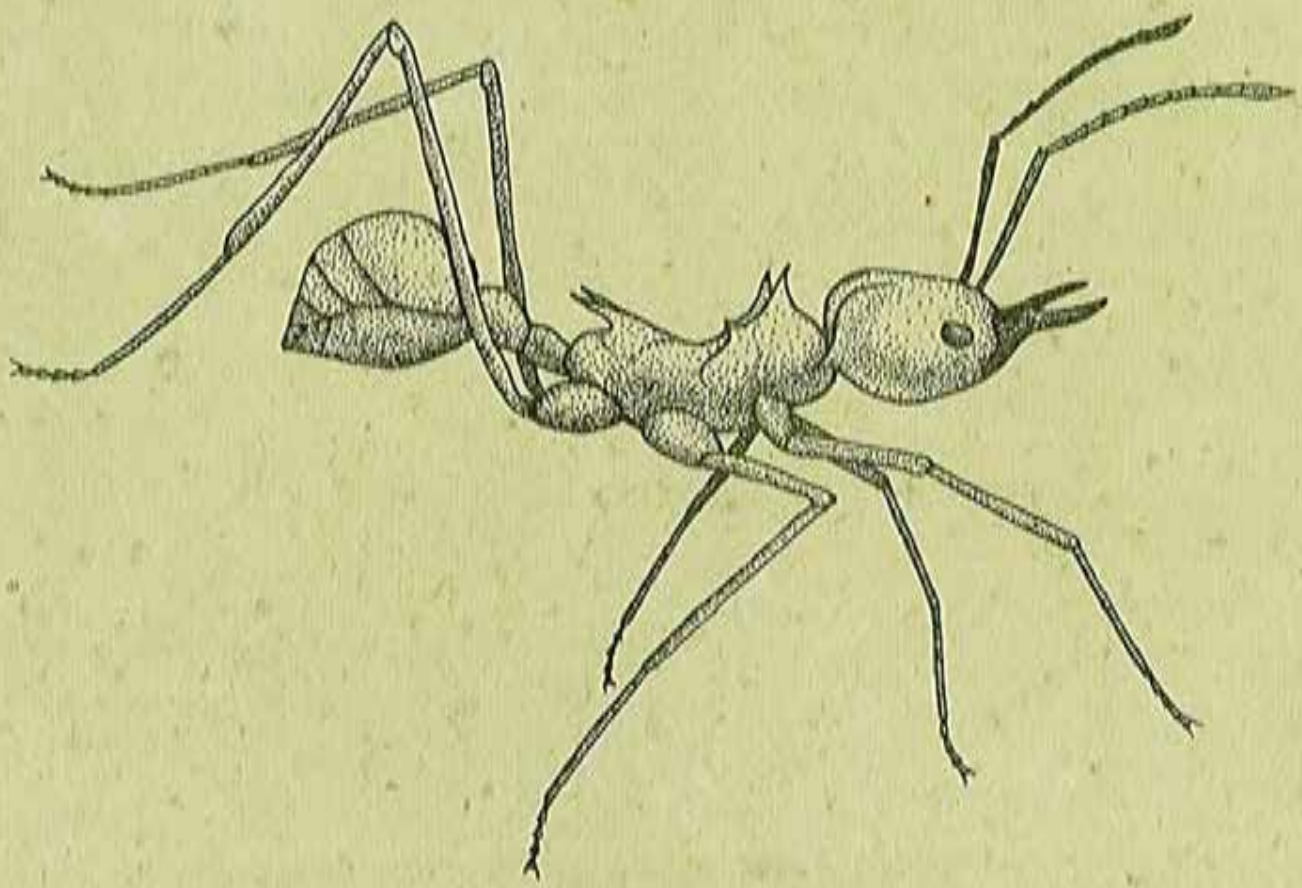
INVERTEBRATES AND ZOOS

DISPLAY AND CONSERVATION POTENTIAL



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CONTENTS

Introduction
Acknowledgements

Section 1: Why consider invertebrates?
* Biodiversity
* Importance
* Conservation

Section 2: Why zoos need to consider invertebrates
* Education
* Visitor attraction
* Species conservation
* Livefood
* Missed opportunities

Section 3: Where to start
* Basic requirements
* Interpretation
*Marketing

Section 4: Examples of proven invertebrate exhibit species.
* An invertebrate garden
* Jellyfish..evolution
* Aquatic leeches..medical value
* Dung beetles..recycling
* Silkmoths..economics
* Leaf ants..complexity
* Jewel wasps..bio control
*Stick insects..variation
* Sri Lankan bush cricket..camouflage
* Red-knee..conservation
* Giant land snail..ecology

Section 5: Examples of species conservation programmes
*Partula tree snails
*British field crickets
*Invertebrate pathology

Section 6: Livefood production notes

Section 7: Further reading

INVERTEBRATES AND ZOOS

INTRODUCTION

The word *invertebrate* is unlikely to crop up in most people's every day conversation. Yet the millions of different species that together make up this animal group have a profound impact on all our lives. For example, bees and other pollinators are vital to healthy crop yields and dung beetles personify the indispensable recycling role of invertebrates. The reproductive patterns of fruit flies and snails have advanced tremendously our understanding of genetics and the mechanisms behind evolution. Chemicals derived from spiders,leeches and ants are providing us with new life-saving medical drugs. Through the science of forensic entomology, invertebrates can even help to solve our crimes.

This booklet has been put together with the intention of encouraging zoos to consider a role for invertebrates as a powerful and much needed component of their exhibit collection and as a highly successful element of their conservation programme work.

Acknowledgements

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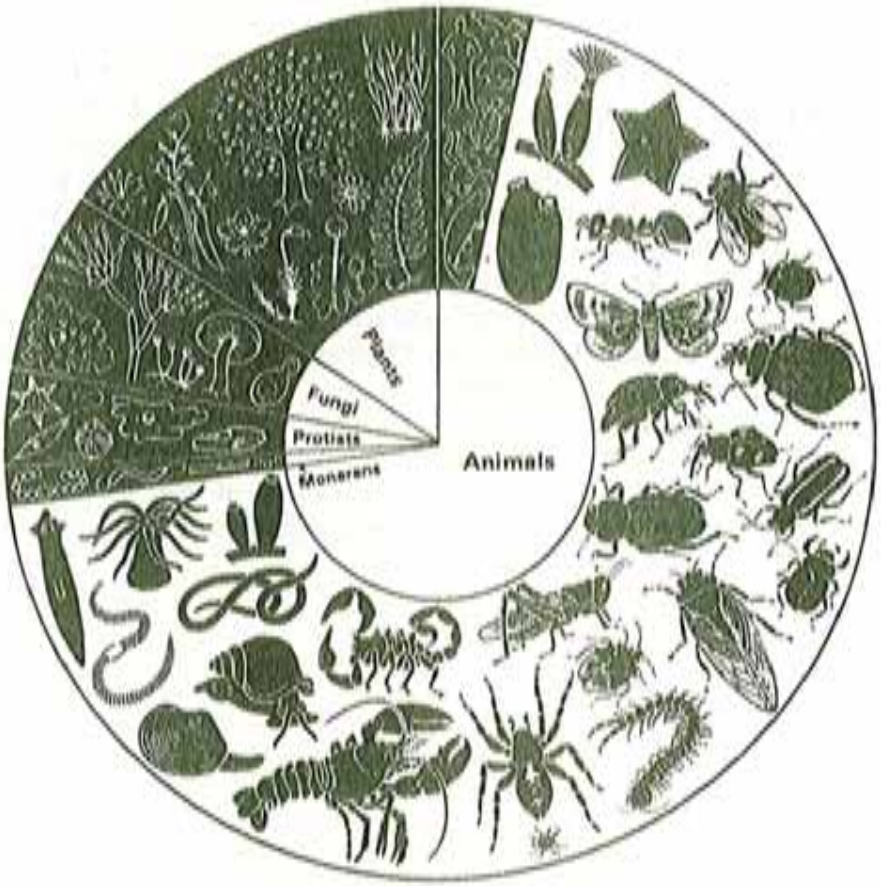

Five kingdoms of living things, distinguished by different levels of cellular organization and modes of nutrition, are here depicted graphically according to the estimated number of living, described species in each. They are far from equal. The 4 smaller kingdoms are dwarfed by the fifth, and largest, the kingdom of the animals. The further subdivision of the animals is still more unequal, with the 3% designated as vertebrates (animals with backbones) showing up as a tiny minority next to the 97% that are lumped together as invertebrates (animals without backbones). With invertebrates occupying the large white sector of this graph, and the rest of the living world (including the vertebrates) confined to the black, the *preponderance of invertebrates among living organisms* stands forth in stark contrast.

Of the 5 kingdoms, the two smallest also have the smallest members, most of them **unicellular** and microscopic. The least complex is the kingdom **MONERA,** which includes the archebacteria, eubacteria, and cyanobacteria (formerly called blue-green algas). Monerans differ radically from all the other living organisms in that they have no well-defined nucleus that holds the genetic material. Thus they are said to be **prokaryotic.** The kingdom **PROTISTA** (or Protoctista) consists of protozoans and unicellular algas. These have a membrane-bound nucleus that (between cell divisions) confines complex chromosomes. Such a cellular organization is said to be **eukaryotic.**

Organisms in these 2 kingdoms may be **autotrophs** ("self-nourishing"), synthesizing their own food from inorganic constituents with the aid of solar or chemically derived energy. Or they may be **heterotrophs** ("nourished by others"), obtaining their food from the bodies of other organisms. Or they may be both.

The members of the other 3 kingdoms are all eukaryotic like the protists, but they are **multicellular.** The three differ in mode of nutrition. In the kingdom **FUNGI** are the **saprobic heterotrophs**—the mushrooms, yeasts, molds, and others that take up nutrients from organic matter, either alive or decomposing. The kingdom **PLANTAE** is made up mostly of **photosynthetic autotrophs,** the familiar green plants. And the kingdom **ANIMALIA** consists primarily of **ingestive heterotrophs,** which live by eating other organisms.

Section 1

Why consider invertebrates?

Biodiversity

As the pie chart at the front of this booklet strikingly illustrates, invertebrate species constitute over 95% of all recorded living animal species. If this overwhelming percentage were not enough, there are estimated to be a further 30 million invertebrate taxa waiting to be described. Even after including the Plants, Fungi, Protista and Monerans the invertebrates still constitute the submerged bulk of our planet's "biodiversity iceberg".

Importance

The biologist E.O.Wilson neatly summed up the importance of invertebrates by stating that if all the vertebrates were to be wiped out the world's ecosystems would be upset for several years but if the invertebrates were to be wiped out our planet would never recover.

In addition to their indispensable role as recyclers, pollinators and key food-chain organisms, many invertebrate species have an important economic, scientific, cultural and aesthetic value for mankind. Indeed, some of our planet's most beautiful and fascinating animal species are invertebrates.

Conservation

When it comes to extinction threat, invertebrates are the most sensitive of all animal groups. This is highlighted by the fact that there are more cases of documented endangered invertebrate species than any other group. Invertebrates therefore require, and deserve, as much consideration as is rightly currently devoted to vertebrate conservation.

Section 2

Why zoos need to consider invertebrates

Education

One of the primary contributions to conservation that all zoos lay claim to is the important role they play in educating the public about the nature and value of biodiversity. However, without reference to the invertebrates any zoo can at best only claim to be presenting its visitors with a tiny and highly skewed impression of biodiversity. Without including the invertebrates how can any zoo hope to be able to educate the visitor about how nature works and why it is so important that all species be considered and valued if the environment is to prosper? The educational themes that can be conveyed with invertebrates are as diverse as they are numerous. Pollination, recycling, medicine, forensic science, genetic research, pollution and, of course, conservation are more bound up with the invertebrates than with any other animal group.

Visitor attraction

In cases where zoos have given due consideration, and resources, to the invertebrate component of their collection they are invariably rewarded with strong public (and media) interest and support. This is particularly so in the case of children who tend to be fascinated by the world in miniature.

Species conservation

Experience suggests that invertebrates provide perhaps the most viable and cost-effective form of zoo-based species conservation. With an estimated combined capacity of some 12,000 hectares, the world's zoos have been estimated to be able to support viable populations (i.e. 500 head) of around 800 land vertebrate species (Maier & Page, 1990). This figure is in stark contrast to the estimated potential for zoo-based invertebrate breeding programmes. If just 1% of the total world zoo space was devoted to housing invertebrate collections it can be calculated that some 15,000 invertebrate species could in theory be preserved as viable *ex situ* populations (Morton 91).

At the 18th General Assembly of IUCN held in Perth in 1990 a resolution was adopted on the conservation of insects and other invertebrates, urging action to strengthen invertebrate displays by zoos and butterfly houses linked to captive breeding and re-establishment programmes (IUCN, 1991).

It is to be hoped that with increased cooperation between established centres of invertebrate expertise, such as universities and museums, ever more zoos and related institutions will realise their tremendous potential for playing a major role in conserving many of our planet's most threatened invertebrate species, and will begin to allocate resources accordingly.

Livefood

For many zoo animals, invertebrates included, livefood (such as crickets and mealworms) is an important and sometimes essential source of nourishment. Setting up an invertebrate livefood production unit is a simple task which is discussed further on in this booklet.

Missed opportunities

It is clear, then, that by not considering invertebrates the majority of zoos are currently missing out on exhibit attractions and additional resources that could pull in many more visitors. On the conservation species front, zoos are currently failing to realise anything like their true potential for contributing towards species conservation.

HOW CAN THIS SITUATION BE RECTIFIED?

The solution is easier than might be supposed for invertebrates are without doubt the most cost effective zoo animals from every perspective. So, the message here is that **ANY** zoo can become involved with invertebrates whenever it so wishes. All that is required to begin the process is the **will** to do so. Starting perhaps with a single invertebrate exhibit, such as a dung beetle display placed alongside the elephant enclosure, a zoo can over night open up an entirely fresh educational dimension and display experience for its visitors.

Section 3

Where to start

Basic requirements

It is obvious that the degree of resource commitment (measured in both people and materials) will vary greatly depending upon the nature and number of invertebrate exhibits a zoo is considering investing in. Any zoo wishing to establish an invertebrate element to its animal collection can do so virtually overnight by setting up individual invertebrate displays either as stand alone exhibits (eg an observation bee hive) or perhaps situated alongside existing vertebrate exhibits. With due attention to species selection an invertebrate display juxtaposed with a vertebrate display (eg dung beetle and elephant) can both enhance the appeal of both displays and greatly add to the ecological interpretation of an exhibit.

Depending upon the species being considered, the costs involved in setting up a simple individual invertebrate exhibit can be practically nothing. So financial considerations are not the key issue when considering establishing an invertebrate display. Of far greater importance is the creativity and will of the appointed members of staff to make a success of the project.

Invertebrate Houses

By dedicating or building an area solely for invertebrate culture and display, a zoo effectively creates a new department and potentially a massive educational and conservation resource, as an ever growing number of zoos can testify to.

Butterfly Houses

Butterfly houses are a leap forward into the realms of invertebrate exhibition but careful consideration must be given to the justification of such exhibits. Basic requirements for a butterfly house include:-

An environmentally controlled building -
Humidity control (sprinklers, fogging system, steam trays, waterfalls, hose pipes) -
Food plants specific to the species to be exhibited -
Separate areas for larva rearing, mating and food plant recovery -
Emergence units for incoming pupae (these must also quarantine the specimens from introducing viruses and parasites to the resident stock) -
Flowering plants to feed imagines (an alternative method of feeding imagines is necessary should the flowers fail) -
A good educational policy.

Interpretation

The value of most invertebrate exhibits rests on the quality of interpretation. This may be achieved by a) labelling individual exhibits, b) separate information labels, c) explanatory models etc., d) publications.

a) Individual labelling - explanatory labels should give the animal's name, distribution, diet and information referring to behaviour and habitat. An explanation of anatomy would give the layman a better idea of what they are looking at and a better understanding of related species.

b) Separate labelling - the individual exhibits could be more informative if they are laid out in a common theme (e.g. distribution, taxonomic grouping, habitats, evolution). Further information could include anatomy, metamorphosis, web-building, silk, social behaviour, general information (i.e. invertebrate facts & feats), extinct invertebrates, conservation examples, conservation groups, husbandry techniques, invertebrates and man, pollination, parasites (including human parasites!), reproduction, symbiosis, ecdysis, evolution and so on.

c) Explanatory models etc - enlarged and tactile models of whole animals or specific anatomical adaptations nests etc may greatly enhance the interpretative value of invertebrate displays Preserved specimens (of species or life stages of those species that cannot be exhibited) can help further understanding though these should be tastefully displayed with a purpose for being there rather than as briefly labelled curios. Additionally, casts of molluscs, cnidarians, invertebrate constructions and fossils may be used to good effect with accompanying information.

d) Publications - booklets and leaflets may be sold or given away to expand the information available. This means that labelling can be kept to a minimum, revenue can be gained and the popularity of the subject assessed. There are various possibilities for publications but school work-booklets relating the invertebrates to the national curriculum are an obvious choice.

Finally, even if invertebrates cannot be exhibited at all, any information included in displays which relates to invertebrates is useful to conservation in general. The information helps explain the inter-relationships between all living things and leads the reader to question the destruction of habitats, the use of chemical pesticides etc.

Marketing

Invertebrates already have a well established reputation as "creepy crawlies", infamous for venom, diseases, itchiness, bloodsucking, sliminess, infestation, crop-destruction etc. It would be a mistake to dismiss the "creepy crawly" aspects of invertebrates as an initial attractant to the public. Visitors, especially children are attracted to the "creepy crawly corner" type exhibit Once attracted they can be educated as to the benefits that invertebrates have incurred on mankind and their (the public's) attraction into the building can be compared to flowers attracting insects with colours and nectar to be pollinated. ("education by surprise"). This popularist approach can be used to a greater or lesser extent using cartoons, colourful and well known species and popular misconceptions to purvey important points in an exciting and easily remembered way. It is important that the use of popular attractants does not mutate into a useless mockery of the subject or a side-show type exhibit. Positive popular information might include the importance of insects for pollination, honey and silk and the economic importance of plankton in the food chain.

Statements about the use of pesticides and the causes of decline of certain species could also contribute to the conservation potential of invertebrate exhibits along with addresses and information on conservation bodies and how the individual can help contribute to the conservation of invertebrates.

Section 4

Some examples of proven invertebrate exhibit species

It is not the intention of this booklet to give a comprehensive review of all suitable invertebrate exhibit species. However, that said, the following profiles will hopefully provide the reader with a number of species selection pointers as well as an idea of what's involved with their care and exhibit.

It is worth mentioning at the out set that in general it is easier for a zoo to initially focus on developing a largely terrestrial based invertebrate collection, as the technical considerations associated with aquatic species tend to be more demanding. However, there is no denying the value and tremendous public appeal of aquatic exhibits.

A butterfly garden

Provided there are adequate support graphics, a wildlife garden, positioned and planted with local invertebrate species in mind, is certain to make an excellent and popular invertebrate focused exhibit. With careful planting it is possible to attract a diverse range of wild butterfly and other invertebrate species.

Upside-down jellyfish - *Cassiopeia andromeda*

(Phylum Coelenterata, Order Cnidaria)

Exhibit value

Although (being a marine species) jellyfish are more technically demanding than terrestrial invertebrate species, jellyfish (like so many marine invertebrate species) are a fascinating and extremely popular exhibit species. London Zoo's Invertebrate House has used this species to good effect to convey the message that, like all life, the invertebrates had their origin in the oceans. This group's extraordinary reproductive and developmental strategies also provide a rich source of interpretive material.

Description

As their name implies, upside-down jellyfish do not conform to most people's conventional image of free swimming, bell shaped jellyfish. Unusually for jellyfish *C. andromeda* derives most of its nutrition from a symbiotic relationship with photosynthetic algae in the body tissues. This feeding strategy has led to the jellyfish adopting a largely sessile life on the sea floor where they orient themselves so as to provide their algal colonies with as much light as possible.

Keeping requirements

A captive-bred colony of upside-down jellyfish have been housed in a glass aquarium (120 x 60 x 80 cm high) holding over 400 litres of natural sea water at 27-38°C and 1.020 specific gravity. The substrate is coral sand and black aquarium gravel. A black semi-ridged plastic sheet creates a curved background which conceals uplifts to the underground filtration system. Additional filtration is supplied by an external aquarium power filter, used carefully to avoid stress as the jellyfish prefer gentle water circulation.

The species' feeding strategy necessitates the provision of high levels of lighting. This is provided by a double 250 W metal halide light unit. Supplementary food is given in the form of Liquify Marine, which is squirted by syringe at the feeding arms of the jellyfish, and live brine shrimp nauplii *Artemia salina*.

Maintenance of the exhibit is limited to freshwater replacement of water lost by evaporation and 10% water changes with natural sea water once a month. Unsightly brown algae which can build up are regularly removed. To breed and rear this species really requires a separate breeding tank to provide extra care for the complex developmental cycle of the species (Hofman *et al.*, 1978).

The Medicinal leech *Hirudo medicinalis*
(Order Gnathobellida)

Exhibit value

The medicinal leech provides an excellent example of the valuable role that invertebrates can play in directly benefitting the human condition. In addition to their medical use in clearing up blood clots after micro-surgery, the anticoagulant chemicals produced by medicinal leeches are being used to develop new drugs for treating heart conditions. Scientists are also trying to find out how the leech manages to preserve the fresh condition of its blood feed (which can remain in a fresh condition for up to two years!) which has implications for developing non-refrigerated blood storage protocols.

The medicinal leech makes an extremely interesting and entertaining display animal. Provided they are not over-fed they will remain active, swimming round their tank and interacting with each other. Being a Red Data listed species they also provide a classic example of how a species, very valuable to man, has come to be wiped out from most of its natural range due to over collection and loss of habitat.

Description

The leeches belong to the same phylum (Annelida) as the earthworms and are predominantly bloodsucking worms, although there are many non-bloodsucking species. In water the medicinal leech is a fine swimmer, moving with an S-shaped movement of its body. These handsome leeches can attain a resting length of 6.5cm and can stretch up to twice this length. The medicinal leech has five pairs of simple eyes near the front of the body and detects its

prey by a combination of sight and sensing the heat and movement produced by its potential victim. This species feeds on the blood of mammals, frogs and fish. It cuts the skin with the aid of three sharp jaws which leave a Y-shaped incision. While feeding, the leech injects three chemicals into the wound: 1) an anaesthetic, 2) a chemical that prevents the blood from clotting (an anticoagulant), 3) a chemical that causes blood vessels to dilate, thus increasing the flow of blood.

Keeping requirements

The only diet to give the medicinal leech is fresh blood. Although there are several feeding options the favoured method employed at London is as follows: Every few months the Zoo's hospital staff syringe a small amount of donated blood from the arm of the author (freshly collected abattoir blood does just as well!). The blood is then placed in a glass petri dish and allowed to clot at room temperature. The leeches are removed from their display tank and placed on the clotted blood to begin feeding. The big advantage of this method is that it allows precise control of the food intake of each leech: the leeches can be removed at any time, thus ensuring that each animal is fed but not bloated and so will remain active on display.

Container
It is most important that the tank is escape proof as leeches are accomplished escape artistes. We house our own leeches in a large tank approximately 100 x 100 x 65 cm high with a fine mesh lid. The tank is half-filled with water (about 50 litres).

Water
At London dechlorinated water is used (although rain water will suffice) to which is added a simple Hirudo salt solution (0.5g salt to each litre of distilled water).

Temperature
The ideal temperature is 15°C, although the leeches will be fine at temperatures up to 20°C. They must never be placed in direct sunlight because they will over-heat.

Breeding
Leeches are hermaphrodites with cross-fertilisation being the general rule. The sperm recipient of a pairing will lay the fertilised eggs in a protective cocoon in the earth. Each cocoon will contain 12 eggs and each leech can produce up to 50 cocoons in its lifetime. It is most important that the leeches are provided with a ramp that rises out of the water and is covered with damp moss, for it is in this moss that the leeches will secrete their cocoons.

Care of the young
The young leeches can be kept on display with the adults (indeed, they make very active display animals). The most important point to remember is that the young leech is extremely susceptible to osmotic shock and therefore should not be left in the blood feed for more than 20 minutes. The young will take about 18 months to reach adulthood and will live for a further 1 to 2 years.

NB: Hirudo salt: supplied by Biopharm (UK) Ltd, Hendy, Dyfed SA4 1XB, UK.

Dung beetles *Scarabaeus semipunctatus*
(Order Coleoptera)

Exhibit value

Moving on to the terrestrial invertebrate groups, one would be hard put to find a better exhibit species that exemplifies the indispensable recycling role of invertebrates. The ball rolling species make marvellous exhibit animals being very active cutting and rolling dung and also interacting with other beetles (which can include stealing another beetle's dung ball!).

Description

Most people will recognise the classic dung beetle and be aware of its industrious lifestyle. There are hundreds of dung beetle species and the group is found all over the world. In countries where dung beetles are not naturally found, such as Australia, Man has often intentionally introduced them in order to benefit from their prodigious recycling activities in clearing away the vast amounts of dung produced by cattle. In the dung beetles we find one of the great unsung heroes of nature, the loss of which would be catastrophic for the world.

Keeping requirements

At London, a very successful dung beetle exhibit has been established in a vivarium measuring 100x75x100 cm high. The height is important because the beetles will fly if given sufficient space. A net lid is also important to avoid damaging the beetles' delicate wings. A substrate mix of builders sand, sieved soil and silver sand (1:1:1) with a depth of 30 cm has proved to be suitable for the beetles' tunnelling and brood chamber building activities. A 250 W infra-red lamp provides attractive lighting and raises the daytime temperature to 27°C. At night the temperature is allowed to drop to 23°C. A spray of water in the morning maintains a relative humidity of 60-70% and encourages activity.

Fresh elephant dung supplied daily is all the food the beetles require. The dung is also used by the adults for constructing brood-balls. At London, this species has only produced viable brood balls when given elephant dung. When a suitable burying site is found, the male begins the excavation of a subterranean brood chamber. The 30 cm substrate depth has proved adequate for successful captive breeding although the species is known to burrow considerably deeper in the wild (Heinrich & Bartholomew, 1979). Once the chamber is excavated a single egg is laid on top of the brood ball which the female then caps with dung, creating a distinctive pear shape.

The incubation period appears to be quite short, possibly only six or seven days. The newly emerged larva grows rapidly inside its ball of dung and may reach full size in approximately four months. The microclimate in the brood chamber is very important. If it becomes too damp the larva, or more typically the pupa, will suffer from fungal infections. Conversely if the brood chamber is too dry desiccation becomes a problem. The brood chambers have an estimated temperature of 23°C. Adults newly emerged from the pupal membrane have been observed to take four days for their cuticle to harden fully and assume the dark coloration of the mature adults.

Silkworms *Bombyx mori*
(Order Lepidoptera)

Exhibit value

On a par with the dung beetle when it comes to illustrating the intrinsic value of invertebrate species to Man is the silkworm *Bombyx mori*. In addition to being attractive little moths in their own right they are a classic example of an economically important invertebrate species (not least in India!). At London we complement the basic silkworm exhibit (a large tray with a simple framework for the larvae to pupate on) with several raw hanks of silk as well as a selection of beautiful silk scarves which make a suitably enchanting background against which the visitors watch the silkmoth larvae eating their mulberry leaves or spinning their silken cocoons. This species also provides an excellent opportunity to discuss the amazing subject of insect pheromone communication. Each of the insect's life cycle stages can be clearly presented to the visitor.

Description

Cultured by Man for some five thousand years, this silkmoth is now no longer found as a wild insect. The natural range of the original wild silkmoth was China and remained so until some larvae were smuggled out of the country (the penalty for doing so being death!) hidden inside some hollow canes. There are several coloured silk forms (the commonest being white and yellow). From egg to the cocoon stage takes between four to six weeks. The initially tiny larvae quickly develop into impressive larvae that can be kept in fairly high concentrations, which makes for an interesting display.

Keeping requirements

Providing one has access to healthy stocks of mulberry leaves, this species is very easy to maintain in culture and exhibit. Hatching larvae are placed onto shredded fresh mulberry leaves.

Diet
Any species of mulberry leaf. Care should be taken to ensure that the leaves offered are both fresh and clean.

Pupation and mating
If their pupation needs are not met, the mature larvae will start to wander off the feeding tray area in search of a suitable place to spin their cocoons (each of which may contain up to 600 m of silk and takes the larva 150,000 separate spinning movements). Larvae can be prevented from wandering off by the simple expedient of fanning out a handful of straw or twigs on the food tray area so as to provide plenty of sites for the silkworms to spin and attach their cocoons. The adults emerge some two weeks later and will mate and lay their eggs all in the same cocoon laying area, enabling the zoo visitor to observe the entire life cycle.

Overwintering the eggs
By placing the freshly collected eggs into a refrigerator (6-10C) it is possible to keep the eggs in a dormant stage until the following mulberry leaf season.

Leaf-cutting ants - *Atta cephalotes*
(Order Hymenoptera)

Exhibit value

A busy leaf ant colony makes a fascinating exhibits and provides an extremely powerful example of how complex invertebrate communities can be. A leaf ant exhibit also illustrates how invertebrates were actually the first agriculturalists!

Description

Leaf ants cut huge amounts of leaves which are brought back to the underground nest, which in the wild will attain an extremely large size. They break down the leaves there to form compost upon which they cultivate a special species of fungus. This fungus garden provides the ants with all their food. A leaf ant colony comprises several different casts or types of ant. The largest of these is the queen, who can attain an enormous size. Then there are the large soldier ants, which protect the nest and guard the trails. These soldier ants possess huge jaws, so large in fact that they are unable to feed without the aid of smaller worker ants. The next size down are the collecting ants which perform the bulk of the leaf gathering. To this end they will cover an extremely large area and carry back to the nest plant material held up over their heads in their strong jaws. Lastly, there are the tiny minima ants who are found in their thousand, tending fungus gardens, breaking down the leaf material and weeding out unwanted species of fungus.

It is important to bear in mind that the above description is a very general one. The relationships and interactions between the different casts and the many other tasks carried out, such as care of the young, building and cleaning, all make for a very complex story which can only be touched upon here.

Keeping requirements

Housing
A large colony of leaf-cutting ants *Atta cephalotes* is exhibited in a glass aquarium (585 x 50 x 76 cm high). The colony's nest and fungus gardens are housed in inverted glass jars (14 x 14 x 20 cm high). Each glass chamber is set into a plaster of Paris base, which absorbs atmospheric moisture and helps to provide a high relative humidity, >75%, as well as forming an ideal substrate for the fungus gardens. Each chamber has an entrance cut into the plaster base which is just large enough to allow the queen to pass through, should she wish to move between nest chambers.

These glass nest chambers are arranged on a 10 cm high glass table which stands over shallow water heated to 24-25°C. The purpose of the water is to prevent ants escaping, to maintain a steady temperature and to provide the high level of humidity needed by the fungus gardens. It is important that the water is not contaminated with cleaning agents, as it is used by the ants as a drinking source and is also taken into the fungus gardens. The size of the colony can be controlled, to an extent, by the number of glass nest chambers that are provided.

Display

The colony at London Zoo is contained in five chambers situated at one end of the display. Food is placed on a raised platform at the opposite end of the display, which is connected to the nesting area by a branched walkway, providing the public with a wonderful view of all the ants' many and varied activities - collecting and cutting the leaves, carrying them back to the nest, breaking them down into compost, caring for the fungus gardens, feeding the soldiers, looking after the young, cleaning etc. In short, one can observe the animals behaving in a totally natural manner. The exhibit is enhanced by a visitor-operated, closed-circuit video camera linked to an overhead monitor: the viewer can determine the magnification and direction of the camera.

Temperature

The temperature should remain within 25-27°C because queens can become sterile at high temperatures.

Humidity

Ambient relative humidity should be around 70%. The relative humidity within the nest may be almost 100%.

Lighting

Our display colony has both natural light and Grolux fluorescent tubes which are on a 12 hour on 12 hour off system.

Waste dumps

We have tried, in vain, to train our ants to accept and use a dumping area. They seem resolute in their desire to drop their rubbish (old fungus and composted leaves etc) over the edge of the table into the water below. To allow for this behaviour and to prevent the ants from walking on floating rubbish (and hence escaping) we have installed a water pump which keeps the water moving and clear.

Diet

The ants are provided with a food collecting area on which is placed a daily supply of fresh plant material. They will take an extremely wide range of both leaves and flowers, including privet, hibiscus, rose, bramble and grass. They will also take large amounts of orange peel, cut apple and grape. As has been mentioned earlier, the ants do not eat the leaves or fruit they collect (although they will drink the sap and juice) instead they use them to form a compost upon which they grow their fungus gardens back in their nest chambers. It is most important that the food given is fresh and clean. Care should be taken that no insecticides have been sprayed on plants in the zoo grounds - no easy matter when one has to deal with an over zealous gardening department!

Breeding

Alas, with leaf-cutting ants breeding in captivity is out of the question. When a colony wants to expand it will put out large numbers of winged queens and males. These will fly off, mate in the air and land far from the old colony. Upon landing the queen will lose her wings and find a suitable place in the ground to start her colony. The queen takes with her, in a special pouch under her chin, a lump of fungus from the old colony, which she will cultivate to ensure the new colony's food supply. To achieve a successful mating in captive conditions would require an area the size of an aircraft hanger.

The Indian jewel wasp - *Ampulex compressa*
(Order Hymenoptera)

Exhibit value

One of the most striking of all invertebrate display animals is the Indian Jewel Wasp *Ampulex compressa*. In addition to their attractive appearance, jewel wasps make superb exhibit species because of their fascinating behaviour which involves the adult females catching cockroaches on which their young feed. The wasp buries the cockroach and to this end she will spend a large part of the day carrying small stones from every part of the display tank, which makes an enthralling display.

Description

This large, beautiful wasp has an iridescent blue-green body and red femora (thighs) of the second and third pairs of legs. The female is about 22mm long, the male is somewhat smaller and has a more rounded end to the abdomen. Although in the wild these wasps are solitary it is possible to keep a couple of females and many males in a single exhibit tank. The female lays a single egg in a paralysed cockroach where the larva lives as a parasite, eventually killing its host before pupating. The species is found in India, Burma and Sri Lanka and has spread (often intentionally by Man as a biological control agent) over much of the tropics.

The female wasp hunts actively for her prey and once a cockroach has been detected the wasp attacks it immediately. She seizes the cockroach with her mandibles and bends her body round to give a sting to her victim behind its first leg. While paralysis takes hold of the cockroach the wasp retires to preen herself. When she has found a suitable nesting site she returns to her victim and cuts off its antennae, leaving only two short stumps about 1cm in length. She then grabs hold of the cockroach and pulls it to the nest site, where a single egg is laid at the base of the cockroach's second leg. The wasp then seals the nest with small stones. The larva hatches after about three days and proceeds to feed on its host for three to four weeks before pupating. The new adult finally emerges from the nest about 45 days after the egg was laid.

Keeping requirements

Temperature: 23-25°C

Diet
The adult wasps are given dilute honey. The larvae feed on the American cockroach *Periplaneta americana*.

Display
At London, two females and up to eight males are displayed in a large glass tank about 100 x 100 x 70 cm high. The tank is filled to a depth of about 16 cm with sandy soil and sprinkled with a good smattering of aquarium gravel, which the female uses to seal the entrance to her cockroach burrow. The exhibit is planted out to give a semi-arid display. A glass lid allows plenty of light into the tank and prevents the wasps escaping. A small access hole with lid is cut into the main lid to allow the exhibit to be serviced without losing any wasps. Two clear plastic nesting tubes are placed in the substrate against the glass front of the exhibit for public display. These are replaced regularly once occupied.

The jungle nymph stick insect *Heteropteryx dilatata*
(Order Phasmida)

Exhibit value

The Phasmids are an excellent display group being both easy to maintain in culture and popular with the public. The 2,000 odd Phasmid species exhibit amazing diversity in shape, colour and behaviour. One of the most striking species is the jungle nymph *Heteropteryx dilatata*.

Description

The giant green jungle nymph comes from the rain forests of Malaysia. Like all stick insects they rely upon their wonderful camouflage to keep them out of trouble. However, if they are disturbed they are rather more equipped to defend themselves than most members of their order. They are covered in spines which makes picking them up quite a painful experience. In particular they make very good use of the spines on the inside of their strong back legs. They will also make an alarming noise by rubbing their wing cases together. All this makes for a very attractive and interesting display animal. The males are very different from the much larger females, which have lost the ability to fly.

Keeping requirements

Diet
One of the natural food plants of this species is Loquat *Eriobotrya japonica*. They will also happily take bramble leaves.

Temperature
A constant temperature of 26°C

Humidity
Heteropteryx, like most stick insect species, requires a high degree of humidity, generally 70% or more.

Lighting
Natural and fluorescent tubes, 12 hours on 12 hours off.

Breeding
At London Zoo, *Heteropteryx* lay eggs in the peat provided for them in this display. The eggs are collected and transferred them to plastic lunch boxes containing a substrate of moist peat or vermiculite (a sterile medium). The boxes are dated and kept at between 24 and 26°C. The eggs can take 8 months to 2 years to hatch. The young nymphs do well and have a good chance of reaching adulthood.

Display
Our *Heteropteryx* are housed in a large mixed species exhibit. This makes the public work at trying to spot the wonderfully well-camouflaged species, which are often right in front of them!

Sri Lankan bush cricket *Vetralla quadrata*
(Order Orthoptera)

Exhibit value

The Orthoptera is another very well represented group in invertebrate display collections. A good example of an orthopteran display species is the Sri Lankan bush cricket *Vetralla quadrata*.

Description
These crickets are beautiful, relatively large, displayable animals. What makes them stand out are the nymphs which display a diverse range of colour forms (green, red, orange,pink,yellow etc). Another attractive element of this group of insects is their charming, lilting song.

Temperature
They do well at a temperature of around 22°C

Humidity
70% provided by damp peat and a daily water spray.

Diet
This species does very well on a diet of lettuce, orange and apple as well as rhododendron leaves. They require a temperature of around 22°C and a humidity of about 70%.

Breeding
The colony we had at London Zoo was nearly 20 years old with no sign of inbreeding. The species is easy to breed and large numbers of single eggs are laid just below the soil. Incubation takes around 6 weeks and the resultant nymphs take between 6 - 12 months to become adult.

Display
At London they are displayed (as part of our camouflage theme) in a large glass tank (1 m^3 and are provided with plenty of foliage which both provides an attractive and natural backdrop as well as providing the nymphs with sufficient moulting opportunities.

The Mexican red kneed bird-eating spider
(Order Arachnida)

Exhibit value

These spectacular animals are one of the most popular exhibit species due to their large size and reputation. Although normally inactive they are nearly always on show to the visitors.

Description

This is a beautiful spider which with proper care can live for over 20 years in the case of females. Males seldom live for more than 7 years. The sex of a spider can only be determined after the final moult, when sexual maturity is reached. Males mature at approximately 5 years of age. Females mature at 7 years of age and are larger and heavier than the males. Sex determination in both sexes is confirmed when breeding behaviour can be seen, followed in the female by the laying of eggs and the formation of an egg sac. An average female spider measures 13cm from tip to rear and 7cm across the body and legs, males are a little smaller.

All spiders are venomous depending on poison to kill their prey which is normally small insects. Mexican red-kneed spiders very rarely bite and it is generally no worse to humans than a bee sting. Of course, in saying this, one must remember that reactions differ with individuals and with age. An irritated spider can flick urticating hairs from its abdomen with the fourth pair of legs. The abdomen of a quick tempered spider can become quite bald by the time it is due to moult. A spider flicking hairs is best left alone to calm down. Mexican red kneed spiders can be handled, but only by an experienced person. A real risk is that the spider may fall and burst open with loss of body fluid. This type of disaster is usually fatal.

Keeping requirements

A variety of containers can be used - glass or plastic. The floor should be covered with damp peat or horticultural vermiculite to a depth of 6 to 10cm. Pieces of bark or half a flower pot should be provided for shelter. Water must be available in a small pot. Spiderlings can be given a ball of wet cotton wool.

Diet
Locusts, crickets, moths are all suitable for adults. Small cricket nymphs or fruit flies are suitable for the spiderlings. Uneaten food must not be left in the container.

Temperature: 20-30°C

Humidity: 70%

Moulting
Inexperienced owners of spiders are sometimes dismayed to find their spider lying on its back. This is normal and it must not be disturbed. The cuticle of the prosoma splits and the "lid" comes off. The fangs, palps and four pairs of legs are pulled from the empty tubes and the spider scrabbles forward into shelter and safety to allow its new cuticle to harden. It will not feed for a few days.

Conservation
Mexican red kneed bird eating spiders are now rare in Mexico, due to over-collection and the sale of spiders to collectors in Europe and elsewhere, and special permits are required for their export from the country. In Britain captive breeding programmes have been initiated. To ensure a gene pool comparable to that in the wild the programme must be carefully controlled. Inbreeding among the many offspring from one sac is clearly not desirable.

The Giant African land snail - *Achatina fulica*
(Class Gastropoda)

Exhibit value

These impressive molluscs are very valuable for illustrating gigantism in the invertebrates and have an important ecological story to tell, as they have been introduced to many parts of the world, initially as a food source but ultimately becoming a serious pest.

Description

Giant land snails grow up to 25 cm in shell length, but become mature at around 10 cm. They are varying shades of brown on the shell with a dark or light grey body. The average life span is normally 3-5 years.

Keeping Requirements

These animals do best in a fairly large aquarium tank with a glass or plastic cover to maintain a relative humidity of 75-85%. A tank 60 x 30 x 30 cm will adequately house up to six adult snails. The bottom of the tank should be covered to a depth of 21 cm with clean soil mixed with either peat or moss. The ambient temperature should be in the range 20-24°C.

The snails must have a ready source of calcium at all times, which can be given in the form of limestone (preferably in a large block) or washed cuttlefish bone at which they can rasp freely. Failure to supply calcium usually results in the snails rasping each others' shells until they become paper-thin and shatter when touched. In a natural habitat where acid conditions prevail the snails obtain sufficient calcium from the vegetation and from the shells of dead snails.

These molluscs are normally nocturnal and crepuscular in their habits, but rain or overcast skies will readily encourage activity, as will a rise in temperature and humidity during daylight hours. Like some of the *Helix* species these snails appear to have a homing instinct, and readily seek retreats in which to retire. If conditions change radically (too hot or cold, or lack of moisture) the snails will aestivate, usually by burrowing and forming a thin muco-calcareous epiphragm over the aperture of the shell. They can stay in this dormant condition for several months quite happily without food or moisture, but they will not survive if the temperature drops too low. They can survive a fairly cool period provided they are acclimatised to it slowly.

Breeding

These snails are hermaphrodite, each individual producing both eggs and sperm, and any two sexually mature snails can cross-fertilise each other. Eggs are laid in clutches of 50-200. The snail usually burrows into the soil and deposits its eggs in a small cell. The eggs (which are approximately 4mm in diameter) are protected by a hard shell which ranges in colour from whitish to yellow. Hatching is rather unpredictable and may take from 2 weeks to 3 months. The young snails usually eat part of the egg shell upon hatching and start to feed normally after 24 hours.

Diet

The snails will eat virtually anything: most vegetables and fruits, cereals (such as oatmeal), Bemax and biscuits. They will also take some meat and carrion, including their dead companions. They do not normally drink, but after a prolonged period of aestivation they have been seen to take drops of water from leaves and condensation from cage sides.

*Livefood species can also be displayed (see Section 5) especially with supporting graphics explaining the inter-relationship.

Section 5

Example profiles of invertebrate conservation programme work and related initiatives

The *Partula* snail Conservation programme

The 123 species of Polynesian tree snails that make up the *Partulidae* family are, or rather were, spread over a wide group of volcanic islands of the west, central and south Pacific. Each island had it own unique tree snail species, which were often further restricted to individual valleys. The product of extraordinary selective pressures, *Partula* snails have provided evolutionary geneticists with one of the most valuable examples of speciation, uniquely illuminating the processes by which new species originate. *Partula* snails are also a valued part of the Polynesian's rich cultural heritage. Unfortunately, successive introductions of the African giant land snail *Achatina fulica* (a serious agricultural pest) and the ill-conceived biological control agent *Euglandina rosea* (a predatory snail) have had a disastrous effect on the region's endemic snails. The introduced predator paid scant attention to the large African snails preferring instead to attack the smaller endemic species. Within a very short time, many *Partula* species were literally eaten to extinction throughout their natural range. In 1986 the international zoo community, in association with IUCN's Captive Breeding Specialist Group, devised the *Partula* Conservation Programme with the aim of establishing viable *ex situ* populations of as many endangered *Partula* species as possible. UK Federation Zoo members have played the key role in developing the programme, which has grown to include 27 taxa (totalling nearly 11,000 individuals) in 16 collections in Europe and North America. The bulk of these animals are maintained in UK zoos at Jersey, Edinburgh, Bristol, Chester, London and the Wildfowl and Wetlands Trust at Martin Mere. The programme is internationally co-ordinated by London Zoo's Invertebrate Conservation Centre, linking zoos, universities and field workers.

In addition to maintaining nearly a hundred separate genetic line populations of 26 taxa the UK participants have developed a range of related initiatives to improve the survival chances of these delicate snails, which present considerable husbandry challenges. The complex demographic management considerations associated with such large populations of colony species has necessitated the development of a unique computer system (CERCI) which for the first time has enabled the detailed monitoring and analysis of demographic trends, and environmental and genealogical data in colony populations (thereby helping manage other colony species such frogs and bats). Last year programme participants reviewed the conservation status of all 123 species in the Partulidae family and developed a comprehensive Action Plan for the family (copy enclosed) which unifies the *ex situ* and *in situ* elements of the programme. An extensive zoo-based screening protocol is in place to determine the nature and levels of enteric fauna in the wild and captive *Partula* populations (ensuring the captive snails don't become diseased, lose their natural resilience to endemic micro-organisms, or introduce alien microbes when returned to their native habitat). The predator snail is also being monitored. A comprehensive DNA analysis of all the captive populations is also under way (helping to determine the value of keeping inbred and outbred lines for each population in the programme). The effectiveness of the breeding programme in maintaining viable populations was confirmed last year when a group of zoo-bred *Partula*, released onto native Polynesian plants growing at Kew Gardens, proved that even long term captive-bred snails have retained their ability to readapt to a natural environment and diet. This work has in turn created the opportunity of reintroducing *Partula* into their native range by way of managed predator-proof reserves (constructed from cheap, locally available materials and monitored by local wildlife personnel). The first such trial was carried out in August 1994 on the island of Moorea when a 20 square metre reserve, containing three species of captive bred *Partula* snails (all bred in the UK), was established in an area of forest within their natural range.

Building upon achievements to date, we are working towards a situation five years hence where there is far greater local and international awareness (through educational material and other initiatives) of the ecological disaster facing the Pacific region's endemic snail fauna. We also hope to facilitate the construction of a series of *Partula* reserves, built and monitored by local people and seeded from healthy zoo-bred populations representing every endangered *Partula* species. The Partula programme is a classic example of the need for conserving biodiversity in all its forms.

TABLE 2.1: Summary of conservation status of Partulidae by island group

ISLAND OR ISLAND GROUP	TOTAL TAXA	DD	EXTINCT		THREATENED			LR
			EX	EW	CR	EN	VU	
Partula								
Moorea	10	0	2	8	0	0	0	0
Borabora	1	0	1	0	0	0	0	0
Tahaa	6	0	0	0	6	0	0	0
Raiatea	34	0	24	2	8	0	0	0
Huahine	3	0	0	0	0	3	0	0
Tahiti	9	0	0	0	9	0	0	0
Austral	1	0	0	0	1	0	0	0
Cook	2	2	0	0	0	0	0	0
Fiji	2	2	0	0	0	0	0	0
Rotuma	1	1	0	0	0	0	0	0
Hoorn	1	1	0	0	0	0	0	0
New Guinea 'satellites'	2	2	0	0	0	0	0	0
Admiralty	2	2	0	0	0	0	0	0
Solomon	8	8	0	0	0	0	0	0
Santa Cruz	1	1	0	0	0	0	0	0
New Hebides	5	5	0	0	0	0	0	0
Palau	3	0	0	0	3	0	0	0
Mariana	4	0	0	0	4	0	0	0
Pohnpei	2	0	0	0	2	0	0	0
Kosrae	1	0	0	0	1	0	0	0
Eua								
Tonga	1	1	0	0	0	0	0	0
Samoa	3	2	0	0	1	0	0	0
Samoana								
Tonga	1	1	0	0	0	0	0	0
Samoa	5	2	0	0	3	0	0	0
Fiji	1	1	0	0	0	0	0	0
Australs	4	1	0	0	3	0	0	0
Society	3	0	0	0	1	2	0	0
Marquesas	6	6	0	0	0	0	0	0
Mariana	1	0	0	0	1	0	0	0
TOTAL	123	38	27	10	43	5	0	0

For key see Key to Table 2.2

HUSBANDRY METHOD AND BREEDING SCHEME

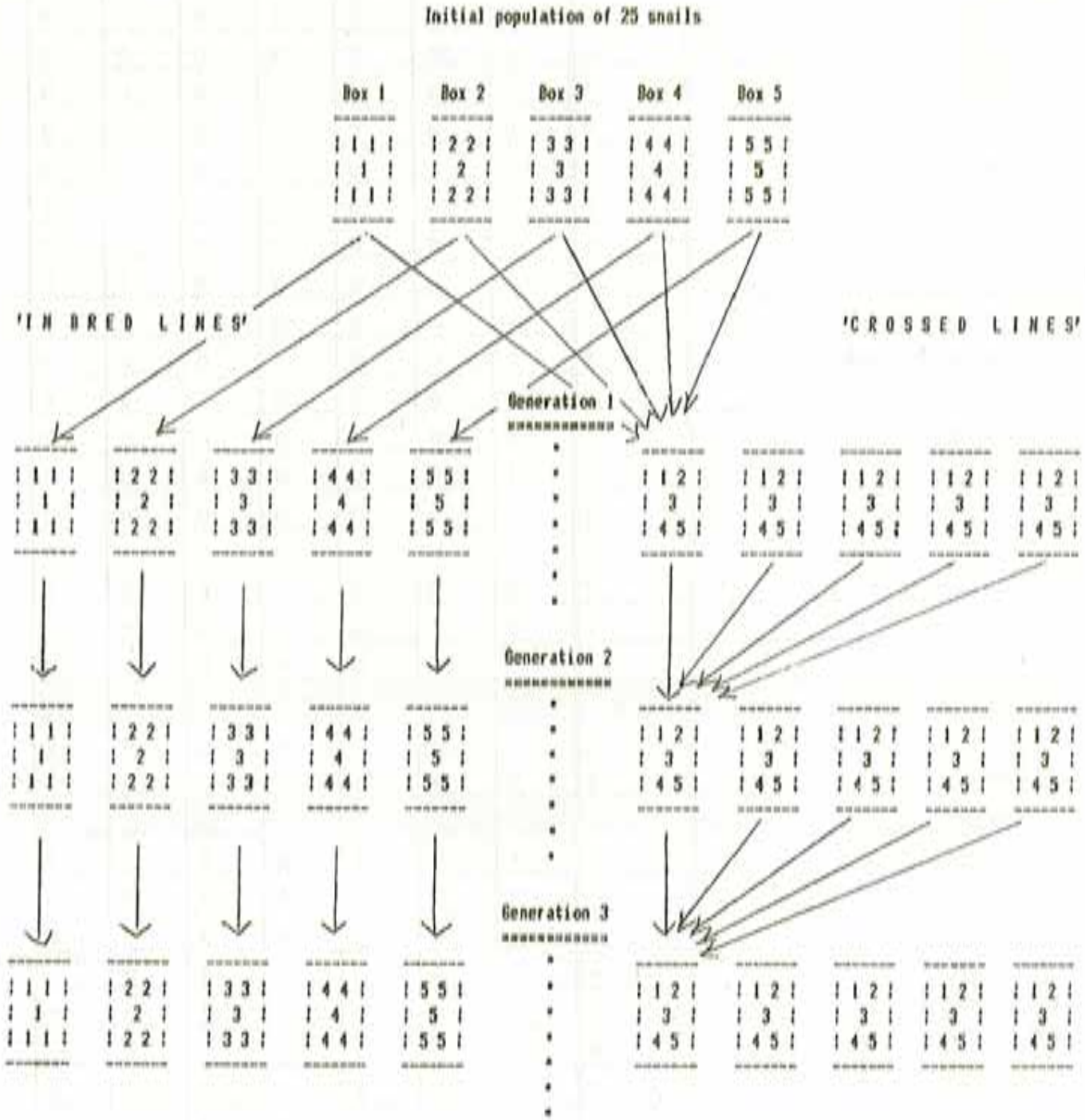

TABLE 2.2: CAMP Table for Partulidae

ISLAND	SPECIES	HABITAT AND LOCATION	RANGE		POP	DECLINES		*Euglandina*		NG flatworm		IUCN classification		RECS	CAPTIVE Adults	
			area	extent	est. no.	y/n	rate	low	est	low	est	cat	criteria		N	REC
Genus Partula																
MOOREA	*P. mooreana*	clumps of *Freycinetia*	0	0	0	-	-	77	87	-	-	EW			93	250
	P. suturalis vexillum	clumps of *Hibiscus*	0	0	0	-	-	77	87	-	-	EW			438	250
	P. suturalis strigosa	*Hibiscus* + shrubs	0	0	0	-	-	77	87	-	-	EW			529	250
	P. taeniata elongata	Shrubs 1-5 m.	0	0	0	-	-	77	87	-	-	EW			540	250
	P.taeniata simulans	Shrubs 1-5 m.	0	0	0	-	-	77	87	-	-	EW			33	250
	P. taeniata nucleola	Shrubs 1-5 m.	0	0	0	-	-	77	87	-	-	EW			173	250
	P. tohivaana	clumps of *Freycinetia*	0	0	0	-	-	77	87	-	-	EW			512	250
	P. mirabilis	*Freycinetia* & shrubs	0	0	0	-	-	77	87	-	-	EW			32	250
	P. mirabilis x taeniata	shrubs	0	0	0	-	-	77	87	-	-	EW			14	100
	P. aurantia	clumps of *Freycinetia*	0	0	0	-	-	77	87	-	-	EX			0	
	P. exigua	Shrubs 1-5m.	0	0	0	-	-	77	87	-	-	EX			0	
BORABORA	*P. lutea*	shrubs & *Angiopteris*	0	0	0	-	-	<87	87-91	-	-	EX			0	
TAHAA	*P. faba subangulata*		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
	P. planilabrum		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
	P.sagitta		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
	P. bilineata		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
	P. umbilicata		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
	P. eremita		?	<100	<10000	Y		86-88	95	-	-	CR	A1d,A2d,B1,2	S,C	0	250
RAIATEA																

(SAMPLE PARTULA TAXA SHEET)

SPECIES+PLOT(COLL)	N	J	S	TOTAL YOUNG	A	GRAND TOTAL	NO.S UNITS	NO.D UNITS	NO.X UNITS	TOTAL UNITS
***P. t. elongata* (TE)**										
TEAXM00001 (NOT)	6	6	1	13	9	22				
TEFAR82004 (JER)	173	42	33	248	179	427				
TEFAR82004 (CHE)	0	99	59	158	75	233				
TEFAR82004 (WIS)	235	12	0	247	152	399				
TEFAR82004 (ZSL)	10	0	1	11	18	29	0	0	1	1
TEFAR82004 (DET)	28	32	12	72	38	110				
TEFAR82004 (KEW)	0	40	20	60	60	120				
TEFAR82004 total				796	522	1318				
TEFAR82705 (NOT)	4	4	1	9	2	11				
TEFAS82004 (NOT)	0	0	0	0	2	2				
TEMAA85002 (NOT)	4	0	0	4	5	9				
TE TOTAL	460	235	127	822	540	1362				

(Kew figures as at release Nov. 1993)

***P. t. simulans* (TS)**										
TSHAA86000 (NOT)	5	4	1	10	12	22				
TSHOT82731 (NOT)	6	2	1	9	9	18				
TSOPO80698 (NOT)	6	1	0	7	12	19				
TS TOTAL	17	7	2	26	33	59				
***P. t. unknown* (TA)**										
TANTH00000 (ZSL)	3	0	0	3	2	5	0	0	1	1
TA TOTAL	3	0	0	3	2	5				
***Partula mooreana* (MO)**										
MOATI82002 (NOT)	11	2	0	13	13	26				
MOATI00MIX (ZSL)	1	3	0	4	15	19	0	0	3	3
MOHAA857+8 (NOT)	1	0	1	2	2	4				
MOMAA852+3 (JER)	23	11	7	41	32	73				
MOMAA852+3 (ZSL)	1	1	0	2	3	5	0	0	1	1
MOMAA852+3 total										

The Field cricket programme

In 1991 the British population of the field cricket *Gryllus campestris* was on a certain extinction curve with only two surviving wild colonies totalling fewer than a hundred individuals. The reason for the decline of the field cricket in England was essentially loss of its close-growing turf sites, largely due to the overgrowth of vegetation as a result of changes in grazing practices. In an effort to avoid the certain loss of the surviving UK populations, English Nature (EN) placed the field cricket onto its Species Recovery Programme. The aim of this conservation initiative was to recreate the cricket's habitat requirements in areas of its former range and to identify existing alternative sites that already provide suitable habitat requirements. The other key need was to establish a captive-breeding programme in order to provide the large number of animals required for founding new colonies. In Autumn 1991 English Nature and London Zoo devised an action plan to establish a captive-breeding programme at the Zoo's Invertebrate Conservation Centre using wild caught crickets from the surviving UK colonies.

In the spring of 1992 twelve wild field crickets were collected from the Sussex colony and taken to the Zoo. These crickets were successfully reared to adult and produced over 1,000 nymphs. These nymphs were reared at the Zoo under close management conditions until the nymphs were large enough to be released. Later that summer over 700 captive-bred nymphs were released into two selected West Sussex sites. Field monitoring the following summer revealed the presence of burrows and healthy adult crickets, confirming that both populations had successfully survived their first winter in the field. The same procedure was repeated in 1993 with some 200 nymphs being released into a third EN selected site. In order to avoid removing any further crickets from the original wild colony, a number of nymphs were retained at the Zoo to be taken through their delicate over-wintering development stage, essential for providing the necessary breeding stock for the following season. This element of the breeding programme necessitated the construction of external rearing units with a turf substrate simulating the natural micro-habitat and environmental conditions similar to that which the crickets experience in the field. This strategy resulted in the successful production of some 1000 F1 generation nymphs which were reared at the Zoo prior to release into a fourth Sussex site. Again, field surveys found over-wintered crickets at all four release sites, confirming the establishment of the F2 field populating at the two initial release sites. The Recovery Programme is continuing into the 1995 season with fresh founder stock enforcing the F2 generation Zoo-bred crickets, the young of which will be used to effect a fifth site release later this summer. In addition to providing large numbers of crickets for site release, the breeding programme has helped clarify some important biological questions such as sex ratios and how many eggs females are capable of producing. A range of autecological work is also being conducted at the Zoo. A specially constructed large natural habitat area supports a feral field cricket population that is being used to observe the patterns of natural behaviour such as burrow usage and social interaction. Genetic finger printing studies are planned to commence at the Zoo later this year to determine just how much genetic variation remains in the mainland population and how much variation exists between the UK and continental populations. Veterinary pathology work has been conducted at the Zoo to ensure that the field release stocks are healthy. This programme is also informing other invertebrate species recovery work such as EN's Wart-biter cricket Recovery Programme. On full display to the public, the Zoo's contribution to the field cricket Recovery Programme has provided an excellent opportunity to help raise public awareness of this species in particular and active species conservation in general.

The success of the field cricket Recovery Programme to date has already enabled EN to declare the field cricket to be considerably more secure in its native UK range. The breeding and site release work is set to continue for the foreseeable future with a further four identified sites requiring introductions of captive-bred crickets. Looking five years hence there is good reason to expect the native UK population to be considered safe. This programme also provides a very valuable model for field cricket conservation action in areas of the species continental range - laying the foundation for a potential Pan European field cricket Recovery Programme.

Invertebrate pathology: a developing and essential science for invertebrate conservation

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Invertebrates comprise over 90% of the described animal kingdom and possibly over 99% of all animals on earth. For a variety of reasons, including a growing awareness of their ecological importance and vulnerability, endangered species of this phylum are being increasingly kept in zoological collections. Concurrent with this is a growing requirement to improve the husbandry, including medicine, of these animals. Research into invertebrate diseases is not new, but such work has largely been in the field of pest control or of studies on basic physiology. Little attention has been paid to diagnostic pathology other than work on certain groups which are of obvious economic importance, such as certain molluscs. In these cases the approach has been to investigate disease at the level of the population rather than the individual animal. However, with the captive breeding of endangered species, the individual invertebrate may be as important as any other (vertebrate) animal in a similar situation.

The diagnosis of infectious disease is particularly difficult when working with invertebrates because of the lack of information on the normal micro-flora and -fauna of the animals. One way to help investigate this is to examine healthy free-living animals of the same species (and from the same geographical area) as those in captivity, but usually this is not possible. At ZSL often we try to screen freshly wild-caught invertebrates in order to learn something of their normal commensal micro-organisms, but this also may be impractical for a variety of reasons, not least because of the costs involved, both in time and money. However, such information is very important, particularly if the animals, or their offspring, are destined for eventual release (see below). Future trends are likely to be to carry out much more of this type of fundamental work, both at ZSL and other collections.

In recent years, the Zoological Society of London has been increasingly involved in captive breeding and release programmes for endangered species of invertebrate and, at the same time, we have been developing approaches to investigating disease in our captive populations. This has involved both the development of diagnostic and therapeutic techniques and the creation of computerised record systems that enable trends in fecundity, growth rates and mortality to be analysed. Such data are essential if optimum husbandry techniques are to be employed and signs of early or subclinical disease are to be detected. Although the individual treatment of animals is considered to be conventional for vertebrates, it still is regarded as unusual for invertebrates. However, at ZSL we have had some successes in the individual treatments of insects in the face of disease epidemics, such as the treatment of Olimpia's ground beetles (*Chrysocarabus olimpiae*) with antifungal drugs.

There is a growing awareness of the dangers of the accidental introduction of alien parasites when translocating animals, and this applies equally whether the target species has an internal or an external skeleton. The science of pathology has a major role to play in this area of wildlife conservation. For example, at ZSL we postponed a release programme for the wart-biter cricket (*Decticus verrucivorous*) when the colony destined for release was found to be infected with a fungus. Similarly, the reintroduction of captive-bred English field crickets (*Gryllus campestris*) was stopped when, on routine pre-release screening of sacrificed

nymphs, the animals were found to be infected with a protozoan parasite of unknown origin. Of course, should this parasite turn out to be natural to the wild population, then the release programme can be recommenced.

In conclusion, it is important that zoological collections and others are aware that veterinary involvement in the captive care of invertebrates can result in improving not only the welfare of the animals but also the conservation value of the breeding programmes concerned. If the commitment to wildlife conservation by such institutions is to be taken seriously then resources must be allocated accordingly. This is an exciting area for zoos and zoo vets and there is much work to be done.

Section 6

Invertebrate livefood

Introduction

Establishing a livefood production unit is a simple procedure. Several different livefood cultures can be housed in a small, well ventilated room (for the health of the keeper and the animals) with a background temperature of around 24-29°C. A range of species can be cultured using very basic materials such as buckets and tanks. The following species profiles are indented to provide a working guide to species selection and maintenance:

Example species

Mealworms

One of the most commonly used livefood species is the mealworm beetle *Tenebrio molitor*. This standard livefood species goes through complete metamorphosis (egg, larva, pupa, adult) and is very easy to maintain in culture. The basic requirements are a bucket, half filled with bran into which are placed the starter colony of adults and larvae. In addition to the bran, the mealworms will readily feed on fruit such as apple and orange and banana etc. Water is obtained from the fruit and from a daily water spray onto paper towels that are placed on the surface of the bran. The adult beetles should be placed in their own bucket where they will lay their eggs in the bran substrate, producing a fresh generation. The mealworms will go through their whole life cycle in the bran buckets. It is a good idea to have several buckets going at once, each of which can have larvae at different stages of development. This practice allows a size gradient to be maintained which eases harvesting and helps to ensure that the colonies do not die out either through over-harvesting or through unintentionally allowing one of the life stages to become under represented. Larvae can be collected from the buckets either by hand or by sieving the bran to catch only larvae of a given size.

In addition to the common mealworm *T.molitor* there is a giant mealworm species called *Zoophobus morio*. It is generally considered that this species makes for a superior livefood animal. In part this is because of its larger size and because of its higher fruit diet. The keeping needs are a little more complex than that of the ordinary mealworm species in as much as the larvae need to be separated just prior to pupation (such larvae are placed into separate compartments of for example egg trays where they will pupate).

Crickets

The most commonly used livefood cricket is the tropical house cricket *Acheta domestica*. Like the mealworms, this species is very easy to maintain in culture and requires little more than a tank (with sides at least 30 cm high to prevent the crickets jumping out) stacked with cardboard egg trays (or similar - crumpled cardboard, for example) to allow the nymphs to hide, and some

hide, and some tubs of moist soil or sand for the females to lay their eggs in. These crickets will eat almost any vegetable matter from potatoes to bananas. For the younger nymphs it is desirable to provide a sprinkling of bran on the tank floor to give them a good start. As for the mealworms it is a good idea to divide the cultures into a series of tanks, each containing different developmental stages of crickets. This allows ease of harvesting of specific sizes of crickets and ensures the breeding stock is disturbed as little as possible.

In addition to the tropical house cricket, a very good livefood cricket is the African field cricket *Gryllus bimaculatus*. This species can be maintained in exactly the same manner as the house cricket. It is a larger animal and many consider it a better food species than the field cricket.
[give egg hatching times and development cycle times]

Locusts

Although nutritious livefood animals, locusts are more demanding animals to keep in culture. There is also a greater chance of their becoming pests in the wild if accidentally released.

Fruit flies *Drosophila melanogaster*.

Fruit flies are very valuable for feeding many other species of young invertebrates such as mantis, and orb spiders.

Fruit flies do very well in culture, and the culture medium can be made very easily, but it is advisable that all apparatus is sterilised in a pressure cooker before setting up the cultures to reduce contamination by bacteria and fungi.
Basic recipe:

water	120ml
cornmeal	16g
molasses	8g
agar	1g

Boil the ingredients together for 15 minutes, stirring well. Add a pinch of 'Nipagin' or other mould deterrent and boil for 5 minutes. While hot pour into 7.5 x 2.5 cm strong glass tubes, to a depth of 2 cm, and add a small pinch of dried yeast. Cover the tubes and leave to cool.

When the medium has cooled, three pairs of flies may be introduced to each tube, which is then plugged with cotton wool or plastic foam. A humid environment will help to prevent the cultures from drying out - this may be achieved by standing the tubes in a tray of water. The flies will mate and start laying eggs immediately. Provided the cultures are kept warm (20°-25°C) the larvae will take a week or so to pupate. Removal of the breeding stock at this point will ensure that only the new flies are used to form the next breeding pairs, thus keeping a strong, healthy stock. Any mite-infected colonies should be disposed of.

The sex of the flies can be determined using a magnifying glass - generally, the males have more rounded abdomens which are black-tipped. If winged forms of the fly are being used **temporary** anaesthesia may be required for ease of handling. This can be achieved by cooling the flies in a refrigerator at 4°C until they appear lifeless.

Section 7

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