wormery of 150 x 80 x 60cm can be constructed to house up to 20,000 worms. This should be sited where it will be protected from sunlight and also frost. If the wormery is constructed without a base, the sides will need to be dug at least 20cm into the ground to avoid escapes. Cover the substrate with hessian or carpet to help maintain moisture levels.

Equipment: Water sprayer. Non-powdered disposable gloves. Plastic containers or timber planks. Peat moss, soil and coarse builders' sand. Hessian sacking or off-cuts of carpet.

Stock management: If worms of different sizes are required, adults will need to be transferred to a new container every two weeks requiring a cycle of seven containers. A three week cycle can also be used which will require five containers if space is limited. Adult worms have to be sorted by hand which can be time consuming in a large set up. If size is not important, then only one container is needed for each colony. Make sure that each container does not become too crowded as space is needed for young worms to develop; regular harvesting of adults should prevent overcrowding. Harvested worms can be stored in breathable containers for up to four weeks at 8°C and up to three months at 2°C. Moist egg cartons can be used as a substrate as long as the humidity is controlled. Worms can be washed by placing them in a sieve and running tepid water over them if required.

Rearing tips:

- Both species can be housed together.
- Remove uneaten food once a week to prevent mould. Ensure fresh food is provided with no exception.
- Remove dead specimens immediately, these can be periodically sent for analysis to monitor diseases within the culture.
- Maximum of 20,000 individual adults per container of 150 x 80 x 60cm.
- Check the pH of the substrate once a month and adjust accordingly. Testing kits are available at most garden centres.
- If worms are 'clumping' together in fist size balls the substrate is too dry.
- Substrate and its runoff is a valuable natural fertiliser, the use of these makes this system environmentally sustainable.
- ***Lumbricus terrestris***, the common earthworm can also be kept using this method.

Mollusca

Scientific name: ***Helix aspersa***.
Common name: Edible, Petit-gris or Garden Snail.

Complete life cycle: 12 months.

Introduction: For thousands of years edible snails have been eaten in many European countries. Their ability to reproduce in high numbers and their significant nutritional value make this species an excellent subject for live food consideration. These molluscs are true hermaphrodites with reproductive organs of both sexes occurring in the same individual, they are capable of self-fertilization, although cross fertilization is normal.

Three main management systems are in use for this species at the present time:
1. Outdoors - This type of snail farming is situated completely outside; the snails are placed in areas enclosed by snail proof barriers (as described in housing). The enclosures are planted out with vegetation chosen for its nutritional importance. Snails are left almost unattended until harvested. Snail farms using this system can cover very large areas (2.5 hectares or more).
2. Indoors -This system uses environmentally controlled rooms in which the best environment for snail reproduction and growth can be maintained. The snails are fed a formulated diet including all the nutritional requirements needed for breeding and development.
3. Indoors/Outdoors - As the name suggests this system uses some of the protocols of both the above mentioned systems. Breeding and nursery areas use the indoor method, whilst the maturing area is situated outdoors.

Most operations requiring this snail as a live food species should consider the indoors and indoors/outdoors systems only; although the breeder must ascertain which system will be most suitable for their requirements.

Food: Snails eat large quantities of food; up to 40% of their total weight can be consumed within a 24 hour period, especially during periods of high activity. Plenty of food must be available in the spring months to compensate for weight loss that occurs during hibernation. 1kg of snails will need to consume approximately 1.7 kg of dry snail food between birth and mature adult.

Two snail food formulas using chicken mash and pellet base are described below:
1. Broiler finisher mash consisting of 7% broiler concentrate, 52% corn, 16% soya meal, 18% sorghum and 7% limestone flour (40% Ca).
2. Chicken pellets (crushed) for layers consisting of 5% layer concentrate,10% corn meal, 15% soya meal, 20% sorghum, 43% barley and 7% limestone flour (40% Ca).
These recommended diets must be crushed into a coarse powder form so that the snails do not expend too much energy masticating the food. Both formulas once crushed can be used for both juvenile and adult snails.

For outside systems and breeders wishing to use a more vegetative diet the following plants are recommended: burdock *Arctium lappa*, borage *Borago officinalis,* plantain *Plantago major*, sorrel *Rumex acetosa*, chervil *Anthriscus cerefolium,* sunflower *Helianthus annuus*, chicory *Cichorium intybus*, beetroot *Beta vulgaris* and radish *Raphanus sativus.*

Environmental requirements: Temperature should be maintained between 20°C (day) and 17°C (night). RH should be maintained at 75% (day) and 90% (night). Photoperiod is important for breeding and an 18 hour day and 6 hour night should be observed. Lighting levels should be as close to natural as possible ensuring that excessive heat is not generated. *Helix aspersa* prefers and functions very well at 20°C; if the temperature should rise another 3°C the snail will "shut down" by secreting mucus to seal its' shell with a temporary covering called the operculum. This behaviour also occurs when temperatures fall below 6°C and at 0°C they will cease to function altogether and die.

Housing: The following four distinct areas will be required. These can be quite modest in terms of size and the breeder will have to identify appropriate sized containment suitable for the size of their operation. The main elements to consider will be pest control, ensuring that predators and parasites are kept out. Barrier methods such as electric fencing and meshed cloches for larger operations and small polythene cabinets or plant propagators for smaller populations can be considered. Elements important in controlling the environmental parameters such as ventilation, shading, humidity and temperature control will be crucial. For outside enclosures, snails can be prevented from escaping over the top of the fences by wire curved inwards, or the use of galvanized sheet metal as snails prefer not to climb this material. Electric fences have been tried with two to six wires, 2mm–4mm apart, powered by a 6 or 12 volt battery.

1. Breeding area – where after being brought out of hibernation the snails can mate and lay eggs. This will require a potting soil base and sufficient barrier and environmental control as described.
2. Nursery area – where collected egg-fields can hatch**.** These can be a series of dated plastic pots prepared as described in the section on egg management.
3. Maturing area – where snails can be reared to attain full size. This area can be a greenhouse, poly-tunnel or lidded glass vivaria construction with appropriate barrier and environmental controls.
4. Hibernation – can be achieved in an environmentally controlled room, refrigerator or cool cellar as long as the correct temperature parameters are provided.

Equipment: The bulk of the equipment needed will be in the housing construction. Basic gardening tools will useful if there is an outdoor element to the set-up. Misting units may be considered to maintain appropriate RH levels. Fans to ensure air movement may also be required.

Egg management: The snail will dig a hole and burrow to a depth of 4-9cm to deposit its eggs. The ideal soil conditions need to be friable and moist but not saturated, the provision of small plastic garden propagators filled with potting mix is ideal. The eggs are spherical and translucent, white in colour and have a diameter of between 3-4mm. The snail lays its eggs in batches that can number from 40-130, the average is about 80. Viability of eggs depends on observing the recommended soil temperature, soil humidity and soil composition. If these conditions are provided the baby snails, which are very small but fully formed, will emerge within 18-21 days.

Rearing tips:

- It is recommended to acquire a founder colony that is free from contaminants and properly identified; other species require somewhat different techniques. If wild collection is the preferred option of acquisition, it is recommended that a 30 day quarantine period be observed to ensure potential toxins or contaminants that have been ingested will be naturally expelled.

- A good potting soil should have a neutral to alkaline pH providing calcium carbonate which is vital for shell growth.
- Hibernation appears to play a significant role in the snail's ability to breed, grow and reproduce. Snails that have been selected for breeding stock (largest size) should be placed into ventilated plastic baskets and stored at a temperature of 5^{o}C, with a humidity of 85%. A lighting system with a timed cycle set for 6 hours of daylight and 18 hours of darkness will induce hibernation. This should be maintained for up to six months.
- After hibernation, the snails are exposed to conditions for reproduction that have optimum temperature, lighting and humidity. The average time between mating and egg-laying is 5-10 days. The snail will lay continuous batches as long as favourable conditions continue. *Helix aspersa* have been found to mate again after a period of 15 days.
- The soil should be 10cm deep to facilitate egg laying.
- Egg batches can be incubated using potting mix filled containers that have been covered with a rigid sheet of plastic. In order to induce the emergence of snails the top 2 or 3cms of potting mix should be removed without uncovering the eggs. Once the snails emerge from their shells they will spend 1 or 2 days near the nest before coming to the surface where they will attach themselves to the underside of the plastic covering that has been placed on top of the containers. They are very delicate at this point, so great care will need to be used to ensure that they are moved to their maturing area without damage.
- When recording information and managing different life-stage populations, it is recommended to maintain different life stages separately; e.g. eggs, new-borns, juveniles, sub-adults and adults. It is also useful to observe and record generation numbers from the wild.
- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.
- It is recommended that housing and equipment is disinfected and replaced periodically.

Health related issues: Bacteria such as *Pseudomonas aeruginosa* can cause intestinal infections which spread rapidly when populations become overcrowded. High densities also affect juvenile growth rates and cause fungal disease that can decimate the stock within 3 days; therefore, no more than 200, 10g snails per square metre is recommended.

Human considerations**:** Snails can carry potential zoonotic protozoans and salmonella, so personal hygiene is very important. Personal protective equipment such as masks and gloves should be worn when servicing these animals, their housing and other associated equipment.

Scientific name: ***Lissachatina fulica.***
Common name: Giant African Land Snail.

Complete life cycle: Average about 5-6 years, but can live up to 10 years.

Introduction: *Lissachatina fulica* are large terrestrial snails originally from Kenya and Tanzania. The average adult shell length is 12cm, with a diameter of 6cm. In exceptional cases the shell can grow to be 20cm long but this is unlikely in captivity. Most of the growth is achieved in the first six months of life, although they will continue to grow for another year or so. It is generally accepted that you can judge the final size of your snail after one year. An adult *L. fulica* can weigh over 600g. The giant African land snail is an obligate-out crossing hermaphrodite, which means that one externally fertilised snail can establish a population. In the wild they would normally breed in the rainy season between the months of April and July. Sperm from one mating can be stored by the snail and successive egg-laying may occur from that single mating.

Environmental requirements: *L. fulica* can be maintained at room temperature but will grow faster and breed regularly if they are maintained at 21-26°C (25-26°C during the day and 21-23°C at night). If snails are kept at room temperature an additional heat source may be required in cooler months. Light bulbs are not suitable as the snails will shy away. Heat mats are recommended but must be arranged so that they create a thermal gradient within the enclosure allowing the snails to move away if they get too warm. The heat mat should be attached to the side of the enclosure rather than underneath to prevent the substrate from drying out. Snails will burrow into the substrate and suffer desiccation if the substrate is very dry. *L. fulica* aestivate when the temperature reaches 27-28°C or drops below 15°C. They can rest for up to six months in this state if the environmental conditions do not change. Snails require moist environments; soil and air humidity of 70-90% is recommended to promote snail activity and growth.

Housing: The snails should be housed according to size with individuals of a similar size being housed together. The enclosure size is dependent on the size of the snails and the number of individuals. Plastic storage containers are easy to clean and store. The containers must be waterproof due to the necessity of being able to withstand the warm humid conditions required to maintain a regular breeding colony of snails. Holes should be drilled into the top of the storage containers to allow adequate ventilation. Branching can be provided for climbing and terracotta shards or pieces of bark can be used for refugia. The provision of refugia will increase the surface area of the enclosure allowing a greater number of snails to be housed.
The substrate is very important; sandy soils do not retain enough moisture and soils with high clay content may become compacted and difficult for the snails to burrow into. Peat free compost is a good substrate choice, the depth of which depending upon the age of the snails. Adult snails require a deeper substrate of approximately 6cm to accommodate burrowing and egg-laying. Leaf litter or bark chippings may also be added. If the substrate is very deep any egg clutches that are laid may be missed. Snails will ingest substrate during burrowing activities, so it is recommended that the soil contains 20-40% organic matter and a high calcium content. Ground limestone can be mixed into the substrate to provide the correct calcium requirement. Soil pH should be neutral. This species is more sensitive to overly wet environments than other Achatinidae species and may die if maintained in such conditions. Any water logged substrate must be removed and regular substrate changes performed to remove mucus and droppings which can cause chemical changes to occur in the soil.

Food: *L. fulica* is an omnivorous species and will consume a variety of fruits and vegetables as well as soil as previously mentioned. Dark leafy greens are an important dietary component as they contain a higher nutritional value than salad leaves such as lettuce. Snails will also take a variety of human foods including bread, biscuits and even meat.
Food should be washed with water before it is given to the snails to remove any toxins or pesticides. One major requirement is calcium (97-98% of a snails' shell is composed of calcium carbonate), so soft chalk or cuttlefish bone should be available at all times. A convenient diet is a mash of rabbit pellets with a little powdered chalk made into a paste with some water. The mash should be changed when it becomes dirty or wet. The snails will require a constant supply of calcium for building their shells. Lack of calcium will result in a thin and fragile shell.
Snails obtain enough water from their food. If a water bowl is provided, ensure that it is not too deep and position a stone in the middle to prevent the snails from drowning. Spray daily so that the substrate is moist and the sides of the enclosures have fine water droplets on the surface.
Care should be taken not to feed a high proportion of spinach and other plants that are high in oxalates. Oxalates can bind with some nutrients (e.g. calcium) and make them inaccessible to the body. This may have ramifications when it comes to the snails' calcium requirement for shell development. As with any animal, a mixed diet is important. Some authors quote feeding *L. fulica* on pasta and rice, these starchy foods have been known to cause water retention through internal blockages and should therefore be avoided.

Egg management: Clutch size varies from 30-90 eggs on average and it has been estimated that a female may be able to produce 1000 eggs per annum. The eggs are cream in colour, roughly spherical and measure 4.5 to 5.5mm in diameter. Clutch size and egg size is thought to be positively related to adult snail size.

L. fulica eggs are easy to hatch and rear. When an egg clutch has been located it should be removed using a spoon or similar object, and placed into a small tank that has been set up as a miniature version of the adult container. Removal of the eggs helps to avoid damage to them and to the young snails as they hatch. This will also improve the hatch rate as the eggs are not disturbed by the digging activities of the adults. Each clutch is put into its own receptacle and covered with a thin layer of peat free compost. The hatchery should be kept humid with food and calcium provided for the hatchlings. Under optimal conditions the hatch rate for *L. fulica* is approximately 90% taking approximately 14 days to hatch at 22-25^{o}C; the hatchlings measure approximately 4mm in length.

Rearing tips:

- Leftovers and detritus should be removed on a daily basis and the sides of the enclosure wiped down twice weekly. Substrate changes need to be carried out whenever the substrate becomes slimey or has large amounts of faecal matter.

- The build up of faecal matter is problematic as the snails will ingest faeces. If the snails have parasitic animals in their guts, they will be constantly re-ingesting them with the faeces increasing their parasitic load which may result in die offs within the snail colony. Tanks must be emptied, disinfected and rinsed thoroughly every month.

- If the snails are not breeding they can be encouraged to do so by increasing the humidity. In captivity *L. fulica* can be a prolific breeder all year round.

- Snails mature at around 5 to 15 months of age, depending on temperature (with cold winter temperatures inducing hibernation and delaying sexual maturity). Snails can begin to lay eggs at 6 months of age and fecundity lasts approximately 400 days.

- Keeping snails on a shallow substrate may discourage egg production, but a deep substrate will require more time to be spent servicing the snails and searching for egg clutches. It is possible to keep breeding snails on a shallow substrate as long as an area of deeper substrate is provided for egg deposition.

- If any snails accidentally hatch in the adult group, split the newly hatched snails into a separate tank as soon as possible.

Health related issues: Snails may become infested with tiny external parasitic mites, but they appear to tolerate these parasites well. A warm wash of the snails should be enough to remove them or at least reduce their numbers.

Human considerations**:** It has recently been reported that there is a risk of catching Eosinophilic meningitis from giant African land snails. Thorough hand washing after working with the snails is enough to eliminate this problem. It is recommended to start the breeding colony from captive bred animals to minimize the risk of having the parasite because it needs an intermediary host.

Crustaceans

Scientific name: ***Armadillidium vulgare.***
Common name: Wood-louse.

Complete life cycle: 2-5 years.

Introduction: *Armadillidium vulgare* will roll itself into a protective ball earning it the name "pill wood-louse". The wood-louse is an isopod, which means “legs that are alike”. These crustaceans rarely reach more than 1.5cm in length. They are an excellent live food species as they live a relatively long time, and are easily bred. They are predominantly nocturnal preferring areas of medium humidity. This species is reared parthenogenetically moulting up to 25 times, but reproductive activity is observed only between the 5th and 13th instars; approximately 18-24 days after emergence. *Oniscus asellus* and *Porcellio scaber* may also be maintained using the advice below, but there will be some differences in the environmental requirements, in particular humidity.

Food: This species feeds on decaying plant material, carrion and faeces although they may be browsing on the fungi or bacteria associated with these food types. Periodically, small quantities of tomato, lettuce, potato, mushroom and mini-corn can be offered. For an artificial diet, powdered dried milk can be added once per week or as required depending on the breeding schedule.

Environmental requirements: Temperature should be maintained between 18^{o}C and 22^{o}C; a local 60 watt spot lamp providing a hot spot is beneficial. Photoperiod should be kept at 12/12. RH should be maintained at 50-70%, which can be achieved by a daily misting.

Housing: Large populations can be maintained in plastic food containers with tight-fitting lids and added ventilation (40cm x 40cm x 40cm). The containers will need to be filled to 10cm in depth with a mix of peat free compost / coir, leaf litter and rotten wood.

Equipment: Plastic food containers. Tweezers. Hand spray gun. Substrate material.

Breeding: Woodlouse nymphs take between 3 months and 2 years to mature, depending on species and environmental parameters. After mating, eggs are transferred to a pouch on the females’ underside. The eggs remain there for 3-5 weeks before hatching. Females may produce 1-4 broods per year.

Rearing tips:

- Always have a number of new breeding and holding containers ready to ensure the continuous development of the culture.

- Introduce 50-100 adults when setting up a new breeding population. Overcrowding will cause low fecundity in high densities of wood-louse. More than 200 adult woodlice can suppress breeding.

- Observe daily and record date of hatching. Provide food immediately after emergence.

- It is recommended to acquire a founder colony which is free from contaminants and properly identified; remember other species will require different techniques and environmental requirements.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- It is recommended that housing is disinfected and substrate replaced on a regular basis.

Scientific name: ***Artemia salina***.
Common name: Brine Shrimp.

Life cycle**:** From hatching (cysts) to adulthood in 8 days (under ideal conditions survival for several months).

Introduction: Brine shrimp, *Artemia salina*, is cultured and reared to function as live food for marine fish species. The *Artemia* larvae, nauplii, (400-500µm) are used as a nutrient for the first larval stage of marine fish and shrimp. Adult *Artemia* (2cm) are used as an extra food source for various smaller fish and as a main food source for pipefish and seahorses.
The cysts that are commercially available are hatched, cultured to various stages and have their nutritional value improved by enrichment. Medication can be administered to various fish species using *Artemia* larvae enriched with the medicine required.

In nature, biological and physical conditions are responsible for the way in which reproduction will take place. The female can produce fertilized eggs that develop in the womb into free swimming nauplii larvae or diapausing embryos called cysts. When conditions are poor the adult female releases up to 75 cysts per day. The floating cysts are blown ashore where they dry out. When the dried cysts are re-hydrated in seawater the embryos resume development.

Environmental requirements:
Temperature: At temperatures of between 25-28°C the nauplii will hatch after approximately 24-26 hours. These temperatures are also preferable for adult growth.

Salinity: Although *Artemia* are excellent osmoregulators and can tolerate high salinities, they prefer a salinity of 30–35%.

Water composition: *Artemia* tolerate a wide range of ionic composition, but the best hatching and rearing results will be obtained in medium that closely approximates seawater.

Oxygen: Heavy aeration or high surface area and a shallow depth usually provide sufficient oxygenation.

pH: The pH of seawater may be influenced by the enrichments which are added. A pH of less than 5 or greater than 10 are usually lethal. A pH of around 8 is best.

Light: A minimum amount of light is necessary for hatching and is also beneficial for adult growth. About 2000 lux with a spectral quality approximating sunlight is adequate.

Housing: The cysts should be placed inside a conical vessel with a tap at the bottom for harvesting. The *Artemia* are harvested by emptying the contents of the vessel over a sieve with a maximum mesh size of 150µm.

Food**:** The newly hatched *Artemia* nauplii have a naturally high nutritional value. After approximately 6 hours the *Artemia* will have used up all of their natural food sources and have to be enriched to improve their nutritional value again. To enrich the *Artemia* nauplii they are fed with a mixture of live micro-algae (*Nannochloropsis oculata, Tetraselmis suecica, Dunaliela tertiolecta* and *Pheaodactylum tricornutum*), flour mixture or DHA Selco. Selco, flour mixture and live algae mixture can also be used as food for adult *Artemia.*

Equipment: Conical vessel. Sieve (maximum mesh size 150µm). *Artemia* cysts. Sea water (34%). Glass tubes with aeration pipes.

Egg management: The cysts should be stored in a dark, dry and cool (4°C) place. Keep out of direct sunlight and use open cans of cysts as soon as possible.

Rearing tips:

- First hydrate cysts for one hour in fresh water to shorten hatching time.
- Cyst density: 2 to 3 g/l.
- Supply air to the bottom of the vessels for aeration and mixing.
- Use bright light but avoid overheating.
- Before harvesting: draw approximately 300ml sea water off the conical vessel to remove non hatched cysts from the vent.
- When harvesting, concentrate nauplii at the bottom of the tank by turning off the light and aeration.

Insecta

Scientific name: ***Folsomia candida***.
Common name: Springtail.

Complete life cycle**:** 42 days.

Introduction: The springtail is a primitive insect belonging to the order Collembola occurring in soil or associated habitats where decomposing plant matter is found. The crucial element for the successful breeding of this species is managing a high level of humidity. This species is reared parthenogenetically moulting up to 25 times but reproductive activity is observed only between the 5th and 13th instars; approximately 18-24 days after emergence.

Food: This species feeds on decaying plant material, carrion and faeces although they may be browsing on the fungi or bacteria associated with these food types. For an artificial diet, powdered dried brewers yeast added once per week or as required depending on breeding schedule is the only requirement.

Environmental requirements: Temperature should be maintained between 20^{o}C and 25^{o}C. RH should be maintained at 95% (avoid water settling on the surface of the substrate as this will reduce oviposition). Rearing should be carried out in complete darkness or low light levels.

Housing: Large populations can be held in plastic food containers with tight-fitting lids and no ventilation (30cm x 30cm x 20cm). These containers need to be filled to 1cm in depth with the following substrate; 200ml plaster of Paris, 20ml of powdered charcoal and 200ml of distilled/RO water and left to set. This substrate must be moistened periodically to maintain high local humidity. The charcoal is used to absorb waste gases and faeces and will also cause the substrate to become darker in colour, aiding springtail observation.

Equipment: Plastic food containers. Plaster of Paris powder. Powdered charcoal. Brewers yeast powder. Tweezers. Distilled/RO water.

Egg management: Egg pod incubation must be maintained between 20^{o}C to 25^{o}C; this will result in a 12 day approximate incubation period. Adults should be removed from the egg field after oviposition (24-48h) for maximum egg yield.

Rearing tips:

- Prepare a number of new breeding containers with a 1cm layer of substrate (described above) to ensure the continuous development of the culture.
- Introduce 100-200 reproductively active adults when setting up a new egg field.
- Observe daily and record date of hatching. Provide food immediately after emergence.
- A light dusting of food on the substrate is required only.

- It is recommended to acquire a founder colony which is free from contaminants and properly identified; other species require very different techniques.

- Remove dead specimens immediately and send for analysis periodically to monitor the disease profile of your culture.

- It is recommended that housing is disinfected and substrate replaced regularly.

Health related issues: Mite infestation can be a problem and is usually introduced via the brewers yeast; this can be controlled by heating the yeast to 50°C. If a mite presence is observed the culture should be discarded. Too much yeast at 25°C may result in excessive fungal growth, which can be a trapping hazard to springtails. The introduction of food and the density of stock should be closely co-ordinated to eliminate any trapping risk. Overcrowding can also be a problem leading to very low fecundity in high densities of springtails. More than 300 reproductively active springtails per recommended container can suppress oviposition and induce egg cannibalism.

Scientific name: ***Schistocerca gregaria.***
Common name: Desert Locust.

Complete life cycle: 3 months (35°C day, 25°C night).

Introduction: This insect is maintained in captivity in large numbers and rearing guidelines have been well documented.

Food: *S. gregaria* should be fed on greens such as Brassica rather than grass as they are particularly susceptible to disease transmission from other grass feeding Orthoptera. Care should be taken that any food plant material is free from pesticides. Other suitable food items include maize, bran and small amounts of apple and pear.

Environmental requirements: Temperature should be as constant as possible and be maintained at 35°C during the day with a drop down to 25°C at night. RH should be as low as possible and is not required for this insect. Photoperiod 12:12. 60 watt bulbs can be used to maintain local cage heating. Egg pod incubation must be maintained as close to 28°C as possible.

Housing: Commercial type breeding units can be purchased but are often too small and used only for storage. Units for rearing/breeding should be at least $1m^3$ and constructed of a wooden or metal framework. If the requirement is to supply in excess of 500 locusts per week, then 10 to 12 of these units will be needed.
Solid wood or metal is recommended for the flooring and lid, with metal mesh for the sides and a sliding Perspex front for access. The floor can be provided with a mesh cover tray so that frass will automatically fall through for ease of daily maintenance. Access should be via the front and side for daily cleaning and the entire lid should be removable for more intensive duties. A smaller receptacle for egg deposition should be provided that is transferable to a reptile or avian incubator.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Vacuum cleaner. Fine builders' sand. 125mm high transparent plastic pots for egg-pod oviposition. Transparent plastic bags. Incubator.

Egg management: Plastic pots with moist soft compacted sand must be provided for oviposition in units housing sexually mature adults. Egg pot removal, replacement and relocation to an incubator (28°C) in a closed plastic bag 3 times per week is essential. Date-label egg-pots to ensure good incubator management.

Rearing tips:

- Remove uneaten food daily and provide daily access to fresh food with no exceptions.
- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.
- Maximum of 500 insects per housing unit – 150 for sexually mature adults to ensure maximum oviposition
- Discard failed and used egg-pots regularly.
- Use a vacuum cleaner with a slit nozzle head to prevent insects being sucked up during cleaning.

Scientific name: ***Locusta migratoria.***
Common name: Asiatic or Migratory Locust.

Complete life cycle: 5 weeks (30°C).
Eggs 11 days; larvae 20 days; start of oviposition 7 days after final moult.

Introduction: Reared in captivity in large numbers; rearing guidelines for this species are well documented.

Food: Fresh food should be provided daily in the form of wheat shoots (minimum 3g per imago per day), lettuce and small amounts of apple and carrot. Grass is unsuitable as a food source as this species is particularly susceptible to disease transmission from other grass feeding Orthoptera. Care should be taken that any food plant material is free from pesticides and washed before use. It is also recommended to provide a dry mixture that consists of bran, rolled oats, sublimated milk, fish food (*Gammarus* sp.) or dog/cat pellets and brewer's yeast.

Environmental requirements: Temperature should be kept as constant as possible with the breeding room being maintained at 30°C both day and night. One 75 watt incandescent lamp must be used to maintain local cage heating at 40-45°C or higher. Recommended photoperiod for mass production is 24 hours of light. RH should be as low as possible and is not required for this insect. Egg pod incubation should be maintained at 30°C.

Housing: Units for mass rearing/breeding should be 50cm x 45cm x 50cm in dimension and constructed out of a wooden or metal framework. Solid plywood or metal are the recommended materials to be used for the flooring and lid, with metal mesh for the sides (including hinged access hatches) and a sliding Perspex front. The floor can be provided with a mesh cover tray so that frass will automatically fall through for ease of daily cleaning. Access should be via the front and sides for daily maintenance and the entire lid should be removable for more intensive duties. A receptacle for egg deposition should be provided that is transferable to a reptile or avian incubator.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Vacuum cleaner. Peat free compost or coir. Builders' sand. 125mm high transparent plastic pots for egg-pod oviposition. Dry food mixture receptacle (e.g. Petri dish). Transparent plastic bags. Incubator.

Egg management: Plastic pots with moist compacted coir and sand mix must be provided for oviposition in units housing sexually mature adults. Egg pot removal, replacement and relocation to an incubator (30°C) in a closed plastic bag 3 times per week is essential. Always date-label egg-pots to ensure population control and good incubator management.

Rearing tips:

- Remove uneaten food daily and provide daily access to fresh food with no exceptions.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- Maximum of 400 sexually mature adults (200 pairs) per housing unit to ensure maximum oviposition.

- Discard failed and used egg-pots regularly.

- Use a vacuum cleaner with a slit nozzle head to prevent insects being sucked up during cleaning.

Scientific name: ***Gryllus bimaculatus***.
Common name: Mediterranean Field Cricket.

Complete life cycle**:** 3 months.

Introduction: The Mediterranean field cricket, *Gryllus bimaculatus*, occurs around the Mediterranean and North African region as its name suggests. They are presently reared in captivity in large numbers primarily as food for predatory invertebrates, birds, mammals and herptiles.

Food: Most food types will be eaten, but it is important to use food of high nutritional quality as always. A dry tortoise pellet together with moisture in the form of carrot and orange has shown excellent breeding results. Although protein levels are higher, some institutions use a fine trout pellet to good effect. Fresh greens including such plants as the dandelion *Taraxacum* sp. and plantain *Plantago* sp. should be offered on a daily basis if available. Brassicas can also be provided in smaller quantities. It is important to remember not to feed excessive calcium to rearer crickets as this can interfere with ecdysis. High calcium loading or dusting should only be utilised immediately prior to use on feeder crickets. A Petri dish containing clean water soaked into cotton wool is also recommended.

Environmental requirements: A recommended temperature range is 30°C with a hotspot of 35°C during the day dropping to around 20-25°C at night. Photoperiod 12:12. 60W or 100W spot bulbs can be used to maintain local cage parameters. Relative humidity is around the 40-50% mark, although the oviposition site will be a lot more humid due to it containing damp sandy soil.

Housing: Commercial breeding units can be purchased, although any smooth sided plastic box or bin that is not too deep will be adequate. They are not able to jump or fly very great distances. Oblong tubs of 60cm x 40cm x 40cm deep have been used successfully. A clip-on lid can have the middle cut out so that the box is almost completely open thus allowing the lamp to hang down into the tub; but the lip around the edge prevents crickets from climbing out. Older tubs that have become scratched in some way offer better grip for potential escapees. These tubs are sufficient to house approx 1000 adult crickets maximum.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Plastic pots. Incubator. Cardboard egg boxes or trays. Clean sand and soil/coir.

Egg management: It is recommended to use circular plastic pots no deeper than 7cm and 10cm in diameter filled to the brim with a 1:1 mix of coir and sand. This mixture should be sprayed with water until it is damp all the way through, but not so that there is standing water on the surface. Remember this will dry out quite a bit during the day. The pot should be positioned so as to give maximum access for the female crickets and not next to any food source to avoid contamination of the egg field. The pots should be changed on a daily basis and placed in the incubator, with a lid on, at 30°C for 7 days. On the 6th day of incubation, removal of the egg container lid is recommended to allow the medium to dry slightly and the hatching crickets to escape into a suitable container.

Rearing tips:

- Remove uneaten food daily and provide daily access to fresh food with no exceptions.

- Maximum of 1000 adult insects per container (60cm x 40cm x 40cm).

- Provide crickets with cardboard egg trays or boxes to maximise the surface area available.

- Refresh your breeding colony weekly with young adult crickets (particularly females). Adults will only live for a few weeks. Ensure that your breeding colony does not contain many sub-adult crickets as this will significantly reduce the quantity of eggs produced.

- It is recommended that housing tubs are cleaned at least every other day to remove old food and dead animals. This will also help to avoid disease problems and keep the smell down. Tubs should be thoroughly washed, disinfected, rinsed and dried each time.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

Scientific name: ***Acheta domesticus***.
Common name: House Cricket.

Complete life cycle**:** 2 months (28°C day, 25°C night).
Eggs: 7-10 days
Hatchling to adult: 45-48 days. 7 instars.
Adult: 30-40 days.
First eggs: after 1 week. Each female will lay 50-100 eggs.

Introduction: The house cricket is native to south-western Asia, but has been widely distributed by man. *Acheta domesticus* is a species that is presently reared in captivity in large numbers primarily as food for predatory invertebrates, birds, mammals and herptiles. Obtaining a reliable supply of these insects can be difficult, especially if one requires a constant supply of newly hatched 1st instar crickets.

Food: Requirements as for *Gryllus bimaculatus.*

Environmental requirements: Temperature should be as constant as possible and be maintained at 28°C during the day with a drop down to 25°C at night. 60W or 100W spot bulbs can be used to maintain local cage parameters. Relative humidity should be around the 40-50% mark, although the oviposition site will be a lot more humid due to it containing damp sandy soil. Photoperiod 12:12.

Housing: Requirements as per *Gryllus bimaculatus.*

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Plastic pots. Incubator. Cardboard egg boxes or trays. Clean sand and soil/coir.

Egg management: Requirements as for *Gryllus bimaculatus.*

Rearing tips:

- Remove uneaten food daily and provide daily access to fresh food with no exceptions.
- Maximum of 1000 adult insects per container (60cm x 40cm x 40cm).
- Provide crickets with cardboard egg trays or boxes to maximise the surface area available.
- Refresh your breeding colony weekly with young adult crickets (particularly females). Adults will only live for a few weeks. Ensure that your breeding colony does not contain many sub-adult crickets as this will significantly reduce the quantity of eggs produced.
- It is recommended that housing tubs are cleaned at least every other day to remove old food and dead animals. This will also help to avoid disease problems and keep the smell down. Tubs should be thoroughly washed, disinfected, rinsed and dried each time. Discard failed and used egg-pods regularly.
- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

Scientific name: ***Gryllus assimilis***.
Common name: Jamaican Field Cricket.

Complete life cycle**:** 4 to 5 weeks at 30°C for newly hatched nymphs to develop into adults. At 26°C the development time is about 9 weeks.
Incubation of eggs is approximately 8 days at 30°C.

Introduction: From 1915 until 1957, many species of North American *Gryllus* were generally classified as *Gryllus assimilis*; it is therefore possible that collections may hold similar species that have been wrongly identified. All individuals are long-winged. It is successfully reared in captivity in large numbers and has a rapid development time and so is an especially appropriate live food species.

Food: *G. assimilis* is an omnivorous cricket that requires a high protein element in its diet. This can be provided in the form of trout pellets or ground dry dog or cat food (use brands with less than 12% fat). Fresh food such as carrot, apple and orange should be made available on a daily basis. Brassicas can be provided in small quantities. It is important to remember not to feed excessive calcium to rearer crickets as this can interfere with ecdysis. High calcium loading or dusting should only be utilised immediately prior to use on feeder crickets. A Petri dish containing clean water soaked into cotton wool is also recommended.

Environmental requirements: Temperature should be as constant as possible and be maintained at 28-30°C. A 60W bulb can be used to provide local temperature requirements. Relative humidity must be as low as possible, although a light spraying once daily is recommended for the nymphs. Photoperiod 12:12.

Housing: Large plastic boxes 40cm x 70cm x 40cm can be used to house the adults. Height is as important as floor space. The boxes need to be well ventilated (two sides provided with fine meshed holes). If the container is not deep enough to prevent crickets from jumping out, cover the container with a lid (also with meshed holes for good ventilation). If the sides of the box are not smooth, it may be necessary to add a stripe of Vaseline or similar substance along the inside upper section of the box to prevent escapees. Wood shavings (a depth of 1.5-2cm) may be used to line the base of the box. Nymphs can be reared in smaller versions of the adult housing boxes. When they are about 1cm long they can be transferred to the adult size containers.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves face masks and eye protectors). Plastic housing boxes. Plastic pots for egg oviposition. Hand spray gun. Incubator. Cardboard egg boxes or trays. Clean sand and soil/coir. Wood shavings.

Egg management: It is recommended to use circular plastic pots no deeper than 7cm and 10cm in diameter filled to the brim with a 1:1 mix of coir and sand. This mixture should be sprayed with water until it is damp all the way through, but not so that there is standing water on the surface. Remember this will dry out quite a bit during the day. The pot should be positioned so as to give maximum access for the female crickets and not next to any food source to avoid contamination of the egg field. The pots should be changed on a daily basis and placed in the incubator, with a lid on, at 30°C for 8 days. On the 7th day of incubation, removal of the egg container lid is recommended to allow the medium to dry slightly and the hatching crickets to escape into a suitable container.

Rearing tips:

- Remove uneaten food daily and provide daily access to fresh food with no exceptions.

- Maximum of 200-300 crickets per housing box of 40cm x 70cm x 40cm to ensure maximum oviposition.

- Crickets need more rearing space than most other insects. Over crowding is stressful and leads to premature death. It is important to provide vertically arranged cardboard egg trays or paper towel roll cores inside the box to increase surface area.

- Refresh your breeding colony weekly with young adult crickets (particularly females). Adults will only live for a few weeks. Ensure that your breeding colony does not contain many sub-adult crickets as this will significantly reduce the quantity of eggs produced.

- Discard failed and used egg-pods regularly.

- It is recommended that housing tubs are cleaned at least every other day to remove old food and dead animals. This will also help to avoid disease problems and keep the smell down. Tubs should be thoroughly washed, disinfected, rinsed and dried each time.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- ***Gryllodes supplicans***, the tropical house cricket, can also be bred using the above method, but be aware that this species can become a pest in well heated premises.

Health related issues: Recently many *G.assimilis* cultures have suffered from viral diseases in European collections. Protozoans have also been found in cricket cultures. Please refer to a veterinarian or invertebrate pathologist for further advice. Bacterial infections can occur and the maintenance of low humidity and the reduction of overpopulation stress are crucial in the control of bacterial outbreaks.

Scientific name: ***Medauroidea extradentata*** (synonym*:* ***Baculum extradentatum***).
Common name: Annam Stick Insect.

Life cycle: Egg incubation takes between1.5-3 months. Nymphs mature in 4 to 6 months and the adult lifespan is 4-6 months.

Introduction: Distributed throughout Vietnam these medium sized phasmids have been bred in Europe for many years. In many stocks the males died out and they are now bred as a parthenogenetic culture. A very easy species to rear, especially at average room temperature.

Food: Suitable food plants include the fresh leaves of bramble *Rubus* sp., rose *Rosa* sp., oak *Quercus* sp. and hawthorn *Crataegus* sp. Ensure that the food is free from pesticides and wash before use.

Environmental requirements: This species should be maintained at a comfortable room temperature of between 22-24ºC. The temperature should be allowed to drop several degrees at night time (no less than 19ºC). They should be kept at a low humidity, so well ventilated housing is recommended. Mist with purified water twice daily. Photoperiod 12:12, with normal room lighting.

Housing: An enclosure that is 50-60cm tall will enable the phasmids to develop properly. Good ventilation can be achieved by 2 meshed holes diagonally situated on opposite sides of the unit. Access to the unit is via a transparent front door for easy daily service (avoid a sliding door due to the risk of injury to the insects whilst opening and closing). The floor should be covered with a thin layer of paper towels.

Equipment: A housing unit. Secateurs. Gardening gloves (if collecting bramble). Plastic box for egg incubation. Jars to insert the food plant branches. Cotton wool. Paper towels to cover the base of the unit. Fine water sprayer filled with purified water.

Egg management: Eggs are catapulted by the female stick insects and drop onto the enclosure floor. Small plastic boxes (15cm x 10cm x 7cm) for egg incubation are required. The boxes are usually air-tight, so at least 2 small ventilation holes measuring 4cm in diameter are necessary (it is possible to make holes in the lid). Eggs should be positioned on top of moist sand, peat free compost (or mix of both), or vermiculite or coir. Provide the eggs with a light misting of water once a week (avoid extra watering). Egg incubation must be maintained at 20-24ºC.

Rearing tips:

- The base of the food plant should be placed in a jar of water. The water should be changed regularly to keep the food fresh for a number of days.
- Plug the top of the jar (e.g. with cotton wool) to prevent the phasmids from drowning in the water.
- Ensure that the food plant is only given a light misting as small larvae can drown in big water droplets.
- Avoid overcrowding – they require space for moulting.

- Do not position in direct sunlight, extreme temperatures can cause death in these phasmids.

- Remove excrement/frass from the substrate once a week. Separate any eggs that have become mixed with the frass and keep them apart in date labelled incubation containers.

- Monitor the moisture levels in the egg incubation containers. Mould will form on eggs that are kept too damp and eggs can dry up if left unattended for long periods.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- Disinfect housing and replace paper towelling on a regular basis.

- It is recommended to acquire a founder colony which is free from contaminants and properly identified; remember other species will require different techniques and environmental requirements

Health related issues: Little is known about diseases of Phasmidae. They sometimes die without a known cause. It is usually due to inappropriate conditions (incorrect temperature, humidity, overcrowding or food with insecticide sprayed on it). If an infection occurs, housing must be cleaned out and disinfected thoroughly.

Scientific name: ***Carausius morosus.***
Common name: Indian Stick Insect.

Complete life cycle**:** 12-16 months.
Egg**:** 3-8 months. Nymph**:** 4 months, 5 instars. Adult**:** 8 months.

Introduction**:** This insect originated from Palmi Hills (Tamil Nadu in Southern India), and has been the subject of study in many laboratories and schools. This species will tolerate the ordinary range of a European indoor climate and is therefore not at all difficult to rear in captivity in large numbers. Males are rare, only 1 to 1000 females. Males grow to 48.5-61mm in length and females between 70-80mm. It is a nocturnal species and sits well camouflaged under leaves and on branches.

Food: The easiest food plants to offer are privet *Ligustrum* sp. and ivy *Hedera* sp., but a wide selection of other plants can be offered including bramble *Rubus* sp., hawthorn *Crataegus* sp. and *Pyracantha* sp. These food plants must be kept in fresh clean water that is changed regularly.

Environmental requirements: Temperature should be maintained at 26°C. Lower temperatures can be tolerated by the stick insects but this will slow down their reproduction. RH 60%. Photoperiod 12:12, with normal room lighting.

Housing: Commercial type breeding units (35cm x 60cm x 70cm) will give enough height for the stick insects to have clearance beneath them equal to twice their adult length. The provision of perching is very important for successful moulting. The substrate should be 4cm deep and comprise of a coir/soft sand mix in a 50/50% ratio.

Equipment: Breeding unit. Secateurs. Gardening gloves (if collecting bramble). Jars to insert the food plant branches. Cotton wool. Plastic box for egg incubation. Coir and sand. Fine water sprayer filled with purified water.

Egg management: Eggs will be dropped onto the sandy substrate; 90% of them should emerge. A newly adult female produces 4-9 eggs every night. It is possible to collect eggs and manage them using the same protocols as described for ***Medauroidea extradentata***, the Annam stick insect.

Rearing tips:

- The base of the food plant should be placed in a jar of water. The water should be changed regularly to keep the food fresh for a number of days.
- Plug the top of the jar (e.g. with cotton wool) to prevent the phasmids from drowning in the water.
- Ensure that the food plant is only given a light misting as small larvae can drown in big water droplets.
- Avoid overcrowding - they require space for moulting.
- Do not position in direct sunlight, extreme temperatures can cause death in these phasmids.

- Remove excrement/frass from the substrate once a week. Separate any eggs that have become mixed with the frass and keep them apart in date labelled incubation containers.

- Monitor the moisture levels in the egg incubation containers. Mould will form on eggs that are kept too damp and eggs can dry up if left unattended for long periods.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- Disinfect housing and replace substrate on a regular basis.

- It is recommended to acquire a founder colony which is free from contaminants and properly identified; remember other species will require different techniques and environmental requirements.

Health related issues: Little is known about diseases of Phasmidae. They sometimes die without a known cause. It is usually due to inappropriate conditions (incorrect temperature, humidity, overcrowding or food with insecticide sprayed on it). If an infection occurs, housing must be cleaned out and disinfected thoroughly.

Scientific name: ***Gromphadorhina oblongonota***.
Common name: Hissing Cockroach.

Complete life cycle: 2 years plus.

Introduction: *Gromphadorhina oblongonota* has been misidentified in many instances as *Gromphadorhina portentosa.* The hissing cockroach has been bred by enthusiasts for many years with great success and will be familiar to many zoo visitors for its use in educational demonstrations. As their name suggests they will hiss loudly although this behaviour appears to diminish as they become used to handling. Hissing cockroaches live in the dark, damp environment of the leaf-litter of the forest floor in Madagascar. They lack wings and have a flattened shape allowing them to move amongst the leaves with comparative ease. In the wild they will consume fruits, leaves, seeds, berries and bark; almost any vegetable matter in fact. One of the largest cockroaches in the world, *G. oblongonota* can reach a length of over 8cm. The nymphs will moult 6 times during the course of their lives, the last moult occurring approximately 5 months after the nymphs were born. At the last moult the nymphal roaches become sexually mature adults.

Food: Hissing cockroaches will eat a variety of foods, including fruits and vegetables such as lettuce, cucumber, tomato, orange, apple, pear, grapes, mushrooms and bananas. Uneaten food should be removed daily and fresh offered. They will also eat dry food such as dog biscuits, rat chow or chicken feed. The roaches also need a supply of fresh water; this can be provided in moist cotton wool.

Environmental requirements: Coming from a warm humid environment, they should be kept slightly damp (a good misting spray once a day will usually suffice). A RH of 75-80% is appropriate. Temperature will need to be between 23-27°C. This can be achieved by keeping the roaches in an environmentally controlled room, or by attaching a heat mat to one side of the tank. Ensure that the heat mat is not positioned underneath the tank as this will dry the substrate out and prevent the insects from burrowing.

Housing: *G. oblongonota* can be housed in an aquarium tank with a well fitting lid, measuring 500cm x 500cm x 100cm. The lid must allow good ventilation, but any holes should not be large enough to allow a newly hatched nymph to escape. The floor can be covered with a mixture of bark chippings, leaf-litter and coir no less than 10cm in depth. There must also be a number of shelters for the cockroaches to hide under (large pieces of bark are an excellent choice). Male hissing cockroaches love to perch on top of logs, so tank furniture ought to provide some high perching opportunities. Lighting is essential for viewing, a 12/12 photoperiod from a low wattage bulb (40-60W) will suffice, basking or heat lamps are not required.

Equipment: Aquarium tank. Coir, leaf litter, chippings and bark. Fine water sprayer filled with purified water.

Egg management: The nymphs can take up to 10 weeks to emerge given you have your environmental parameters correct. Nymphs can be left with the adult group as no cannibalism has been observed. 20-50 individuals per ootheca can be produced.

Rearing tips:

- Sex determination can be difficult in the nymphal stages. However, adult males have large protudences on the prothorax and slightly hairier antennae. There are also clear structural differences in the terminal abdominal segment.

- They produce their eggs in a small purse-like capsule known as an ootheca, which will be retained within the body until the eggs hatch. You may occasionally see a female with the ootheca extruded. This is observed during production of the ootheca and once completely formed it will then be retracted into a special cavity in the tip of her abdomen.

- Introduce 10-20 adults (10:10 sex ratio, although it possible to have a higher proportion of females) when setting up a breeding tank.

- Observe daily and record date of hatching and subsequent development.

- Newly-moulted cockroaches are white in colour. The new cuticle takes many hours to harden, and as it does so a gradual darkening will be seen.

- It is recommended to acquire a founder colony which is free from contaminants and properly identified; although other species require similar husbandry techniques.

- Remove dead specimens straight away and send for analysis periodically to monitor the disease profile of your culture.

- It is recommended that housing is disinfected and replaced periodically.

Health related issues: Mite infestation can be a problem and if observed the substrate should be discarded and replaced. Overcrowding can also be a problem leading to very low fecundity and reduction in adult body size. A maximum of 200 individuals of various life stages can be kept in the above recommended housing.

Scientific name: ***Blaptica dubia***.
Common name: Guyana Orange Spotted Cockroach.

Complete life cycle**:** 4-5 months at 30ºC. Sexual maturity is reached in 2 months. Total lifespan is 1.5 years.

Introduction: This species of cockroach is native to French Guiana and Brazil and is reared in captivity in large numbers. It has been found to be an especially appropriate live food species as they are unable to climb glass in either the adult or nymph stages and have almost zero odours. Adults can reach lengths of 40-50mm. The female cockroaches have very short wings and are attractively spotted in red-brown, black and buff.

Food: Omnivorous. High protein dry dog or cat food should be offered in addition to a variety of fruit and vegetables, such as carrots and apples. The fruit and vegetable matter also provides the cockroaches with all of their water requirements.

Environmental requirements: These cockroaches prefer to be in low light levels, so no additional lighting is necessary. Temperature should be maintained in the region of 28-30ºC. RH should be as low as possible, although the roaches will benefit from a light misting of distilled water once daily.

Housing: This species can be housed in a tank with a well fitting lid, measuring 500cm x 500cm x 100cm. The lid must allow good ventilation, but any holes should not be large enough to allow a newly hatched nymph to escape. The nymphs predominantly live in the substrate which can be provided in the form of a 1.5- 2cm layer of peat free compost or coir. The adults can be given cardboard egg trays and/or paper towel roll cores on top of the substrate to increase the surface area available to them. Service lighting can be given via a 40-60 watt bulb; basking or heat lamps are not essential.

Equipment: Plastic boxes. Peat free compost or coir. Egg storage trays or paper towel roll cores. Fine water sprayer. Distilled water. Food trays.

Rearing tips:

- ***Shelfordella tartara*** the Turkmenistanian cockroach and ***Blaberus discoidalis*** the death's head cockroach can also be kept using this method.
- Offer plenty of fresh food on a daily basis, using separate food trays for the dry food and the fruit and vegetable matter.
- Avoid overcrowding – this will help to prevent disease and improve the productivity of your cockroach cultures.
- Ensure that humidity levels stay low to prevent bacterial infections and mite infestation. Reduce misting if concerned. If necessary, clean out housing and provide fresh dry substrate and egg trays.
- It is recommended to acquire a founder colony which is free from contaminants and properly identified; although other species require similar husbandry techniques.

Human considerations**:** This species could become a pest in appropriate conditions, i.e. in well heated premises.

Scientific name: ***Zootermopsis angusticollis***.
Common name: Damp Wood Termite.

Complete life cycle: Colony life cycle is indefinite (see introduction).

Introduction: Endemic to western North America, the damp-wood termite is one of the world's largest termite species, so the potential for nutritional value is significant. They inhabit primary and secondary forest and are found in fallen logs, stumps and dead standing trees. Termites belong to the order Isoptera which is believed to have evolved from cockroach ancestry. These are eusocial insects differing from Hymonopteran insect species in a number of ways, most notably their developmental method in that they employ incomplete metamorphism and also that all castes have both sexes present. Their reproductive flexibility enables them to reproduce by means of supplementary reproductives (workers that become reproductively viable in the absence of a primary reproductive pair). This is important in founder acquisition and for colony development and succession. The crucial element for the successful breeding and development of this species is managing a high level of humidity.

Food: This species feeds on decaying wood using a number of flagellates that exist within the hindgut of this species to act as cellulose digesters. Food type used should be trees such as Pine *Pinus* sp. but many other species can be used. No other food items are required. Avoiding new wood, they prefer sections which are surface weathered and a have good softwood content. The sections should be 4cm thick, although other dimensions can be as required to fit internal vivaria dimensions.

Environmental requirements: Temperature should be maintained between 20°C and 24°C. RH is crucial and should be maintained at 100%. To maintain high RH a bed of coir or peat free compost can be used, which is moistened as required. Small ventilation panels can be fitted into tank lids which will provide limited air exchange and reduce the incidence of mould. A photoperiod of 12:12 should be given, but conditions for optimum development and colony growth require a dimly lit environment.

Housing: Large colonies can be held in glass vivaria measuring 1m x 50cm x 50cm with tight-fitting ventilated lids. These containers need to be filled to 8cm in depth with the recommended substrate.

Equipment: An insect aspirator. Glass vivaria. Coir or peat free compost. Fine water sprayer.

Egg management: Non-applicable. Reproduction is managed completely by the colony itself.

Rearing tips:

- Prepare a number of new breeding containers to ensure the continuous development of the culture and available live food surplus.
- When colony initiation is desired, split an existing colony in half, or thirds if very populous, and supplementary reproductives will be generated.
- Observe daily and record date of colony initiation and supplementary reproductive presence.
- Provide recommended food wood as and when required.

- It is recommended when acquiring a founder colony, that it is free from contaminants and properly identified; other species require very different techniques.

- Ensure *Zootermopsis angusticollis* is a permitted in your country; it may be banned due to is potential as an agricultural pest in some countries.

- Remove dead specimens as soon as possible and send for analysis periodically to monitor the disease profile of your culture.

- It is recommended that housing is disinfected and replaced periodically.

Health related issues: Damp-wood termites have a number of adaptations that reduce the risk of disease. However, if signs of any apparent disease incidence is noticed it should be dealt with promptly.

Scientific name: ***Galleria mellonella***.
Common name: Greater Wax Moth or Bee Moth.

Complete life cycle**:** 3 months.

Introduction: Wax moths occur throughout warmer regions of the world and are classed as a pest species; especially among bee keepers. Their larvae cause damage to the honeycombs. They are now commercially bred in their millions as feeder insects for invertebrates, birds, mammals, herptiles and as fishing bait.

Food: For culturing this insect, it is recommended to use a mixture of bran, wheat-germ, milk powder, glycerol and honey in the following proportions: 500g bran plus 500g wheat-germ plus 100g dry milk powder. This dry mixture is thoroughly mixed together. To this is added the wet mix comprising 500ml Glycerol [glycerine] and 300ml of runny honey mixed together. The resulting mixture must be thoroughly mixed up to ensure a homogenous culture. The mix is then dispensed into a suitable container to a depth of approx 10cm. If the mixture is any shallower, it may be depleted before the culture matures. If the mixture is too deep, the culture can become stale or infested with mites or mould and have to be thrown away.

Environmental requirements: In the early stages of the culture, it is advisable to keep the temperature up to around 30°C. Provided the temperature is monitored, standing a new culture on top of a warm vivarium or very gentle heat mat is beneficial initially. Once the culture is seen to be thriving, the temperature can be reduced to 25-30°C as the larvae will produce quite a bit of metabolic heat themselves.

Housing: Containers for wax moths are ideally constructed out of metal or glass. The larvae will eat wood, some plastics and will eventually compromise a metal container! The container must have a tight fitting but well-ventilated lid. Ventilation holes or mesh should be very fine fruit-fly screen as the wax moth larvae are extremely small in their early stages. The quantity of mixture detailed above is sufficient to start 2 cultures each in 30cm standard glass tanks, each with tight-fitting metal lids. Approximately 20 larvae or pupae are introduced to the culture and left to breed and eventually produce eggs. Initially the microscopic larvae that hatch will travel away from the light into the culture; their growth rate is dependant on temperature. After a few weeks, the larvae will have grown sufficiently to be visible from underneath the tank. These can be allowed to grow on or harvested as required so long as some pupae are retained for the next culture. Breeding containers should be thoroughly washed out, disinfected and dried between cultures.

Equipment: Glass fish tanks or metal tins with tight-fitting well ventilated lids. Fruit-fly screen mesh. 500g bran. 500g wheat-germ. 100g milk powder. 500ml Glycerol (glycerine). 300ml runny honey. A large mixing bowl or bucket.

Egg management: Where moths or larvae are added to the new culture, eggs are left to develop within the culture medium. Alternatively, they can be scraped off an existing mature culture containing breeding moths and transferred to a new container. They are usually laid near the top of the tank or near the edge of the lid.

Rearing tips:

- Once the culture is set up, do not disturb the mixture unduly until the larvae are ready to harvest.

- If the culture is very successful, it is likely that additional food will need to be added at some point to keep the larvae developing. This is done by carefully ‘peeling’ the existing culture up and adding the new mixture underneath. The existing culture will be bound together in silk produced by the larvae.

- Maximum of 20 to 30 adult moths per containers of size outlined above.

Scientific name: ***Bombyx mori***.
Common name: Silkworm.

Complete life cycle: 56-60 days. Eggs: 10-14 days. Nymphs: 27 days (5 instars).

Introduction: Through centuries of refinement of culture in China, the process of rearing *Bombyx mori* is now relatively simple. All you need is a controlled environment and a supply of fresh mulberry leaves *Morus* sp.

Food: Fresh leaves of mulberry, *Morus alba* or *M. nigra*. Artificial diet formulas of leaf powder and protein are not recommended due to poor breeding results. Provide larvae with clean, fresh leaves cut into 2cm pieces. As the larvae grow, provide larger pieces or full leaves. Feed the larvae a few times per day or as frequently as required, ensuring that leaves are always available for consumption.

Environmental requirements: Temperature should be maintained at 25°C. RH 60-70%. A photoperiod of 17 hours of daylight and 7 hours of darkness is required.

Housing: No special housing is needed. A simple dish, shallow box or tray lined with tissue paper will be sufficient. Caterpillars will stay on their food as long as it is fresh. The adult moths do not move and will mate and lay eggs in approximately the same area. Female moths can lay 300-800 eggs in their lifetime.

Equipment: Dish, shallow box or tray. Wire mesh or egg carton. Tissue paper. Petri dishes. Regular supply of mulberry leaves. Secateurs.

Egg management: Eggs will be glued onto any material available (no egg laying material has to be provided). The eggs can be left where they are deposited by the female, or collected and relocated to tissue lined Petri dishes. The eggs will hatch in approximately 10 days at 25°C. During winter, when mulberry leaves are not available, it is possible to induce diapause and store the eggs in a refrigerator at 4°C.

Spinning cocoons: Approximately 27 days after hatching, silkworms begin spinning cocoons. Providing support such as egg-carton, wire mesh or a partitioned box will give the mature caterpillars something to climb on to construct their cocoons efficiently. Cocoons spinning takes about 3 days.

Rearing tips:

- Ensure leaf material offered to larvae has not dried out. Rear your caterpillars on tissue paper and remove/clean it daily.
- Remove dead specimens straight away. Diseases can be transferred on the egg shells. Do not use these eggs for breeding, start again with fresh eggs.
- Collect eggs daily and date-label them.
- This species will produce lots of eggs. Be sure to have enough mulberry leaves available to feed the larvae; the late instar larvae need a lot of food.
- The maintenance of hygienic conditions is extremely important for this species.

Scientific name: ***Drosophila melanogaster.***
Common name: Vestigial Winged Fruit Fly.

Complete life cycle: 37 days (25°C constant). Generation cycle will be about 15 days and from egg to emergent adult should be approximately 9 days.

Introduction: The fruit fly was one of the first animals to be used in the study of genetics and is probably still the most extensively selected for this purpose. This species is easily cultured and is highly prolific making an excellent live food subject.

Food: Vestigial fruit flies may be raised on any fermenting medium and there are many commercial diets available for purchase. There are also countless numbers of favourite home-made diets that do just as well and may not need refining. However, a simple culture medium can be made by following the method below:

1. Peel 15 bananas and roughly chop.
2. Remove the skin from half a pineapple and roughly chop (discard the hard flesh in the centre of the fruit).
3. Roughly chop 1 apple (discard the core).
4. Weigh 150g rolled oats and measure out 1 teaspoon of dried brewers yeast powder.
5. Place all of the above ingredients into a blender (you may need to do this in 2 batches).
6. Blend, until the mixture becomes 'porridge like' in consistency.
7. Pour the mixture into a suitable jug or bowl and microwave until the mixture boils.
8. Stir the mixture, and then divide between 5 clean coffee jars that have been sterilised in a microwave. Take care not to spill the mixture onto the top or sides of the jars.
9. Microwave 25g rolled oats and 5 small bananas (or 5 banana halves) until they are piping hot to the touch.
10. Sprinkle the oats into the jars to form a crust on top of the culture mixture.
11. When the bananas have cooled, insert 1 into each of the coffee jars in an upright position with one end in the culture mixture. You can also insert a strip of cardboard egg boxing into the jar at this point to assist with pupation.
12. Add approximately 30 fruit flies to each jar, covering the top with a piece of fine net curtain material and securing with an elastic band.

Environmental requirements: The most appropriate conditions are temperatures between 21-25°C, RH of 45-55% and a 12:12 photoperiod.

Housing: The entire generations life-cycle can be carried out in the same container, jar or vial. It is recommended that you use glass for ease of cleaning and that you aim to use 500ml containers for mass rearing (large coffee jar).

Equipment: 5 large (500ml) coffee jars. Blender. Microwave oven. Microwave safe bowl or jug. Wooden spoon. Net curtain or cheesecloth material. 5 elastic bands. 20 medium sized bananas (well ripened). 1 apple. Half a pineapple. 175g rolled oats. 1 teaspoon of dried brewers yeast powder.

Rearing tips:

- Special care should be taken to maintain containers at the recommended environmental parameters as higher temperature and humidity is conducive to the growth of moulds, bacteria or mites.
- If mould growth does become a problem, try adding a mould inhibitor to the ingredients of the next batch of cultures.
- Pupation will occur around the 7th day after hatching depending on temperature. The larvae will crawl out of the medium and stick to any available dry surface; towelling or cardboard placed in the medium is perfect for the task. The banana skin used in the culture preparation will also suffice.
- It is important to create new cultures when the next generation of *Drosophila* have hatched to ensure a continuous supply.
- All equipment including jars/vials, tools, utensils and covers for both the animal housing and the media preparation should be sterilised and kept clean at all times.
- Discarded cultures should be cleaned out and washed thoroughly as soon as possible.
- Cultures should not be kept longer than 1 month.
- Personnel should maintain a high level of hygiene, e.g. hand-washing and clean overalls.
- Colonies should not be exposed to direct sunlight and excessive heat will sterilise the males.
- It is important to ensure a good barrier method to prevent wild flies from compromising your vestigial-winged stock; mating can take place through mesh netting!
- It is very important to label containers, especially with dates and usable/non usable status.

Health related issues: Mite infestation can be a difficulty and if observed the culture should be discarded and replaced. Overcrowding will lead to a reduction in egg output and an increase in the adult death rate. Seeding the recommended containers initially with approximately 30 freshly emerged flies is sufficient.

Scientific name: ***Musca domestica.***
Common name: House Fly.

Complete life cycle: 15 days.

Introduction:
Larvae: The mature larva or maggot is 3 to 9mm long, typically creamy whitish in colour and of a cylindrical shape tapering towards the head. The larva emerges from the egg in warm weather within 8-20 hours and immediately feeds on and develops in the material in which the egg was laid. The larva develops through 3 instars before pupation.
Pupae: The pupa is dark brown and approximately 8mm long. The pupal case or puparium is formed from the last larval skin. This varies in colour from yellow, red, brown and finally black as the pupa ages.
Adults: The house fly is 6-7mm in length; the female is usually larger than the male. Its' head has red compound eyes and sponging mouthparts. The thorax is grey in colour with 4 dark longitudinal lines on the back. There is a sharp upward bend in the fourth longitudinal wing vein. The sexes can be readily distinguished by comparing the space between the eyes, which in females is almost twice as broad as in males.

Food:
The ingredients for the larval rearing medium are: 150g rodent pellet and water. The pellets are placed into a 500ml measuring jug and water is added, until it reaches approximately 2-3cm above the pellets. The pellets are soaked for at least 2 hours. The flies will require water. To avoid the flies drowning, it is recommended that a 250ml pot be filled with water. A cotton wool lined Petri dish lid can then be positioned on top and the whole set-up turned upside-down.
Sugar cubes are provided and can be placed on a Petri dish in the enclosure. For breeding females a 1:1:1 mixture of egg powder, milk powder and icing sugar can be offered as a source of protein for egg development. All the above food items should be checked daily and replaced as necessary.

Environmental requirements: The fly colony should be maintained at 25°C ± 3°C, with a 16:8 photoperiod.

Housing: Flies can be housed within a metal-framed unit measuring a minimum of 30cm x 30cm x 30cm. This should be placed inside a large fine net bag which can be tied up in a knot at the opening. Plastic 0.5ltr drinks glasses have been successfully used for holding eggs and larvae medium.

Egg management: Egg collection: Sheets of tissue paper are soaked in a mixture of milk powder and water (as directed on the container) and are placed in a plastic tub with lots of folds and peaks as an egg-laying site. This tub is then positioned in the breeding unit and left for 24 hours or until a sufficient number of eggs are laid. To avoid egg desiccation, it is important not to let the tissue dry out. Be careful not to overcrowd the egg pots with high numbers of eggs. The tissue and eggs are then removed from the unit and transferred into pots containing the larvae medium.

Larval-Adult rearing procedure: A layer of sawdust 1-2 cm thick is placed over the eggs in order to provide cover for the larvae. The egg pots are then covered with netting secured with an elastic band. Complete development to the adult stage takes place within the pots. These are checked daily for newly emerged flies, which are released into housing units on the day that they emerge.

Rearing tips:

- A starter colony should start with 150-200 flies.
- The netting and metal frame can be separated and thus easily cleaned each time the unit requires disinfection.
- A strict adherence to a programme of cleaning and sterilisation between generations is crucial to reduce the risk of disease.

Health related issues: It is important that the fly larvae be raised on a vegetable diet. If the maggot eats meat, it may have contact with the bacteria associated with droop-neck *Clostridium botulinum*. A vegetable diet for the larvae eliminates this concern. It is also beneficial to allow the freshly emerged flies a 24 hour period (with a slice of fruit) prior to feeding to other animals. This is so that they can defecate and release detrimental toxins stored within the larvae and pupa throughout its earlier development.

Human considerations**:** There are more than 100 pathogens associated with the house fly, so the possibility of disease transmission should be considered. Good personal hygiene is very important when working with this species.

Scientific name: ***Pachnoda marginata.***
Common name: Sun Beetle.

Complete life cycle: 3.5-5 months.

Introduction: *Pachnoda marginata* is one of many very similar species found throughout Africa; most of which require very similar husbandry requirements. It is an excellent starter beetle, relatively easy to breed and both adults and larvae can be a used for live food.

Food: The larvae require a mixed substrate consisting of leaf mulch (Oak *Quercus* sp. and Beech *Fagus* sp.), rotten wood (not coniferous) and manure from an herbivorous species such as a Goat *Capra* sp., Sheep *Ovis* sp. or horse *Equus* sp. Be careful that the manure has not been collected from a recently wormed animal; this can be detrimental and potentially life-threatening to the larvae. The adults will require slices of different fresh fruits including banana, orange and apple. A dry equal mixture of bran, rolled oats, powdered milk, brewer's yeast and fish flake should also be provided.

Environmental requirements: Temperature and humidity should be comparably high, but the ranges will differ for adults and larvae. The larvae should be maintained at a temperature between 23-25°C during the day, with a night time reduction to between 20-21°C. The humidity for both 1st and 2nd instar larvae should be kept at 60-80%, and at approximately 50% for 3rd instar larvae and pupa. Adults require a higher temperature range of between 26-28°C (maximum 30°C) and a humidity of 60-80%. The substrate temperature for both larvae and adults should not be lower than 18°C and not exceed 30°C. Lighting should be provided in a 12:12 photoperiod using a 60W bulb. Additional lighting is also recommended to stimulate adults to mate. Lighting can also double up as local heating.

Housing: Adults and larvae can be kept using the same housing method, however it is recommended that adults and larvae are kept separately. A typical set up would consist of a plastic or glass tank measuring 40cm x 30cm x 50cm with a tight fitting ventilated lid. The tank should be filled with substrate to a minimum depth of 20cm with some branches and pieces of bark on the surface. This set up is suitable for 100 larvae or up to 80 adults.

Breeding: Begin by introducing an initial ratio of 10 males and 20 females into the above set up; males can be distinguished by the presence of a small groove on their abdomen. Given the right conditions they will soon mate and produce eggs in 5-7 days (up to 100 per female); the larvae will hatch after a 7-10 day incubation period. It is very important not to let the substrate dry out. The larvae require an average of 2 to 3 months to mature, at which point they will build a cocoon and pupate. The cocoons are often attached to the sides of the container, it is important not to disturb them. The adults emerge from their cocoons in 4-5 weeks.

Equipment: Transparent containers. Fine water sprayer. Leaf mulch. Manure. Branches/pieces of bark.

Rearing tips:

- Substrates will become exhausted at a rate depending on the size and number of adults or larvae present.

- The substrate will need to be changed periodically, taking care not to discard eggs or injure larvae or damage pupae.
- When transferring larvae to new substrates add a handful of the previous substrate to the new mix to ensure that beneficial bacteria required by the larvae to properly digest its food are present.
- Remove uneaten food every second day, this will reduce the presence of mould and mites.
- To maximise your breeding, you may wish to periodically transfer first instar larvae from the substrate in the adult tank as they will consume the eggs.
- Overcrowding will cause adults to diminish in size and increase the incidence of pupation failure.
- Many species of this genus have similar care requirements.
- It is recommended when acquiring a founder colony, that it is free from contaminants and properly identified.

Health related issues: Mite infestation can be a problem, large infestations can lead to ill-health and also death. The only means of control is to change the substrate when a mite presence is detected.

Scientific name: ***Zophobas morio.***
Common name: Giant Mealworm or Superworm.

Complete life cycle**:** Eggs: 1-2 weeks. Larvae: 8-10 weeks. Pupae: 2-4 weeks. Adults: 2-4 months.

Introduction: *Zophobas morio* is a large black Tenebrionid beetle from South America. The larvae which are known as giant mealworms or superworms can reach a length of approximately 6cm.

Food: Wheat or oat bran should be used as a substrate which the giant mealworms will also consume. It is recommended to maintain this at a depth of between 5cm and 8cm. The substrate should be kept dry enough to stop the growth of mould and will need to be changed prior to it becoming exhausted. As it is consumed, the substrate will become a fine powder and can be separated by sifting and moving the larvae to fresh substrate. Providing a water source is vital; potato or apple slices work well. It is important to ensure these are replenished daily to prevent the build up of mould. If the larvae do not have a suitable water source, they can become cannibalistic.

Environmental requirements: *Z. morio* require between temperatures 23°C and 26°C. They cannot be kept in the fridge; even to prolong their life (as with *Tenebrio molitor*) as these temperatures will kill them.

Housing: A large glass or plastic tank measuring 40cm x 60cm x 40cm with a tight fitting ventilated lid is ideal for maintaining 250 larvae or 30 adults. Both life stages can be kept in the same way, the only difference being that adults also require a moist soil substrate area for oviposition. Egg-boxes and pieces of bark can be included to allow the larvae and adults to climb.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Housing container. Egg boxes. Bark. Peat free compost or coir. Wheat or oat bran. Fruit/vegetables e.g. potato, apple. Sieve.

Rearing tips:

- Daily checks are recommended to remove moults and any dead larvae, pupae or adults.
- This species does not automatically pupate at room temperature; they need to be stimulated to pupate. This can be achieved by separating individual larvae into small containers, such as film canisters or other similar sized alternative. Place 1 larva per canister and cover with a small amount of bran. Replace the ventilated lid and maintain between 24°C and 27°C. Once isolated, the larvae will pupate within a few weeks. To initiate a good breeding group, 30-50 larvae should be pupated.
- The canisters should be checked weekly until the beetles emerge and are relocated to the breeding tank.
- The female beetles are larger than the males and can lay up to 500 eggs.
- Eggs will be laid in the soil or on egg boxes and bark if provided.
- The eggs hatch approximately 1 week after they are laid.
- Adults and larvae should be kept separate.

Scientific name: ***Tenebrio molitor*.**
Common name: Mealworm beetle.

Complete life cycle**:** 2.5 to 3 months.

Introduction: Mealworms are naturally found throughout the United States but have been accidentally introduced by man to many other countries. Their fast growth, high productivity and comparable simplicity of husbandry has made this species popular as a live food subject.

Food: Adults require fresh vegetables including carrot, beetroot, potatoes and lettuce. They will also eat other food items such as apple, orange, banana rinds, pieces of dry bread, bran (as a food and a substrate) and fish or meat slices.
The larvae require the same food products, although 2nd and 3rd instar larvae require a protein rich diet for rapid reproduction. The larval substrate should consist of a dry mixture of bran (50%), rolled oats (20%), powdered milk (5%), fish food (20%) and brewers' yeast powder (5%).

Environmental requirements: The optimal temperature range is between 27°C and 28°C with a drop at night to between 23°C and 25°C. Humidity should be maintained at 60-70%. Substrate for adults and larvae must be kept dry, friable and regularly sifted. It should also be changed when it becomes exhausted or soiled with larval frass and uneaten food.

Housing: Metallic, glass or plastic containers can be used for rearing or breeding and should measure 60cm x 45cm x 25cm. This size will support 1.5kg - 2.0kg of larvae. The substrate should be 5cm deep and covered by 2 or 3 layers of rough paper or coarse fabric.

Equipment: Personal protection equipment (e.g. non-powdered disposable gloves, face masks and eye protectors). Housing container. Sieve. Fine water sprayer. Rough paper or coarse fabric (e.g. dishcloth). Fruit and vegetables. Bran. Rolled oats. Powdered milk. Fish food. Brewers' yeast powder.

Rearing tips:

- Paper/fabric layers covering substrate must be misted with water every day.
- Adults have to be transferred to a fresh substrate every 7-10 days.
- Adults begin to mate a week after full maturity.
- Females can lay up to 250 eggs during their lifespan.
- It is advisable to keep different life stages separate.
- Larvae will start to hatch after 5-7 days; during the next 7-10 days they will not need fresh vegetable food.
- Newly pupated adults need to be carefully separated from last instar larvae, as they may be damaged or eaten.
- Ensure that the eggs found within the sifted substrate are kept at the recommended temperature but are not allowed to dry out.

- The food can be presented on the top layer of paper or fabric; dried up leftovers must be removed on a daily basis.

- It can be useful to build a racking or shelf system allowing the different larval stages to be kept at different heights. Eggs and 1st instar larvae will suit conditions on the upper shelf where the temperature is 1°C-2°C higher. The 3rd instar larvae and pupae should be positioned on the lower shelf where it is slightly cooler.

Human considerations**:** The rearing room should be fitted with a good ventilation system due to the amount of dust produced by this species' management. The use of personal protective equipment is recommended.

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www.biaza.org.uk

European Zoo Nutrition centre (EZNC) – An animal based nutritional resource. **www.EZNC.org**

International species information system (ISIS) - Operates the current and is developing the next generation of animal records software. **www.isis.org**

Sonoran Arthropod studies institute – Good resource for the captive husbandry of invertebrates. www.sasionline.org

Watkins and Doncaster - Entomological supplies**.** www.watdon.com