

why



taxonomy matters

Taxonomy - the science of discovering, naming, and understanding our fellow travellers on Earth - not only produces fascinating knowledge on the characteristics of life, above all it delivers basic and indispensable knowledge for many fields of human interest and contributes in many ways to the sustainability of our planet. It helps us pollinate our trees, manage pests, improve human, animal and plant health, facilitate trade, respond to climate change, conserve our environment, and more. From our earliest time as a species, knowledge on the life surrounding us was essential for our survival. We needed to discover and name the plants we could eat, identify the poisonous ones, and distinguish the harmful animals from those we benefit from. Today, we still depend on our knowledge on the living world around us.

The origins of taxonomy lie in the 18th century when Linnaeus developed his famous naming system. His students and their successors have devoted lifetimes to collecting specimens and poring through literature up to 250 years old in their quest to name and describe species. At first glance, the outcomes of their work may not look relevant to society. In fact, taxonomists are often perceived as specialists pursuing eccentric interests relevant only to natural history museums and universities. Some ask: is this a science that is needed in the 21st century? We say it is. Taxonomy does matter. It is very relevant to today's challenges.

Whether you live in the centre of London, the outskirts of Timbuktu, or in a high mountain valley in Nepal, taxonomic knowledge can improve and, at times, even save your life. Taxonomy is the pivotal but hidden service behind sectors ranging from conserving and managing biodiversity to food security, poverty reduction, health, bio-security, new industrial product development, and eco-tourism. Trained taxonomists identify the known organisms we are dealing with in our daily life and describe, classify and name the unknown ones – and collectively discover on average 50 living species each day!

Taxonomy and the work of taxonomists should not be underestimated. Its impacts on society are often beneficial, sometimes in unpredictable ways. Did you know that the work of taxonomists has improved Namibian roads and ensures the safety of Chinese medicine? In this series of case studies we see 'Why Taxonomy Matters'. We see how taxonomic knowledge is applied around the world to save LIVES, save CROPS, save HABITATS, save SPECIES, save MONEY and more...

Introduction by Elizabeth Watson, Richard Smith and Kornelia Rassmann

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Epidemiology of amoebiasis: an age-old problem solved by taxonomy

Problem statement: Amoebic colitis and amoebic liver abscess (amoebiasis) are among the most important diseases of man. They are caused by the intestinal amoeba *Entamoeba histolytica*. In 1986, estimates suggested that about 480 million people are infected annually with *E. histolytica* of whom about 36 million developed clinical symptoms, and 40,000 died. Until 1993, the question that had vexed scientists for generations was ‘Why did such a small proportion of those infected with the parasite develop serious symptoms?’

Methods: In order to address this problem, Diamond and Clark (1993) tested the decades-old hypothesis that *E. histolytica* comprises two morphologically identical species, one pathogenic, the other non-pathogenic.

Three types of evidence were used to test the hypothesis: i) biochemical evidence, using electrophoretic isoenzyme analysis; ii) immunological evidence, using monoclonal antibodies; iii) genetic evidence, using DNA probes to analyse genomic organization of genes, comparisons of small subunit ribosomal RNA genes, etc.

Outcomes and impacts: Following an exhaustive analysis of the data, it was concluded that the overwhelming body of evidence supported the concept that *E. histolytica* was a complex of two species: *E. histolytica* Schaudinn, 1903 (emend. Walker, 1911), which is a pathogenic species displaying varying degrees of virulence and capable of invading a variety of tissues, and *E. dispar* Brumpt, 1925 which is not capable of tissue invasion.

Lessons: The existence of two species within what was previously called *E. histolytica* has profound consequences for the interpretation of epidemiological data, for clinical evaluation of carriers and for estimating the proportion of symptomatic infections.

References: Diamond, L.S. and Clark, C.G. 1993. A redescription of *Entamoeba histolytica* Schaudinn, 1903 (Emended Walker, 1911) separating it from *Entamoeba dispar* Brumpt, 1925. *Journal of Eukaryotic Microbiology* 40: 340-344.

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Regions: Global

Themes: Health



Description of a new mealybug species saves US\$ billions across Africa

Problem Statement: Cassava (manioc or tapioca; *Manihot esculenta*) is a drought resistant, staple food crop for over 200 million people in sub-saharan Africa. In 1973 a new mealybug species, since described as *Phenacoccus manihoti*, was found seriously damaging the cassava crop in the Republic of Congo. Initial attempts to control the pest using natural enemies from South America failed. By the early 1980s, the infestation was causing production losses of over 80 per cent throughout tropical sub-Saharan Africa, severely impacting the livelihoods of tens of millions of people.

Methods: Finding natural enemies of a pest requires finding its place of origin. Initial taxonomic work suggested that similar mealybug material had been collected earlier from Brazil, so searches for natural enemies were focused on Central and Northern South America. A natural enemy was identified and introduced to Africa as a biological control agent but failed to have an impact. Further taxonomic work revealed that the mealybug material initially collected in South America had been mis-identified; though similar, it was not the same as the pest species devastating cassava in Africa, *P. manihoti*. As a result of this mis-identification, an ineffective natural enemy had been introduced as a biological control agent. Once this was recognised, a hymenopteran parasitoid (*Anagyrus lopezi*) of *P. manihoti* was located and introduced to Africa.

Outcomes and Impacts: The initial lack of taxonomic knowledge resulted in a misidentification, and misdirected pest eradication efforts resulted in wasted effort and hundreds of millions of dollars in further crop losses. Following further taxonomic studies, *A. lopezi* proved to be a highly effective biological control agent; by 1990 it had successfully established itself in 25 African countries. *P. manihoti*, the cassava mealybug (CMB), is now considered to be under control throughout its range in Africa. As a result of this problem, it was recognised that another such introduction could easily occur, and funding was made available for a taxonomic revision of the mealybugs of the Neotropics so that any future introductions could be quickly and accurately identified and, hopefully, controlled. While the total project costs reached over \$30 mil (in 1994 \$ values), revenues to African farmers (depreciated over 40 years), are estimated at between \$8 billion and \$20 billion, implying a cost / benefit ratio between 1:200 to over 1:600.

Lessons: The use of natural enemies to control pests is highly cost effective but requires sound taxonomic expertise. Through the project's success on the ground across all of sub-Saharan Africa and the vast training and public awareness effort, it became the starting point for a series of biological control successes involving the same partners, thus contributing to widespread poverty alleviation.

References: **1:** Cox, J.M. & Williams, D.J. (1981) An account of cassava mealybugs (Hemiptera: Pseudococcidae) with a description of a new species. *Bulletin of Entomological Research* 71: 247-258. **2:** De Santis, L. y N.P. Ras 1988. Control biológico de la cochinilla *Phenacoccus manihoti* en Africa (Insecta). *Academia Nacional de Agronomía y Veterinaria* 62 (7): 5-11.S. **3:** Herren, H.R. & Neuenschwander, P. (1991) Biological control of cassava pests in Africa. *Annual Review of Entomology* 36: 257-283. **4:** Neuenschwander, P. 2001. Biological control of the cassava mealybug in Africa: a review. *Biological Control* 21, 214-229. **5:** Norgaard, (1988) The biological control of cassava mealybug in Africa. *American Journal of Agricultural Economics* 70: 366-371. **6:** Watson, G.W. (1999) The role of taxonomy in biological control. Pp. 1-6 in: *Proceedings of the Fifth Congress of the Indonesian Entomological Society: Sustainable Insect Management, Bandung, 24-26 Juni 1997* (plenary paper). **7:** Zeddies, J., Schaab, R.P., Neuenschwander & Herren, H.R. 2001. Economics of biological control of cassava mealybug in Africa. *Agricultural Economics* 24, 209-219.

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Regions: Africa

Themes: Agriculture



Authentication of Chinese plants helps deliver safe medicine

Problem statement: In 1999 two cases of kidney failure resulted from the use of a Chinese herb called *Aristolochia manshuriensis* (Chinese name: Guan Mu Tong) prescribed by practitioners of Chinese herbal medicine.

Methods: Botanists identified the contents of two herbal prescriptions (comprising a variety of loose dried plants) using gross morphological characters (i.e. characters visible to the naked eye). Key to the successful scientific naming of these plants was comparison with reference plant material, which included herbarium specimens whose identity had been confirmed by plant taxonomists. Once one of the ingredients, *Aristolochia manshuriensis* had been identified in both prescriptions, the *Aristolochia* material underwent chemical chromatographic analysis to check for the presence of renal toxins called aristolochic acids. These were found in both prescriptions. The patients involved underwent thorough toxicological investigation to eliminate all other possible causes of renal failure.

Outcomes and impacts: Recognising the potential severity of adverse reactions to this plant species, the then Medicines Control Agency (MCA) of the UK Department of Health passed new legislation in 2001 banning the manufacture, import, sale or supply of any unlicensed medicine in the UK which contained herbs in the *Aristolochia* and Mu Tong group. The Royal Botanic Gardens Kew undertook further research to improve detection methods for aristolochic acids, especially in unlicensed multi-ingredient patent herbal remedies.

Lessons: The design and implementation of scientifically rigorous herbal authentication systems are vital if herbal medicine is to be safely practised in the UK. Without such systems, herbal medicine has the potential to cause life-threatening adverse reactions. Furthermore, plant taxonomic expertise is an essential prerequisite for the construction of such herbal authentication systems.

References: **1:** <http://www.rbgekew.org.uk/scihort/ecbot-cmpac.html>; **2:** Lord, et. al. 1999. Nephropathy caused by Chinese herbs in the UK. *The Lancet*, vol. 354, August 7: 1999, pp. 481-482; **3:** Kite, G.C. et al. (2002). Detecting aristolochic acids in herbal remedies by liquid chromatography/serial mass spectrometry. *Rapid Communications in Mass Spectrometry*, 16(6):585-590; **4:** The Medicines (Aristolochia and Mu Tong etc.) (Prohibition) Order 2001 SI 1841.

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Regions: Global

Themes: Health



Significant economic losses prevented by access to local taxonomic information and expertise

Problem Statement: Namibia's most agriculturally productive lands lie in the north-central and northeastern regions of the country. These areas are the 'grain baskets' of the country, allowing for a degree of self-sufficiency in food production. When maize production was adversely affected by false cutworm damage to seedlings, the culprits were identified as larvae of a darkling beetle (Coleoptera; Tenebrionidae; Genus *Zophosis*). The larvae were undeterred by the standard treatment of maize seeds and were not previously known to attack maize.

Methods: Adult beetles obtained from breeding larvae could be identified relatively easily using reference collections and a comprehensive taxonomic treatise that were available within the country. A literature search revealed an obscure reference to similar problems in northeastern Africa.

Outcomes and Impacts: Following identification of the pest and after testing various alternative seed treatments, a pesticide formulation was found that prevents beetle damage to sprouting maize. The economic value of finding an early solution to an emerging problem is not known nor easily calculable, but is considerable.

Lessons: The risk of pest damage causing economic losses could be reduced effectively and promptly because, some ten years before, a local taxonomist completed a comprehensive study of the relevant insect group. The existence of a comprehensive reference collection of taxonomic voucher specimens and information made rapid identification possible. This demonstrates that taxonomic information and expertise can be applied to solve a variety of problems but that these cannot always be determined in advance.

References: Penrith, M.L. (1977) The *Zophosini* (Coleoptera: Tenebrionidae) of western Southern Africa. *Cimbebasia* Memoir 3.

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Regions: Africa

Themes: Agriculture



Taxonomic tools allow rapid problem-solving by non-specialists

Problem Statement: Date production for export is an emerging industry in the arid parts of southern and western Namibia. However, after severe flooding in 2001, the viability of the local date industry was threatened by an epidemic outbreak of an unknown crown rot disease that killed date palms in affected plantations.

Methods: Investigators used various products produced by BioNET-SAFRINET (the Southern African LOOP of BioNET-INTERNATIONAL) including electronic manuals on collecting techniques for a variety of micro-organisms as well as information products. With such tools at hand, it was possible for local entomologists to identify the likely causal agent as a fungal disease and to evaluate the symptoms and characteristics of the organism in order to accurately report and request assistance, as well as to prepare appropriate isolates for further investigation. As a result of BioNET-SAFRINET networking, it was furthermore possible to consult and submit samples to a taxonomic expert within the subregion for identification at negligible cost.

Outcomes and Impacts: The causal organism was identified as *Fusarium oxysporum*, a species that may be of quarantine concern, though definitive identification will only be possible at an exorbitant cost since no isolates of the particular fungal strain are available in the subregion. The cost was regarded as unwarranted for an emerging industry and economy. Though the problem disappeared after a while (most likely because of soils drying out and prophylactic treatment), date plantations are now carefully monitored to report any recurrence of such symptoms. Though the economic costs have been fairly insignificant to date, it proved the value of appropriate taxonomic products that may allow rapid investigation and preliminary identification of a problem, as well as the value of taxonomic networking. The value of definitive voucher collections should also not be underestimated, as the question still remains as to which variety of the fungus caused the problem.

Lessons: Taxonomic networks facilitate important information exchange. Appropriate information tools in taxonomy allow rapid inter- and cross-disciplinary communication. Regionally accessible taxonomic voucher collections, particularly of quarantine pests, are essential for taxonomic self-sufficiency.

References: SAFRINET Training Manual: Fungi. Contact bionet@bionet-intl.org.

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Regions: Africa

Themes: Agriculture



Use of taxonomy for quarantine pest detection allows for effective bilateral trade

Problem Statement: Namibia currently exports grapes to Europe. A company was expanding its production and wished to penetrate new markets, particularly the USA. Increased production would result in significant job creation, but is dependent on market access. Export of agricultural produce to the USA requires extensive information on likely pests that may threaten domestic production within the USA. Of particular significance are certain species of fruit flies, e.g. the Mediterranean fruit fly. The little information available seemed to indicate that quarantine pests were unlikely to occur within that area. The Mediterranean fruit fly was not known to occur in Namibia.

Methods: Taxonomists at the National Museum of Namibia advised a comprehensive survey programme to record all fruit flies within the production area, later to be expanded to the surrounding area if results were negative. A preliminary survey was conducted by deploying three sets of McPhail traps, baited with a general fruit fly attractant Nu-Lure, and six sets baited with Trimed lure (specific for Mediterranean fruit fly) or Cue lure (specific for certain other species of quarantine concern), supplemented by specialists collecting in the surrounding area. The collected material was processed and forwarded to a consulting taxonomist for identification.

Outcomes and Impacts: Sixteen species of fruit fly were collected from the area, including Mediterranean fruit fly. No fruit flies were collected in traps baited with Trimed or Cue lure. The survey proved that quarantine pests do indeed occur within the area, albeit at low density, and that negative results with species-specific lures do not imply that a target species is absent. The results enabled the company to plan for export procedures commensurate with likely US quarantine provisions. No information is available on what the likely costs to the company would have been if early identification of such quarantine pests were not available, nor is information available on the economic implications of Namibia not being able to be trusted to generate and provide sound information to its trading partners.

Lessons: Implementing appropriate taxonomic procedures at an early stage in economic planning allows for early recognition of potential problems. Taxonomic networking allows rapid and cost-effective sourcing of expertise. Taxonomic self-sufficiency allows for honest communication.

References: **1:** Hancock, D. H., Kirk-Spriggs, A. H. & Marais, E. 2001. An annotated checklist and provisional atlas of Namibian Tephritidae (Diptera: Schizophora). *Cimbebasia* 17: 41-72. **2:** Hancock, D. H., Kirk-Spriggs, A. H. & Marais, E. 2003. New records of Namibian Tephritidae (Diptera: Schizophora), with notes on the classification of subfamily Tephritinae. *Cimbebasia* 18.

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Regions: Africa

Themes: Trade



Taxonomic expertise and tools underpin alien species monitoring, saving unnecessary control programmes and expense

Problem Statement: Introduced (alien) species sometimes become invasive, causing biodiversity loss and inflicting major economic and / or ecological damage. As control of invasive species typically involves high and ongoing costs, significant savings can be realised by monitoring introduced species and starting control programmes only if and when a species shows signs of becoming invasive. In the Galápagos Island Archipiélago de Colón Biosphere Reserve, three species of the family Gekkonidae (*Phyllodactylus reissi*, *Gonatodes caudiscutatus* and *Lepidactylus lugubris*) are found, representing the only introduced reptiles which have established reproductive populations in Galápagos. These species were identified as most suitable in order to illustrate a very basic management question when dealing with introduced species, i.e. whether they were potentially invasive and a threat to the survival of the native fauna and hence whether they needed to be controlled or eradicated.

Methods: A monitoring study of the Gekkonidae of the Galápagos Islands was undertaken in which samples were taken from the villages and surrounding rural areas of Puerto Ayora (Santa Cruz), Puerto Baquerizo Moreno (San Cristobal) and Puerto Villamil (Isabela). The distribution patterns of the introduced geckos suggest that they were introduced unintentionally via boats, because they only occur in inhabited islands.

Outcomes and Impacts: The study suggests that introduced and endemic genera have different habitat requirements. Only *P. reissi* shows the habitat preference of endemic geckos for arid coastal areas, and needs to be considered as a potential threat to the native fauna. Preventing unnecessary control programmes has allowed saving of significant costs, and those funds have rather been invested in the setting up of monitoring programmes, which rely heavily on taxonomic expertise and para-taxonomic skills.

Lessons: Alien species do not necessarily have to be invasive, as they can become integrated into an ecosystem in a non-harmful way. Despite the fact that negative human impact on the Galápagos Islands needs to be prevented and reduced, selected experiences such as that described here would seem to suggest that the influx of alien species introduced incidentally or intentionally can be tolerated, as long as the taxonomic expertise and tools to enable an efficient and effective monitoring system are in place.

References: Biosphere reserve e-fact sheets: <http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=ECU+01>

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Regions: Pacific

Themes: Invasive alien species



Correct identification of fungus saves \$5 billion/year US wheat export market

Problem Statement: In 1996 and 1997, much of the \$5-billion/year U.S. wheat export market was threatened by the supposed discovery of a fungus, *Tilletia indica* (which causes the disease Karnal bunt) in wheat crops in Arizona and a small part of California. It is estimated that about one third of countries that might buy wheat from the United States will not buy Karnal-bunt-infected wheat. During the U.S. national Karnal bunt survey of 1996, *T. indica*-like fungal spores (teliospores) were found in wheat grain washes from the south-eastern United States. However, no bunted i.e. blackened and foul-smelling, wheat seeds were found. Ryegrass seed infected with a similar fungus sometimes gets harvested along with the wheat. Initially, available tests incorrectly identified this fungus as Karnal bunt. As a result, in 1996-97, restrictions were placed on the movement of suspect wheat from Alabama, Georgia, Florida, and Tennessee.

Methods: An incorrect identification was suspected by taxonomists because no bunted wheat kernels were found but the wheat grain wash samples in the south-eastern United States were testing positive for the Karnal bunt fungus using the then-available molecular test. After close taxonomic re-examination of the bunt fungi family using light and scanning electron microscopy of the spores, it was determined that the *Tilletia* species on the ryegrass was an unnamed species new to science. With these techniques, it was determined that, with experience, visual characteristics could be used to tell the two fungi apart.

Outcomes and Impacts: The new techniques quickly showed that 100 percent of each of the wheat samples collected from south-eastern farms in 1996 were contaminated with the new fungus (named *T. walkeri*) and not Karnal bunt. As a result, in March 1997, restrictions on the movement of the suspect wheat were lifted. Federal plant quarantine officials now use the new technique as a first cut, to decide if possible quarantine actions are needed.

If Karnal bunt had been incorrectly confirmed in the south-eastern US wheat crop, it would have indicated that Karnal bunt was widespread in the US and that all wheat produced in the US was potentially infected. This would have threatened the entire US \$5 billion export market, with disastrous consequences.

Lessons: Taxonomic expertise allowed for the distinction between the different fungal species. The correct identification of a new fungus led to the lifting of the ban on movement of the wheat crops from the south-eastern United States and prevented the wholesale rejection of all wheat export produce from the US. What could have been a trade and agricultural disaster was avoided.

References: Castlebury, L.A. and Carris, L.M. *Tilletia walkeri*, a new species on *Lolium multiflorum* and *L. perenne*. Mycologia 91: 121-127. 1999. <http://www.ars.usda.gov/is/AR/archive/mar99/bunt0399.htm>.

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Regions: Global

Themes: Trade, agriculture



Lack of taxonomic expertise results in extended loss of coffee crops

Problem Statement: In 1923, an introduced mealybug became a serious problem on arabica coffee in the Kenya highlands, causing up to 10 per cent crop loss, death of some coffee trees, and incurring considerable costs in attempts at chemical control. Repeated misidentification of the pest, with attendant failed biological control efforts resulted in over 15 years of crop losses to the Kenyan coffee industry.

Methods: The pest was initially identified as *Pseudococcus citri* Risso, and natural enemies of this mealybug were imported to Kenya from outside Africa for several years from 1924. These failed to establish and the infestation continued to spread in spite of the use of expensive pesticides and massive releases of cultured local predators (inundative biological control). In 1933 the mealybug was re-identified as *P. lilacinus* Cockerell, and in 1936-37 searches in Indonesia, the Philippines, Sri Lanka and southern India located several natural enemies for screening. However, despite expensive screening processes, these also failed to impact on the pest.

Meanwhile, it had been shown taxonomically that the pest was biologically and morphologically different from *P. lilacinus*. In 1935 it was described as *P. kenyae*, a species new to science (now known as *Planococcus kenyae*), and subsequently was found to be native to Uganda (the area of origin of coffee). Hymenopteran parasitoids were collected from Uganda and five species were selected for screening and introduction in 1938. One (*Anagyrus* sp. nr *kivuensis*) proved to be especially effective at suppressing the mealybug and the pest has remained under good control since 1941.

Outcomes and Impacts: In the 1920s, taxonomic knowledge of mealybugs in Africa was limited. The pest was misidentified twice, each time resulting in the introduction and failure of natural enemies introduced from South East Asia. Once the correct area of origin was located as a source of natural enemies, establishment of effective biological control was achieved in 3 to 4 years. It was estimated that by 1959 the project had saved Kenya at least £10 million for an outlay of less than £30,000. No new calculations on subsequent savings are available. As a result of this case, the taxonomy of African mealybugs was subsequently studied more thoroughly to try and prevent similar outbreaks.

Lessons: The 15-year time-lapse between outbreak and control of the pest affecting arabica coffee in the Kenya highlands was due to the poor taxonomic knowledge of African mealybugs at the time. Misidentification of the pest species caused misdirection of the control effort on two successive occasions.

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Regions: Africa

Themes: Agriculture



Correct identification of pest prevents mango crop destruction and saves millions

Problem Statement: In 1981-1982, a new insect was found to be seriously damaging mango, citrus and other fruit trees in Ghana and Togo, and soon spread to the rest of West Africa. The loss at this time to the mango and avocado export industries in Ghana alone was estimated as at least £130,000/year.

Methods: Samples sent to a taxonomist were compared with material in collections, and, although the mealybugs of southern Asia are not well documented, the taxonomist was familiar with the fauna and was able to recognise the pest and its area of origin immediately. The pest was identified as an undescribed species of mealybug from the genus *Rastrococcus* native to southern Asia. Consequently the search for natural enemies was targeted on India and Malaysia.

Outcomes and Impacts: The species was quickly recognised as an Asian species new to science and was named *Rastrococcus invadens*. A undescribed hymenopteran parasitoid (since described as *Gyranusoidea tebygi* Noyes) was found in India and, after screening, was introduced to Togo in early 1987. It spread rapidly and has provided good ongoing control of the pest. Effective control in Africa was achieved within 18 months of location of a parasitoid, thus preventing potentially significant crop and economic losses. Socio-economic surveys indicate that the savings in Benin alone have amounted to US\$ 531 mil over 20 years, with a cost / benefit ratio of 1:145.

Lessons: This example illustrates how quickly biological control can be established if timely, authoritative taxonomic input is available. It also highlighted the poor knowledge of the Asian mealybug fauna, which could result in similarly damaging introductions in the future. Subsequently the genus *Rastrococcus* was thoroughly researched and revised. A large monograph on the mealybugs of southern Asia is currently being completed, but the difficulty of obtaining support for large-scale taxonomic revisions means that, at present, funds are not available to publish this important work, despite the dramatic potential consequences of not doing so.

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Regions: Africa

Themes: Agriculture



The critical role of taxonomy in preventing harmful micro-algae impacting tourism, human health, fisheries and aquaculture

Problem Statement: Almost 100 marine micro-algae are now known or suspected to produce toxins. Coastal states across the world experience harmful algal blooms (HAB). The frequency, intensity and geographic distribution of HABs have increased over the last few decades. Microalgae may cause intoxication in humans consuming shellfish which have accumulated algal toxins, fish mortality in wild and aquaculture stocks, loss of market confidence in seafood, negative impacts on tourism, etc. Taxonomic identification of harmful algal species is complicated by the high degree of variation expressed among and within populations. Many institutions have, over the last 20 years, lost their taxonomic expertise in micro-algae, just as it has been the case for many other groups of organisms.

Methods: Identification of micro-algae is typically based on the light microscope and morphological characteristics. Nevertheless, this is inadequate to distinguish between many species, and electron microscopy, molecular probes and other highly specialised methods are routinely required.

Outcomes and Impacts: In most countries facing problems with harmful microalgae, the importance of taxonomic skills for identification of causative species is recognised. Countries trading within or with the European Union, Asian Pacific Economic Co-operation, or USA have to comply to certain regulations regarding HAB and algal toxin monitoring in order to be able to market seafood products. Most countries that have established HAB monitoring programmes have greatly minimized the negative health and economic impacts and have thereby made e.g. aquaculture operations sustainable. This applied use of taxonomy has in turn helped secure funding for basic research in phylogeny, ecology, etc. of micro-algae. It has so far not been feasible to make a reliable estimate of the actual scale of losses as many countries do not release such figures in order to protect their markets and due to the fact that such an estimation would be very complex as so many facets of society are affected.

Lessons: This case demonstrates how taxonomic capacity can be enhanced when pursued in a socio-economic context. The monitoring of harmful micro-algae requires sound taxonomic skills and research to describe new species and deliver identification keys, and development of new tools to help with species identification. The problems faced by agencies responsible for protecting seafood resources, the marine environment, and human health has led to an international focus on enhancing national capacity to identify and monitor potentially harmful micro-algae. It is a good example of building demand-driven taxonomic capacity. It is also an example of how governments can address the taxonomic impediment by requesting assistance from international organizations with the ability to organize capacity enhancing activities and raise the required funding. In this specific case the organizations that have taken an interest in taxonomy because of its socio-economic relevance are primarily the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the International Council for Exploration of the Sea (ICES) and a number of bilateral development aid agencies.

References: The web site of IOC of UNESCO <http://ioc.unesco.org/hab> contains numerous links and documents on the details of the HAB issue, international research and taxonomy capacity enhancement activities etc. For general background see also <http://www.bigelow.org/hab/>

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Regions: Marine

Themes: Health



Proactive taxonomy allows prevention of damaging viral epidemic in crops

Problem Statement: Whiteflies (Hemiptera: Aleyrodidae) are well-known for transmitting viruses harmful to crops. Viral outbreaks in the 1990s seriously affected the farming areas of Argentina, principally the cultivation of cotton and soya (in Santiago del Estero and Tucumán) and market gardens in Buenos Aires (tomato, eggplant, some ornamentals, associated weeds etc.).

Methods: Using published taxonomic information on the whiteflies that affect crops of economic importance, as well as their associated parasites (Hymenoptera), the species responsible for the infestations, as well as their natural enemies, could quickly and easily be identified. The whiteflies were initially identified with classical methods using the larvae and pupae. One of the species encountered was *Bemisia tabaci*, a complex biotype requiring molecular analysis. (The group *B. tabaci* is the principle transmitter of the geminivirus, a type of virus that causes serious damage to infected plants.)

Outcomes and Impacts: Some of the species of aleirodids encountered were new cases for host plants and included the registration of a new species from outside Argentina. This species, *Siphonius phillyreae* Haliday was seriously affecting forest plantations around the city of Mendoza. Access to information allowed ready management of the outbreaks via the registering of a natural enemy, *Encarsia hispida*. Further access to information on natural enemies permitted the establishment of two other biocontrol species not registered before in Argentina, *E. protransvena* Viggiani and *E. transvena* Timberlake. As a result, the outbreaks were quickly and effectively brought under control.

Lessons: Knowing what species to treat and, in particular, of which biotype, is very useful for the determination of a strategy of preventative management. Likewise, being able quickly to establish which natural enemies are the most effective is fundamental to the implementation of effective biological control. However, having access to information, whilst required, is not sufficient in itself; the presence of trained taxonomists is also necessary in order to utilise this information.

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Regions: South America

Themes: Agriculture



Taxonomic surveys could prevent costly and non-sustainable nematode control programme

Problem Statement: A grape-producing company in Southern Namibia is currently the largest user of methyl bromide in Namibia, using in excess of 150kg of methyl bromide annually (of a countrywide annual usage of around 200kg). The vineyards are irrigated as they are situated in an hyper-arid desert environment with almost no natural vegetation. The company is currently being advised to apply methyl bromide for soil fumigation in vineyards as a precautionary measure to reduce and prevent nematode infestations of rootstocks. However it is quite possible that nematode pests do not occur in the area, but in the absence of even basic taxonomic surveys it is impossible to predict the likely risk. Since methyl bromide contributes to ozone depletion, every effort needs to be taken to avoid its use and an international agreement has been reached to phase out methyl bromide usage worldwide.

Methods: Appropriate simple taxonomic surveys would allow for sound planning and environmentally responsible activities.

Outcomes and Impacts: No information on the possible presence of pest nematodes is available from the area, but expert opinion suggests that it is unlikely that any nematodes of agricultural concern occur naturally here. Even if problem nematodes do occur, the company is likely to incur significant expense when permission to use methyl bromide is withdrawn.

Lessons: Before implementing expensive, environmentally harmful and time-consuming prophylactic treatment of possible pest problems, it should be determined whether a realistic threat exists.

References: None

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Regions: Africa

Themes: Agriculture



The Oil Palm pollination mystery and the \$370million/year yield increase

Problem statement: Although native to West Africa, the oil palm's high commercial value has led to its introduction in many regions of the world. Malaysia was the first country (1917) to embark on large-scale planting and processing of oil palm but just 25 years ago the newly established oil palm estates of SE Asia were frustratingly failing to produce fruit. The necessary cross-fertilisation was generally believed to be via wind-pollination. Failure was blamed on the heavy rains in the region and to make the plantations viable, hundreds of local people were employed to pollinate the palms by hand. This costly process did increase yields, but they were still significantly lower than in Africa.

Methods: Investigations done into the pollinating agents in SE Asia showed that they were less effective than the pollinating agent in West Africa (the weevil). Further detailed studies were carried out in Cameroon of the six *Elaeidobius* species of weevils. *E. kamerunicus* was chosen as the most promising for Malaysian conditions. Following intensive screening tests and after obtaining clearance to import the beetles into Malaysia, a captive-breeding programme began. Two releases of the weevil were made in 1981 on two oil palm estates. The weevil was subsequently introduced to Sabah, Papua New Guinea, the Solomon Islands, Sumatra and Thailand, where it has successfully established and quickly increased yields. It has since been introduced to other parts of Africa and South America as well.

Outcomes and Impacts: Initial entomological studies showed conclusively for the first time that insect pollination is important. Research into the pollinators of SE Asia showed that they were not as effective at increasing yields as in Africa. Within a year of the release of *E. kamerunicus* into Malaysia, the weevils had spread throughout the entire Peninsula and were thriving in all the plantations, with impressive increases in yields. Thanks to this small West African weevil, Malaysia and Indonesia are now the world's leading producers of palm oil. It was estimated that Malaysian palm oil output in 1982 alone increased by 400,000 tonnes and palm kernels by 300,000 tonnes, with a total value of US\$370 million. Malaysia is now the largest producer and exporter of palm oil in the world, accounting for 52 per cent of world production and 64 per cent of world exports in 1997. Worldwide, oil palm fruit yield has risen from 70,000 hectogramme/hectare in 1980 to 122,000 hg/ha in 2001. This study provided a strong case for the use of beneficial insects in agriculture. A positive knock-on effect is that the weevil's success encouraged plantation owners to look into natural biological control to manage the palm's insect pests, so that chemical treatments, harmful to the pollinating weevil and so likely to depress palm fruit yields, could be avoided.

Lessons: Without the taxonomic expertise that identified an insect pollinator, costly and less-effective manual pollination might still be in use. Further, without sufficient taxonomic expertise to provide identifications to the species level, researchers would have worked with all 6 members of the genus, spent significant funds and may not have found the solution.

References: None

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Regions: Tropics

Themes: Pollinators, agriculture



Responding to suspected incursions of fruit flies and other exotic pests

Problem Statement: Fruit flies, family Tephritidae, are one of the most economically important pests of fruit crops in the tropics. Subtle variations in morphology and feeding behaviour also make them one of the most commonly misidentified groups of organisms in the biological sciences. There are approximately 4,500 species occurring worldwide, primarily in tropical to sub-tropical forests where they feed and oviposit on the fruits of native and introduced plants. The majority of fruit flies pose minimal risk to cultivated fruits but those that do often cause serious damage and require costly management practices to limit their impact. As a result, there is always concern from government and industry when a potentially exotic 'dorsalis-like' fruit fly is detected in areas where the pest is not yet known to occur.

Methods: The most economically important group of fruit flies in South East Asia, the Pacific and Australia are members of the 'dorsalis' complex. Originally the 'dorsalis complex' was believed to consist of only a few species of oriental fruit fly. However, taxonomic work has shown that the complex is comprised of at least 52 species. In fact, many earlier records of *Bactrocera dorsalis* from Southern India, Sri Lanka and South East Asia were based on misidentifications of what are now known to be other species. At least seven species of the 'dorsalis' complex are major pests of fruit crops and other plant communities in many areas throughout their native range in South East Asia and have invaded islands in the Pacific and parts of North and South America. In 1974 flies collected on the Cape York Peninsula of Northern Australia were identified as *B. frauenfeldi*, a species known from Papua New Guinea as a pest of mangoes. The arrival of this species resulted in a series of detection traps being established along a lengthy stretch of coastline from Queensland to Western Australia; the threat of the pest arriving from the north was perceived to be very real. The trapping program specifically targeted the oriental fruit fly and the melon fly (*B. cucurbitae*).

A discovery in November 1975 of a fly identified as the oriental fruit fly from Melville Island off Darwin brought fears that there had been another invasion. However, this species, while a member of the 'dorsalis' complex, was not found in commercial fruits. After isozyme, cytological and host plant studies it was found that the fly was not the oriental fruit fly but an indigenous species restricted to one local fruit, *Opilia amentacea*. The species found on Melville Island is endemic to northwestern Australia and has now been named *B. opiliae*.

Outcomes and impacts: The misidentification of the 'exotic' fruit fly and the subsequent response to identify and define the limits of the pest infestation in 1975-76 cost about A\$1.6 million but saved the significant expense of an eradication programme, such as the A\$35 million elimination of papaya fruit fly from Queensland in 1995-6.

Lessons: Deficient knowledge of the fruit flies of north Australia resulted in a false invasive pest alarm and unnecessary mitigation measures being implemented. The absence of rapid and accurate identification procedures prolonged the mitigation response and increased its cost. The availability of taxonomic expertise prevented further unnecessary measures being taken to control the falsely identified 'exotic' fruit fly.

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Regions: Australia

Themes: Agriculture



Economic, social, water and biodiversity benefits from invasive alien species management

Problem Statement: Fynbos vegetation is highly endemic, e.g. of some 1600 plant species that are to be found in the reserve, more than 150 are endemic. The reserve acts as a water catchment basin for a wide region (including the Cape Town Metropolitan Area). Due to the well-preserved fynbos, it also has a high potential for tourism. In addition, some parts of the reserve are used for agriculture and forestry (e.g. *Pinus* plantations, apple orchards, and pastures for sheep and cattle). But woody invasive alien species such as *Hakea* spp. and *Acacia* spp. are threatening the ecological balance. As a consequence, in heavily invaded areas, fire has become more intense, resulting in progressive soil erosion and diminished water flow and quality.

Methods: The data were gathered in selected test areas of the Kogelberg Biosphere Reserve, including controls which, due to periodic clearing, had remained relatively uninfested by alien species.

Outcomes and Impacts: Results suggest that if periodic clearing were discontinued, the cover of alien plants would increase from 2.4 per cent to over 63 percent within 100 years. Invasion of catchment areas would result in an average decrease of 347m³ of water/ha/yr over 100 years, resulting in average losses of more than 30 percent of the water supply to the city of Cape Town (already water-stressed). Continued uncontrolled invasion and gradual displacement of fynbos vegetation by alien species will irreversibly damage this unique ecosystem and affect the aesthetics and the ecotourism potential of the region. Further, given the relationship between biodiversity and water supply, subsequent loss of biodiversity will induce substantial constraints to economic development of the region. Control of alien species in moderately infested areas would cost roughly US\$ 4.50 ha/yr but annual gains in water alone would greatly outweigh these costs.

Lessons: Correct identification of invasive alien species allows cost-effective control measures to be identified and implemented, with positive returns for biodiversity conservation and economic use e.g. ecotourism and improved water supplies.

References: Biosphere reserve e-fact sheets.

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Regions: Africa

Themes: Invasive alien species



Timely identification of water weed indicates there is no need for a costly control programme

Problem Statement: *Salvinia molesta* occurs naturally in South America but has become a serious invasive water weed in Africa, Australia, Papua New Guinea, Indonesia, Malaysia, Sri Lanka and Southern India. In the mid 1980s, an entomologist from the Department of Agriculture, Thailand, upon a directive from the Ministry of Agriculture & Cooperatives, proposed a project on biological control of this weed in Thailand. The weevil *Cyrtobagous salviniae* (from South America), successfully introduced as a biological control of *S. molesta* in Australia, was proposed for testing and release. The proposal was sent to local taxonomists for review and evaluation.

Methods: Locally available taxonomic experts were able to show that *S. molesta* did not occur in Thailand. The locally occurring *Salvinia* species had been misidentified and was in fact *S. cucullata*, a species very similar in morphology and appearance to *S. molesta*, but smaller in size and less weedy.

Outcomes and Impacts: The local taxonomists informed the relevant government officials that *S. molesta* did not occur in Thailand and that an eradication programme was therefore unnecessary. The proposed biocontrol project was thus withdrawn. Should the correct and timely identification of this weed not have been made, the Royal Thai Government could have spent at least the budgeted US\$5million and a period of no less than 5 years implementing a wholly unnecessary biocontrol project.

Lessons: The timely use of taxonomic expertise resulted in the prevention of government spending millions on an unnecessary biocontrol programme.

References: Julien, M.H. and M.W. Griffiths (eds.). 1998. 4th edition. Biological control of weeds. A world catalogue of agents and their target weeds. CABI Publishing, Wallingford, UUK.

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Regions: Asia

Themes: Invasive alien species



Early identification of a new invasive pest brings cost / benefit ratio of at least 1:50 and billions of dollars in savings to Africa

Problem Statement: The New World Screwworm fly (NWS), *Cochliomyia hominivorax* (Diptera: Calliphoridae), is an obligate parasite (i.e. cannot live independently of its host) of warm-blooded vertebrates during its larval stages. The feeding activity of its larvae on living tissues of the host causes serious injury and can result in death. The pain and suffering caused by even mild infestations makes NWS an important animal welfare problem. The hosts most commonly infested are larger mammals, including wildlife and domestic livestock, although humans can also be infested. In the spring of 1998 numerous infestations of livestock by NWS were found in the Libyan Arab Jamahiriya (Libya), the first time that this species had become established outside of the Americas. This establishment was not just an emergency situation for Libya, but also represented a wider threat to North Africa, the Mediterranean Basin and possibly further afield.

Methods: The parasite was identified as NWS by light microscopy techniques, using standard taxonomic identification keys and reference to specimens in museum collections of international coverage. Because of the potentially serious consequences of this introduction, international organisations concerned with agriculture, including the Food and Agriculture Organisation of the United Nations (FAO) and the United States Department of Agriculture (USDA), were notified. This action led to the raising of international awareness and an eradication programme was developed. As local veterinarians and entomologists were unfamiliar with the NWS, taxonomists from the Natural History Museum (UK) participated in regional training courses and produced clear and simple identification guides.

Outcomes and Impacts: The entire eradication programme in Libya cost some US\$80 million, including a major input from Libya equivalent to US\$7.5 million. However, the cost / benefit ratio for the region was estimated to be at least 1:50. Accurate taxonomic identification at the outset enabled the programme to be launched swiftly and continuing taxonomic input helped focus the programme during its operation. If the programme had been launched late or had failed, then NWS could have spread much further in the region with far greater economic and human and animal health consequences.

Lessons: The main taxonomic issue was early and accurate identification of an introduced pest species and recognition of the potentially disastrous consequences it posed in an uncontrolled new environment. Thereafter, the important issue was to raise the identification skills of local scientists. Accurate identification of larval and adult specimens from infestations and traps was vital to monitoring and directing the eradication programme, ultimately saving billions of dollars in impacts such as stock losses, human health and eradication programmes.

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Regions: Africa

Themes: Invasive alien species, health



Significant cost savings in road maintenance result from comprehensive taxonomic surveys

Problem Statement: Namibia has an extensive all weather gravel and surfaced road structure network. In the northern parts of Namibia, where less arid conditions and higher biological diversity prevail, extensive shallow termite burrowing adversely affects the structural integrity of roads. Deterioration of road surfaces due to subsurface collapse leads to road-safety problems, higher maintenance costs and the need to regularly rehabilitate roads.

Methods: A comprehensive survey and taxonomic treatise on Namibian termites was used to provide advice on the species that are likely to be of concern and how to prevent these negative impacts.

Outcomes and Impacts: Following comprehensive taxonomic surveys, contract requirements for road construction in certain areas of Namibia now include provision for extensive treatment of successive layers with persistent pesticides and repellents to reduce burrowing activity by termites, primarily those species that construct extensive, shallow underground galleries. No figures are available to determine cost implications, but the reduced road maintenance costs and greater safety resulting from higher standards of roads have been significant.

Lessons: Comprehensive taxonomic surveys may bring unexpected benefits. Accurate knowledge of species diversity and distribution allowed for an evaluation of the occurrence of species capable of damaging the structural integrity of roads. Problem species should be accurately identified and surveyed to allow the implementation, where necessary, of precautionary steps to counter particular problem species.

References: Coaton, W.G.H. & Sheasby, J.L. 1972. Preliminary report on a survey of the termites (Isoptera) of South West Africa. Cimbebasia Memoir 2.

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Regions: Africa

Themes: Civil engineering



Incorrect identification of termite threat costs hundreds of thousands of dollars

Problem Statement: The Omatako Dam is the main large storage dam for the supply of water to towns and cities in central Namibia. Engineers feared that ant and termite activity might affect the structural integrity of its earth ramparts. A non-taxonomist investigated the earth structure, observed some ant and termite activity, and advised the responsible utility company to initiate a control programme. A product was selected on advice from an agricultural pesticide supplier for a quarterly spraying programme to protect the ramparts. Three years later no reduction in ant and termite activity had been observed.

Methods: Following the lack of results from the initial attempts at control, taxonomists from the National Museum of Namibia were consulted regarding the potential termite threats.

Outcomes and Impacts: Expert field investigations revealed no evidence of ant or termite species with the ability to move considerable amounts of soil and potentially affect the structural integrity of the dam; the species present build only superficial nests. In addition, the pesticide being used was formulated to protect seeds, and had not been registered for application on either ants or termites. It was therefore unlikely to be effective when applied as a contact pesticide on the surface for the targeted organisms. The spraying programme, which reportedly cost in excess of US\$ 200 000 annually in pesticides alone, was terminated and replaced by annual inspections on wall integrity. Five years later, no discernable deterioration of structural integrity has been observed.

Lessons: Proper surveys need to be carried out by qualified taxonomic personnel and correct identification needs to be ensured before deciding on a course of pest management action. If action is required, it needs to be ensured that the pesticide is registered for the target organism and that the application procedure will have the desired effect.

References: None

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Regions: Africa

Themes: Civil engineering



Access to expertise and sharing of experience controls invasive species while avoiding destructive and costly pesticide use

Problem Statement: Around 1980 the spiralling whitefly, *Aleurodicus dispersus*, native to Central America, was found spreading and causing heavy damage to many agricultural crops in Asia and the Pacific Region, Australia included. It seemed to attack any "green" broad-leaved crops and fruit trees such as guava and mango. However, in Thailand and some other countries it was initially thought to be *Bemisia tabaci*, *B. argentifolia* or an alien whitefly species, *A. destructor*, already present in the region for quite some time, and its potential economic importance was ignored.

Methods: Following good networking and communication, a Thai entomologist visited Hawaii to learn about similar infestations. The use of this knowledge and the relevant taxonomic keys led to the definite identification of this invasive alien pest as *A. dispersus*. Further, a potential biological control agent existed that could be introduced from Hawaii to help lessen the infestation and provide an eventual long-term control. Researchers favoured the use of biological control as the best way to avoid an eradication programme involving the widespread use of non-specific pesticides and the resulting high biodiversity and environmental costs. It was only after the infestation peaked in the early 1980s that entomologists were able to introduce a coccinellid, *Nephaspis oculatus* (formerly *N. amnicola*) from Hawaii in 1984 to control it.

Outcomes and Impacts: The economic damage and loss have been felt in almost all the infested Asian and Pacific countries. In Thailand alone, the damage caused by this whitefly is estimated at several million US dollars over a decade spanning from the 1980s to 1990s. However, it is not known how much more economic damage the whitefly could have caused if a pesticide-based eradication campaign had been carried out. The introduction of the coccinellid to control this whitefly cost less than a few thousand US dollars and provided an effective long-term control. Today, *A. dispersus* is only found sporadically, causing negligible damage.

Lessons: Access to taxonomic expertise, the use of earlier case studies and co-operation among entomologists from various regions with infestations and facing the same economic problems led to the discovery of a solution. Avoiding the destructive use of non-specific pesticides allowed application of the more sustainable biological control approach.

References: Waterhouse, D.F. and D.P.A. Sands. 2001. Classical biological control of arthropods in Australia. CSIRO Entomology, Australian Centre for Agricultural Research, Canberra. p. 559

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Regions: Asia

Themes: Invasive alien species



Major biocontrol agent of invasive water weed (*Salvinia molesta*) nearly missed

Problem statement: *Salvinia molesta* D.S. Mitchell is an aggressive aquatic fern and one of the world's worst weeds. It has been introduced from its native Brazil to many areas of the world, where environmental damage caused by its spread has been enormous. It chokes lakes, reservoirs, slow-moving rivers, irrigation systems, rice paddies, fishponds etc. with continuous meter-thick mats of dense vegetation. In addition to rendering the water useless for normal purposes its presence can lead to an increase in mosquito populations. *S. molesta* was initially mistaken for a different water weed species, *S. auriculata* Aublet, but attempts to control the invasive weed in Africa, India, Sri Lanka and Fiji using a weevil, *Cyrtobagous singularis* Hustache, collected from *S. auriculata* in Trinidad failed.

Methods: The weed was then correctly identified as *S. molesta* and the native range of *S. molesta* was discovered in Brazil in 1978. A hunt began for a pest that could be introduced as a biocontrol agent in countries where *S. molesta* has become an invasive alien species. A weevil, first thought to be *C. singularis*, was found on *S. molesta* that successfully decimated a large population of the water weed in Queensland, Australia. The dramatic success of this biocontrol operation was reported by Room, Harley, Forno & Sands in 1981. In 1983, however, it was reported that, in fact, the weevil was not *C. singularis* as originally thought, but a new species, later described as *C. salviniae*, distinguishable from *C. singularis* only on microscopic characters.

Outcomes and Impacts: The weevil *C. salviniae* has now been introduced in Africa, New Guinea, the US and elsewhere; the use of the correct species has resulted in massive clearance and control of the invasive water weed *S. molesta* over vast geographic areas.

Lessons: Biological control was achieved only after the true identity of *Salvinia* had been recognized, its native range found, and a previously unknown herbivore discovered. This illustrates vividly the crucial importance of sound taxonomy for understanding and solving ecological problems. Without taxonomy, funds would have been wasted on ineffective control projects.

References: **1:** Calder, AA & Sands, DPA (1985) A new Brazilian *Cyrtobagous* Hustache. (Coleoptera: Curculionidae) introduced into Australia to control *Salvinia* J. Aust. Ent. Soc. 24: 57–64. **2:** Room, PM, Harley, KLS, Forno, IW & Sands, DPA (1981) Successful biocontrol of the floating weed *salvinia*. Nature 294: 78–80. **3:** Room, P.M., 1990, Ecology & Evolution, 5:77. Doeleman, J.A., 'Biological Control of *Salvinia molesta* in Sri Lanka; an assessment of costs and benefits', Australian Centre for International Agricultural Research, Technical Report 12. **4:** Sands, DPA (1983) Identity of *Cyrtobagous* sp. (Coleoptera: Curculionidae) introduced into Australia for biological control of *Salvinia*. J. Aust. Ent. Soc. 22: 200.

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Regions: Global

Themes: Invasive alien species



Correct identification of disease-carrying insects allow targeted control programmes for yellow fever, filariasis, dengue and malaria

Problem statement: Yacyretá is a man-made reservoir, begun in 1996, covering approximately 1,600 square km. It is situated on the Río Paraná between Argentina and Paraguay, and supplies a hydroelectric powerplant that generates electricity for these countries. The reservoir has significantly affected the natural fauna and flora of the region, and the resultant expansion of the adjoining marginal forest from Brazil (Selva Marginal Paranaense del Paraná) could create new breeding grounds for the particular species of mosquito that carry illnesses such as malaria, dengue and yellow fever.

Methods: Monitoring of mosquitoes in the region began in 1993 with the start of a reference collection. A study took place in 2000-2001, during which sampling stations were located on both the Argentina and Paraguay sides of the reservoir. Adult mosquitoes and larvae were collected monthly and the captured specimens were added to the reference collection. Results of the monitoring and associated taxonomic research including identification of specimens to genus and species level was published in taxonomic keys, descriptions and revisions in scientific journals and books for universities, research institutions and national and international health organisations.

Outcomes and impact: The study identified 13 genera and 58 species of the Culicidae family for the Argentinean side of the Rio Parana. Of the 58 mosquito species, five were proven to be disease carriers of epidemiological significance in the region: *Anopheles darlinghi* and *A. albitarsis*, both carriers of malaria, *Aedes aegypti*, a carrier of dengue and yellow fever, *Haemagogus leucocelaenus*, a carrier of yellow fever, and *Culex pipiens*, a carrier of filariasis and secondary carrier of yellow fever.

Lessons: In areas subjected to significant land use changes, expert taxonomic identifications and reference collections of disease carrying and related species are needed to evaluate changing risks and target monitoring and control programmes. Accurate knowledge of current disease vector distributions avoids unnecessary control programmes for other similar but benign species.

References: Tricio, A., Morawicki, P.M., Fernández Díaz, C. I., Krsticevic, F. & Araki, S. (2002) Monitoreo de dípteros vectores hematófagos en el área de influencia de la represa Yacyretá. Periodo, 2000-2001. In: Oscar Salomón (ed.) Actualizaciones en Artropodología Sanitaria Argentina. Serie Enfermedades Transmisibles. RAVE. Fundación Mundo Sano, Buenos Aires, 301 pp.

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Regions: South America

Themes: Health



Use of taxonomy leads to criminal convictions

Problem Statement: Correct taxonomic identification of many insects and other Arthropoda (spiders, scorpions, centipedes etc.) can provide vital clues to the time and location of a death. Such organisms use decaying organic matter, including the bodies of humans and animals, as a source of food. They are the first to arrive at a corpse, often within minutes of death, and the subsequent stages of decomposition are influenced and characterised by different guilds (groups that share habitats or characteristics) of insects. Taxonomic information is required to identify these different guilds.

Any forensic investigation that involves entomology is consequently based on the initial identification of the insects that are present. If the precise taxonomic status of certain insects on a crime scene is known, it is possible to interpret the biology, especially the development time and role of that particular species. Certain species only occur under specific conditions, and only an accurate identification can provide the necessary information in the entomological analysis at a crime scene.

Methods: By identifying the insects on a body and applying knowledge of their biology, especially the rate at which they develop from egg to adult, it is possible to determine their respective guilds, their state of development (age) and hence the stage of decomposition. This information can then be extrapolated to estimate the time of death.

Outcomes and Impacts: By establishing the time since death, investigators of a crime can identify persons who disappeared at a particular time, trace the movements of potential suspects, and determine whether a body has been moved.

Forensic entomology is being utilised in many parts of the world, and especially in South Africa, where the South African Police Service is making increasing use of entomologists to assist them in crime scene analysis. In South Africa, over 200 cases of murder and unnatural causes of death have been investigated using forensic entomology since 1993. These analyses have assisted in the interrogation of suspects and several have been presented as evidence in court.

Lessons: Through the use of taxonomy, detailed information regarding the classification of the insects and their life stages can be found and thus the cause and time of death may be determined. Blowflies provide the most exact and important evidence of all the insect guilds. Forensic entomology is a clear example of the application of taxonomy being fundamental to important social issues, namely crime investigation and prevention through successful prosecutions.

References: None

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Regions: Global

Themes: Forensics



Identification of marine hotspot allows for protection of biodiversity and spawning ground for fishing industry

Problem Statement: Many of the world's marine biodiversity hotspots have been over fished. These hotspots are seldom recognised as such due to a lack of taxonomic information.

Methods: Surveys and more detailed programmes of sampling and identification were undertaken.

Outcomes and Impacts: Sampling revealed that an area of seafloor approximating 20 x 10 square km is the most diverse so far known for the New Zealand region, with high levels of local endemism. New hydroid, gorgonian, and barnacle taxa also occurred in the samples. The hitherto unsuspected species diversity of macrobenthos in this small area of seafloor off northern New Zealand resulted in the Ministry of Fisheries closing the area with the greatest number of species (in the 50-70 m depth zone) to trawling, Danish seining, and commercial scallop dredging, effective from 11 November 1999, to allow areas of affected habitat to regenerate.

Lessons: Only detailed, authoritative taxonomy allowed for the recognition of this area as New Zealand's marine-biodiversity hotspot, and thus for the protection of the area from fishing activities. Now, testable hypotheses based on geography, tectonics, hydrography, and the biology of the organisms themselves can be erected to explain this diversity and the area will be able to provide a spawning ground for the surrounding fishing industries.

References: 1: Ocean Biogeographic Information System (OBIS) International Committee: <http://www.obis.org>.
2: Species 2000 Taxonomy Group: <http://sp2000.org>. Species 2000 Asia-Oceania Working Group: <http://www.sp2000ao.nies.go.jp/index.html>.

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Regions: Marine

Themes: Conservation, fisheries



Biodiversity and waterways win in a weevil's battle against *Azolla*

Problem statement: Floating water fern / fairy fern (*Azolla filiculoides*) has, for years, been a highly effective invasive species in South Africa, creating problems in inland waterways. These problems include increased flood risks, hindrance to recreational activities, threats to livestock and loss of aquatic biodiversity. Fragmentation of the weed fronds has made control by mechanical means virtually impossible, a problem compounded by the annual production of millions of tiny spores, which are released in autumn and grow into new plants in the following year.

Methods: Investigators sought to identify an effective biological agent for the eradication of the invasive aquatic fairy fern (*A. filiculoides*). The weevil, *Stenopelmus rufinasus* was found to feed only on species of *Azolla*, consuming large quantities of the plant.

Outcomes and Impacts: Since its release by South African scientists, the weevil has brought even the most heavily infested sites under control within a matter of months, without the need for chemicals or further control measures. Control of *Azolla* has lessened its impact on aquatic biodiversity and reduced its blockage of waterways and the associated problems of flooding, livestock loss and obstacles to the recreational use of waterways.

Lessons: Eradication of this invasive water fern species is now possible without damage to fresh water biodiversity. Identification of an effective biological control agent for *Azolla* depended on expert taxonomic work.

References: None

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Regions: Africa

Themes: Invasive alien species



Cabbages, kales and the Diamondback

Problem Statement: The Diamondback moth *Plutella xylostella*, is a major crop pest which occurs mainly on crucifers (cabbages and kales) worldwide. The moth is a particular problem in East Africa, where crucifers are part of the daily diet and provide most of the vitamins and minerals for the poor segment of the population. Although an estimated \$1 billion is spent on pesticides to control this species, it has developed resistance to almost all commercial pesticides.

Methods: As parasitisation rates by native parasitoids are very low (<15%), the International Centre of Insect Physiology and Ecology (*icipe*) in Kenya developed a biological control programme, financed by the German Ministry for Economic Cooperation and Development. The parasitoid *Diadegma semiclausum* was considered on the basis of its success in South East Asia, but its taxonomic status was unclear. Due to previous misidentifications, Kenyan authorities would not allow a release unless it was shown beyond doubt that the exotic species was different to the local one and a more effective parasitoid. Molecular tools were used in addition to classical morphological tools to prove that the native *Diadegma* species from Kenya was different from the exotic *D. semiclausum* from Taiwan, which had been shown to be a much superior parasitoid of Diamondback moth.

Outcomes and Impact: A year after the release of *D. semiclausum* in Kenya it was established in the pilot sites, and parasitisation rates had already increased (>40%). Permission for a general release was then issued in Kenya and more activities are planned in other east African counties to build on the promising results. In an ex-ante economic impact assessment conducted by the project for Kenya alone, cost / benefit ratio of 1:31 was predicted over a time period of 20 years.

Lessons: Biological control agents can provide highly cost-effective alternatives to pesticide use, particularly where target species have built up resistance. Molecular techniques can help taxonomists to differentiate between morphologically similar species and to identify effective biological control species.

References: Wagener, B.; Löhr, B.; Reineke, A. and Zebitz, C.P.W (2002) Molecular identification of *Diadegma* species (Ichneumonidae) parasitising diamondback moth *Plutella xylostella* (Plutellidae) in eastern and southern Africa. Proc. International Symposium Improving Biocontrol of *Plutella xylostella*. 21-24th October 2002, Montpellier, France.

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Regions: Africa

Themes: Agriculture



Biocontrol of a red scale boosts citrus industry in North America

Problem Statement: Red scale was a serious pest affecting citrus crops because early attempts at control were ineffective.

Methods: It was originally thought that the red scale pest species was *Aonidiella citrina*. However, taxonomic investigations revealed that red scale was in fact a closely related species, *A. aurantii*. This discovery provided the basis for further research, again drawing on expert taxonomic inputs, that led to selection of host specific parasitoids from the genus *Aphytis*.

Outcomes and Impacts: The host specific parasitoids were eventually used successfully in control of red scale.

Lessons: Taxonomic expertise was needed both for the correct identification of the red scale pest and for selection of parasitoids for biocontrol.

References: None

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Regions: North America

Themes: Agriculture



Food scare or scientific fascination? Larval tapeworms in the flesh of fishes

Problem statement: In the early 1990s, the Parasitic Worms Division at the Natural History Museum, London, (UK) had two almost identical enquiries concerning parasitic worms in the flesh of food fishes. One arrived in the diplomatic bag from the British Embassy in Quito, Ecuador, where fisheries authorities started getting reports of large cysts containing worms in the muscles and body-cavity of popularly eaten coastal fishes (groupers). As a precaution, sale of these fishes was temporarily stopped and existing catches condemned, with resulting economic hardships for fishermen. The second case concerned larval worms from the flesh of commercially important fishes (again groupers) in the Arabian Gulf. These were forwarded by the Scientific and Applied Research Centre of the University of Qatar, as the presence of these larvae in fish muscle had caused the price of some fishes in the Gulf to plummet, again causing considerable financial problems to local fishermen and fish-mongers.

Methods: The worms were first removed from fish tissue and processed (cleared) using standard procedures so that internal details of the worms could be seen under a microscope. Museum staff then used their taxonomic expertise to identify the group of worms responsible for the problems. Further research using the scientific literature resulted in more detailed identifications.

Outcomes and impacts: The worms were determined by Museum staff as larval tapeworms of the Order Trypanorhyncha, the adult forms of which tapeworms occur only in elasmobranch fishes (sharks and rays). The Museum was therefore able to assure the authorities in both countries that while these 'wormy fish' may be aesthetically unappealing, the worms found in the groupers were of no danger to human health. The worms comprised more than one species, which were subsequently identified and added to the Museum Collection. One possible reason for the sudden appearance of these worms in fishes off Qatar may have been a southwards movement of elasmobranchs due to pollution after the first gulf war.

Lessons: Taxonomic expertise is needed to determine both the identity of parasites and recognise stages in their life cycle. Such expert knowledge has a key role in ensuring the safety of fish consumption. Identification work by expert centres provides the opportunity to make scientifically important observations about species distributions.

References: None

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Regions: Global

Themes: Health, fisheries



Lack of local information on native species allows major pest slugs and snails to become established in Sri Lanka

Problem Statement: Introduced slugs and snails are currently the most serious agricultural and horticultural pests in several areas of Sri Lanka but their recent arrival has passed unnoticed and largely unrecorded. Because it has not been possible to identify many of the native species in Sri Lanka, exotic pest species had been mistakenly assumed to be native to Sri Lanka and the agricultural authorities had not been alerted to their presence. Sri Lanka is a global biodiversity hotspot with the greatest category of threat to biodiversity owing to high human population density. It possesses a species rich and highly endemic land snail fauna with several ancient relict groups. Much of the original forest in Sri Lanka has been degraded or converted to plantations and other forms of agriculture and it is in these habitats that exotic gastropod species have become established.

Methods: Addressing the problem of a lack of taxonomic resources in Sri Lanka to allow identification of land snails was the focus of the Darwin Initiative Project Land snail diversity in Sri Lanka (1999-2002). Nearly all of the taxonomic resources for the region such as specimen reference collections, particularly type material, and specialist literature are concentrated in The Natural History Museum, London and a primary objective of the project was to provide access to such resources. In Sri Lanka the project focussed on a national survey of terrestrial molluscs to allow the establishment of specimen reference collections and a database on distributions.

Outcomes and Impacts: The survey established that, particularly in the Central Highlands, the most damaging species of exotic pest gastropods were firmly established in very high densities. We now have a good knowledge of what pest species are present and have produced identification guides to the native fauna which will allow a speedy response to the arrival of new exotic slugs and snails, making it possible to prevent further damage to both agriculture and biodiversity.

Lessons: Lack of knowledge of what species are native to an area can allow exotic pest species to become firmly established without any attempts at their eradication or control being put in place. Identification guides prepared by taxonomists are essential tools in the prevention of epidemics of invasive species.

References: **1:** Naggs, F. 2002. Molluscan pests in Sri Lanka: voracious exotics having a major and rapidly increasing impact on agriculture. Zoology Department, The Natural History Museum, London. Land snail diversity in Sri Lanka: Darwin Initiative project information leaflet. **2:** Naggs, F., & Raheem, D. 2002. Sri Lankan Snails. Department of Zoology, The Natural History Museum, London. **3:** Mordan, P. et al. A guide to the pest and exotic snails and slugs of Sri Lanka. Department of Zoology, The Natural History Museum, London. **4:** Naggs, F. et al. (In Preparation). Ancient relicts and contemporary exotics: faunal change and survivorship in Sri Lanka's snail fauna. Slugs & snails. Agricultural, veterinary & environmental perspectives. British Crop Protection Council.

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Regions: Asia

Themes: Invasive alien species



A review of *Verticillium* taxonomy gains market access for New Zealand buttercup squash

Problem Statement: Each year some consignments of buttercup squash from New Zealand, worth about US\$600,000 per year to growers, were being destroyed or reshipped by South Korea because of a fungus that was believed to threaten their domestic rice crop. Potatoes from USA have also been destroyed when the same fungus was detected. The Korean National Plant Quarantine Service had listed *Verticillium tenerum* in their Controlled Pathogen List as a Category 2 organism – “commodity allowed into country with proper treatment, or otherwise contaminated material to be destroyed or otherwise disposed.” New Zealand authorities had also listed this fungus as a quarantine pest on *Pinus* seed imports into New Zealand.

Methods: A thorough literature review and consultation with colleagues on the naming, biology, distribution, and pathogenicity of *V. tenerum* was undertaken to convince Korean authorities that this fungus is neither a parasite of rice nor a legitimate quarantine pest.

There has been extensive confusion over the naming of the fungus known as *V. tenerum* and debate over whether or not it is the anamorph of *Nectria inventa*. The correct name for the fungus is *V. luteo-album*, and it is not related to *N. inventa*. Molecular and morphological studies (communicated by Dr W. Gams, Centraalbureau voor Schimmelcultures, Netherlands) have shown that *V. luteo-album* possibly belongs in a separate genus from the well-known plant pathogenic species, *V. albo-atrum* and *V. dahliae*. *V. luteo-album* is a cosmopolitan saprobe with no damaging effects on rice.

Outcomes and Impacts: Both the Korean and New Zealand authorities have now removed *V. luteo-album* from their pest lists after accepting the results of research that showed it was not a threat. New Zealand buttercup squash growers now have an assured market and Koreans have access to off-season, high quality squash.

Lessons: Taxonomic expertise and a thorough review of *Verticillium luteo-album* provided the evidence that quarantine authorities required to remove a non-tariff trade barrier.

References: McKenzie, E.H.C. 2003: *Verticillium luteo-album* (syn. *V. tenerum*), Biology, Distribution, Pathogenicity. Landcare Research Contract Report: LC0304/022.

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Regions: Asia

Themes: Trade, agriculture



Resolving the paradox of the alien termite pest species from Southeast Asia

Problem Statement: The termite genus *Coptotermes* has a few species that are notorious as pests of timber on an international scale. They are responsible for enormous losses in buildings throughout the tropics and subtropics. The ability of these termites to nest in pieces of moist timber and form new nests from fragments of the colony enables them to survive as stowaways on board ships that spread them to new geographical areas. Large amounts of money are spent annually to control these pests and in the development of control measures. However, there has been for many decades, till recently, a paradox in the pest status of these species of termites. *Coptotermes havilandi*, which is a serious alien pest in parts of South and North America, is thought to have been introduced from Southeast Asia, yet in countries in its supposed area of origin, it has never been accorded much importance as a pest. Instead, the pest species known to the region were said to be primarily *C. gestroi* and *C. travians*.

Methods: This paradox prompted the Forest Research Institute Malaysia (FRIM) to undertake a study on the taxonomy of these species. The degree of variation in castes, individuals and populations in Malaysia and neighbouring countries was examined. The study showed that *C. havilandi* and *C. gestroi* were in fact the same species. Thus, the alien species introduced to the Americas should be known as *C. gestroi* instead of *C. havilandi*. It was also shown that the true *C. travians* was not a pest that enters buildings but, rather, a species of the forest, and that what was wrongly called *C. travians* in Malaysia and neighbouring countries was in fact *C. gestroi*.

Outcomes and Impacts: In Southeast Asia there is, in fact, a single pest species, *C. gestroi*, that was introduced to various parts of the world, including the Americas and islands in the Caribbean and Pacific and Indian oceans. In view of the status of *C. gestroi* as a pest species of international concern, it was given a common name, the Asian Subterranean Termite.

Numerous studies have been conducted in different parts of the world on the biology and management of the various termite pest species that were thought to be different. The recognition of a single species is enabling the scientific information from different countries to be pooled. This, in turn, is facilitating the development of improved pest management strategies.

Lessons: The information we have about a species is only as good as the name that is applied to it. If the wrong name is applied, then decisions including pest control practices are based on the wrong information or do not make use of information that is already available. If the taxonomy of a group of species has been insufficiently studied, confusion is likely to abound. This confusion passes down to the level of industry and can have serious economic impacts, or even directly harmful effects on human beings. In this particular example, industry is now able to avoid duplication in the testing and design of control strategies such as baiting technologies. The study that enabled this is only one example of how fundamental taxonomic research can have far reaching impacts on science, industry and society across the world.

References: Kirton, L.G. & Brown, V.K. 2003. The taxonomic status of pest species of *Coptotermes* in Southeast Asia: Resolving the paradox in the pest status of the termites, *Coptotermes gestroi*, *C. havilandi* and *C. travians* (Isoptera: Rhinotermitidae). *Sociobiology* 42(1): 43-63.

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Regions: Asia

Themes: Civil engineering



Keeping the weevils from Bangladesh's cotton

Problem Statement: Cotton Boll Weevil, *Anthonomus grandis*, is a notorious pest of cotton in the USA where it persists despite an intensive, 20-year eradication programme. It is not known to occur in Bangladesh, a country that imports cotton from a number of countries, including the USA, to meet demand from its economically important textile industry. Standard phytosanitary procedure requires imported cotton to be fumigated for 72 hours on board ships at the port of entry to protect Bangladesh's cotton production from alien pest species, especially Cotton Boll Weevil. In a recent incident, Bangladesh Textile Mills Association (cotton importers) and the US Ambassador argued that this fumigation treatment is unnecessary. Bangladesh government authorities had to decide whether to contest the US position.

Methods: The Ministry of Agriculture, Bangladesh, invited several expert entomologists (taxonomists) to advise on the appropriate response to US government assertions that: (a) fumigation requirements are unnecessary from a scientific perspective, extremely costly and not required; (b) prior to shipment, cotton fibre is inspected by the U.S. Department of Agriculture and certified as being free of Boll Weevil; and (c) fumigation only serves to increase the price of U.S. cotton, thereby damaging the competitiveness of garment and textile exports from Bangladesh.

The taxonomists confirmed that the Cotton Boll Weevil is not found in Bangladesh. Importantly, they advised that Boll Weevils can enter a dormant state for 10-11 months (an overwintering survival strategy). It is also possible that their eggs could survive in a consignment of cotton in dormant adult weevils.

Outcome: The taxonomists recommended that: (a) Fumigation at the port of entry must be continued to prevent invasion of any unknown pest including Cotton Boll Weevil. (b) Experts from member countries of the IPPC and APPPC should make a definitive ruling (fumigation is mandatory in other cotton importing countries of the region).

Lessons: The involvement of scientists (taxonomists) is vital for phytosanitary and quarantine services, prevention of invasions by alien pest species and protecting a country from accusations of unfair practice by a trading partner. Without locally available taxonomic expertise, cotton production in Bangladesh would have been put at risk from cotton imports containing Cotton Boll Weevil in dormant or egg form. Lost cotton production and pest eradication costs would have had significant economic and social consequences, as in other countries that are highly dependent on agriculture. Maintaining locally accessible taxonomic expertise is a highly cost-effective approach to protecting agricultural and trade interests.

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Regions: Asia

Themes: Trade, agriculture



Symbiotic fungus provides early warning of invasive and minimises forestry loses

Problem statement: In 1994, while conducting research on another forestry pest, the disintegrated body parts of a metallic bluish-black wasp were found under the bark of a 40 year old *Pinus radiata* tree which had been felled and then rejected in a plantation outside Cape Town. Further examination revealed round exit holes similar to those described in the literature for the woodwasp *Sirex noctilio*, a forestry pest previously unknown in South Africa. *S. noctilio* originates in Eurasia and North Africa where it attacks stressed conifer species. It has since spread to plantations in other parts of the world, killing up to 70 percent of trees.

Methods: It was not possible to identify the wasp from its remains, so a sample of the wood was sent to the mycology division of the National Collection of Insects in Pretoria where it was cultured to test for the presence of a symbiotic fungus (*Amylostereum areolatum*). Female woodwasps inject trees with *A. areolatum* along with a mucus just prior to laying their eggs. Once the larvae hatch they feed on the fungus within the wood, making a U-turn when the less nutritious heart-wood is reached, and eventually pupate in the wood below the bark, before emerging as adult woodwasps after about a year. The presence of this symbiotic fungus would indirectly confirm the presence of the woodwasp.

Outcomes and impacts: Analysis confirmed the presence of *A. areolatum* and hence the woodwasp. The confirmation came a year before the first wasp specimen was captured. Early warning of the woodwasp's presence allowed an immediate start to be made on the importation of biological control agents that had worked successfully in Australia and New Zealand. Within a year, the key parasitic nematode *Deladenus siricidicola*, had been introduced, followed a year later by other biological control agents: Hymenopterous parasitoid *Ibalia leucospoides* and then by *Megarhyssa nortoni*.

Between 1994 and 2001 the woodwasp spread 380km along the west and east coasts but successful biological control meant that at no point were more than 3 per cent of the trees lost.

Lessons: The speed with which biological control was implemented after the indirect identification of the woodwasp was directly responsible for the minimal losses experienced by the forestry industry of South Africa. Taxonomic expertise was essential for the early detection of the invasive pest and for design of the biocontrol programme that contained the threat.

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Regions: Africa

Themes: Forestry



The Larger Grain Borer: the high cost of a slow response

Problem Statement: It is believed that the Larger Grain Borer (LGB), *Prostephanus truncates*, was introduced into Tanzania in the late 1970's, most likely in maize provided as food aid or in the sacks used to transport this maize. When the pest was reported, stored maize was treated as other stored product pests, but without any success. Due to these ineffective control measures and lack of understanding of the pest involved, the LGB spread at an alarming rate, with a major impact upon food supplies. LGB was accidentally introduced in shipments of maize into Togo in West Africa. In addition to attacking grain, LGB also attacks stored cassava.

Methods: LGB specimens were taken to the Natural History Museum in London, UK, where a definitive identification was made and natural enemies indicated from its native areas in Mexico and Costa Rica. One of these, a small black beetle which preys on the grubs (larva) of the Larger Grain Borer, was then introduced into Tanzania to destroy the Larger Grain Borer.

Outcomes and Impacts: By 1998, 13 African countries confirmed the presence of the pest. The area of spread in East Africa is now estimated at one million square kilometres, with one third of this area being affected in West Africa. LGB cost Tanzania roughly US\$91 million annually in lost maize intended for consumption or export. Losses of cassava have been assessed to be as high as 35 percent in 5-6 months storage and up to 60 percent for storage over 9 months, losses which cost West Africa up to US\$800 million. In addition to the physical losses, significant effort has been needed to contain the invasive pest. Between 1984 and 1992, the average annual cost to the Tanzanian government was more than US\$ 3 million.

Lessons: If the LGB had been recognised from the outset, its spread would have been greatly reduced, crop losses would have been significantly lower and the need for cost control programmes much reduced. Early recognition depends on appropriate identification support tools (user-friendly keys), supported by taxonomists.

References: BioNET INTERNATIONAL Business Plan, 1999.

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Regions: Africa

Themes: Agriculture



The struggle to uphold legislation that protects the African honeybee

Problem Statement: Bee keepers in the winter rainfall (western Cape) region of South Africa have colonies of *Apis mellifera capensis*, the Cape honeybee, whereas beekeepers in the summer rainfall region of the country have colonies of a different subspecies, *Apis mellifera scutellata*, the African honeybee. When beekeepers moved honeybee colonies from the western Cape into the summer rainfall region, the population of African honeybees was threatened. According to legislation designed to protect pollinators essential for agriculture, any *A. m. scutellata* colonies that have *A. m. capensis* laying workers must be killed within 48 hours. Typically, only a very few Cape bee workers invade *scutellata* colonies. Correctly identifying their presence is therefore of paramount importance to minimizing the number of colonies killed. However, no clear-cut taxonomic method to distinguish between the workers of the two subspecies is available. The protection of African honeybee colonies is also important for biodiversity because the trapping of tens of thousands of wild bee swarms annually by beekeepers is impacting on the pollination of wild flora.

Methods: At present worker bees are dissected, the spermatheca measured, and the number of ovarioles in each ovary counted. These data give a good indication of the subspecies, but obtaining the information results in the destruction of the specimens. An alternative approach involves a visual examination of live workers in queen-less colonies, however this is not as accurate as the dissection method.

Outcomes and impacts: The lack of a robust taxonomic method of distinguishing honeybee subspecies results in ongoing, unnecessary elimination of African bee colonies falsely suspected of containing Cape bees. Despite legislation to protect their populations, the numbers of African honeybee colonies needed for pollination of fruits and vegetables is therefore continuing to decline.

Lessons: Implementation of the legislation to protect the African honeybee requires new, robust and non-destructive taxonomic methods to distinguish the two subspecies if unwanted destruction of bee colonies is to be avoided. Accurate keys or, ideally, molecular analysis of samples taken from specimens may provide the solution. Such methods would be significantly more accurate, rapid, robust and non-destructive than current procedures.

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Regions: Africa

Themes: Pollinators, agriculture



The conviction of child-abusing parents

Problem Statement: A mother whose baby had died of starvation, neglect and maltreatment claimed she had fed the baby fruit cocktail just before the baby died of accidental causes.

Methods: Police and prosecuting attorneys brought samples of the stomach contents of the dead baby to taxonomists at the University of Colorado, Boulder. The taxonomists were able to state positively that the stomach contained no evidence of peaches, pears, pineapple, grapes or cherries.

Outcomes and Impacts: The parents were convicted on several counts of child abuse and one count of murder. They are currently serving prison terms.

Lessons: The use of taxonomy proved that the mother was trying to mislead the police and the courts.

References: <http://journalsip.astm.org/JOURNALS/FORENSIC/TOC01/4231997.htm>

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Regions: North America

Themes: Forensics



Order out of chaos: taxonomy supports seahorse conservation

Problem statement: Seahorse populations are declining globally as a result of overexploitation, habitat destruction and bycatch. Conservation assessments, planning and controls were constrained by a lack of clarity on seahorse taxonomy: one name could apply to many different species, one species could be known by more than one name, or the species might be unnamed.

Methods: A review of the entire seahorse genus (*Hippocampus*) was undertaken. This involved locating/translating original species descriptions, then visiting 23 museums in 9 different countries to check type specimens, examine large numbers of other specimens from as wide a geographic range as possible, take morphological measurements and, where feasible, take material for genetic analysis. The data were used to identify species boundaries, distinctive features for the different species, and appropriate names for each.

Outcomes and impacts: The publication of a revised taxonomy of seahorses and identification guide enabled communication among researchers and conservationists and led directly to conservation assessments (e.g. IUCN Redlist assessments) and species-specific international trade controls (e.g. through listing on Appendix II of CITES, the Convention on International Trade in Endangered Species of Wild Flora and Fauna). The CITES listing was a landmark for marine species of commercial importance that has led to similar constraints on trade in other species.

The study has also stimulated additional research on seahorses around the world, including the description of new species, the compilation of information on each species (such as distribution and population status) and genetic studies of connectivity among populations thereby furthering conservation efforts at local and regional levels.

Lessons: Updating and clarifying seahorse taxonomy was critical to the implementation of effective conservation measures including new controls of trade. The new identification guide has allowed the status of seahorse populations to be reliably assessed.

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Regions: Marine

Themes: Conservation



Less insecticide, greater control of rice Black Bugs – lessons from the Philippines

Problem Statement: After years of uncontrolled infestation, the highly destructive, sap-feeding rice “Black Bug” *Scotinophara coarctata* (Fabricius) was considered to be a major threat to the “rice bowl” of the Philippines, Central Luzon and insecticides were widely used to manage it. Widespread yet difficult to observe, this highly invasive species has been found in the Philippines in four major islands to date: Palawan (1982), Mindanao (1992-1997), the Visayas (1998-1999) and Luzon (2005-2006). In Palawan, it damaged over 1,200 ha of irrigated rice fields, prompting the provincial government to procure US \$20,000 worth of insecticides. Subsequent reports of Black Bug sightings in six major islands were also attributed to *S. coarctata*. However, many attempts at controlling the assumed pests using insecticides failed, challenging the authorities to investigate the problem further.

Methods: The Philippine Rice Research Institute under the Department of Agriculture commissioned a consultant taxonomist to collect and determine the identity of the invading rice Black Bugs and their natural enemies from the different islands in the Philippines. Intensive sampling was conducted throughout the outbreak areas in 2006 using light traps and hand collections direct from the rice plants. Museum collections were also loaned and examined. Sub-samples of the collections were dissected, fixed, and examined using scanning electron microscopy and individually compared morphologically to detect species differences. Investigations also gathered information on farmers’ knowledge, attitudes and practices in Black Bug management using a structured questionnaire and, through farmers’ forums, advised farmers and workers on the correct name(s), feeding biology, and control of the black bugs.

Outcomes and Impact: Taxonomic investigations revealed why in many cases it is unnecessary to treat “Black Bug” infestations with insecticides: rather than one species, eleven have now been recognized but only three have been observed to act as pests - *S. coarctata* from Palawan and the two *S. coarctata* group members from Mindanao. The other eight Black Bug species feed on rotting rice leaf sheaths and cause no damage to the rice plant. Furthermore, the populations of these eight bug species are controlled by natural enemies that kill the eggs, nymphs and adults. Most farmers - 85% in 24 of 26 provinces - now adopt the no spray approach for Black Bugs. In addition, because abandoned rice stubble was found to serve as breeding grounds for Black Bugs, ground-level cutting of stubbles, plowing and flooding were recommended to control the Black Bug population.

Lessons: Expert taxonomists have a vital role in advising on pest management. They formulate recommendations for the effective management of pests and reduced dependence on insecticides, helping save money and safe-guard the rice environment and both human and animal health. The Black Bug problem persisted for many years in the Philippines before it was possible to secure taxonomic support. There are still only very few well trained local taxonomist with strong knowledge on the natural history of rice invertebrates. It is therefore of paramount importance to increase their numbers by supporting more training programs in taxonomy while providing better career opportunities and job security.

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Regions: Asia

Themes: Agriculture



Protecting African tomatoes from spider mites

Problem Statement: During the last two decades small-scale farmers in southern Africa (mainly Zimbabwe, Zambia, Malawi and Mozambique) faced increasing problems with spider mites (Acari) on tomatoes. The mites caused devastating losses of up to 90% of the yield. They were generally identified as *Tetranychus urticae* Koch, 1836, by the national authorities, a known and common pest of many vegetables and other important crops worldwide.

Methods: Based on the assumption that *T. urticae* was the pest species to combat, a USD 800,000 project was initiated in the 1990's to develop integrated pest management (IPM) strategies. One objective was to reduce the use of broad spectrum insecticides as these were thought to severely harm the natural enemies of spider mites (e.g. *Phytoseiulus persimilis* Athias-Henriot, 1957). The identity of the pest species was checked at the beginning of the IPM project by the Agricultural Research Council - Plant Protection Research Institute in Pretoria (ARC-PPRI), South Africa, with an astonishing result: the damage on the tomatoes was caused by the species *Tetranychus evansi* Baker & Pritchard, 1960, not *T. urticae*. This finding triggered crucial changes to the project and management strategy. Molecular tools were developed to distinguish *T. evansi* from *T. urticae*. The plan to implement an IPM strategy was dropped. Instead surveys were initiated to search for potential biological control agents in South America.

Outcomes and Impact: Spider mites are particularly difficult to identify because they are minute (about 0.5 mm) and only a few taxonomist in Africa have the necessary expertise. With the development of a molecular method, complementing the classical taxonomy based on morphological characters, *T. evansi* now can easily, cost-efficiently and reliably be identified.

T. evansi is an invasive alien species in Africa probably introduced from South America. No indigenous predatory mites and only a few other southern African predator species attack this pest. Therefore, the original approach to preserve natural enemies through reduction of pesticide use would have been ineffective. Instead, hopes rested on finding biological control agents in South America. Biological control benefits growers, consumers and the environment alike. No money needs to be spent on pesticides and growers and customers, as well as the environment, are not subjected to insecticides. The predatory mite *Phytoseiulus longipes* Evans, 1958, was identified as the most promising candidate and introduced into Kenya, where it is currently tested in the field. Thus, the correct species identification triggered a complete change in the pest control strategy, avoiding a waste of almost USD 1 million.

Lessons: Proper identification of the target pest is indispensable for the development of IPM and biological control strategies. In the case of spider mites in Africa, lack of taxonomic expertise is a severe obstacle. Currently only ARC – PPRI in South Africa can offer reliable and affordable identification services, based also on molecular methods. Building and maintaining taxonomic capacity in Africa is critical for the advancement of pest control.

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For more information on spider mites and predatory mites:

http://en.wikipedia.org/wiki/Spider_mites; <http://www.benemite.com/ppersimilis.htm>;

<http://www.pbase.com/holopain/image/57829926>

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Regions: Africa

Themes: Invasive alien species, agriculture



Rapid identification of marine pest prevents infestation and saves Australia millions

Problem Statement: Darwin is the largest port on the tropical northern Australian coast. One of Darwin Harbour's three marinas, Frances Bay Marina, is the base of the pearl and northern prawn fishing fleets, which are major export earners driving the Australian economy. On March 27th 1999, divers in Cullen Bay Marina within Darwin harbour discovered dense aggregations (23,650 individuals/m²) of a thin-shelled bivalve "mussel" that had never before been seen in this area.

Methods: The "mussels" were immediately sent to an experienced taxonomist based at the Museum and Art Gallery of the Northern Territory in Darwin and were identified as *Congeria (Mytilopsis) sallei*. It was confirmed that *Mytilopsis sallei*, as it was named in the marine pest literature, previously did not occur in Australia.

Outcomes and Impacts: *M. sallei* is a recognized invasive species that can breed very rapidly and cause massive fouling on wharves and marinas, seawater systems, and pearl and aquaculture facilities. By April 1st, the Northern Territory Government declared a state of Natural Disaster, closed and quarantined all three marinas of Darwin Harbour, and instigated an eradication campaign. The *M. sallei* populations infesting the marinas were effectively killed through chemical treatments, and all vessels that had recently left the marinas (including the complete northern Australian prawn fleet) were checked. As of November 2007 no further live *M. sallei* have been found in Darwin Harbour or anywhere else along the Australian coastline. Efficient monitoring of the sea traffic helped to detect subsequent incursions of these "mussels", e.g. on the hulls of boats caught illegally fishing in Australia waters, eliminating the risk of new invasions of this notorious pest species.

Lessons: Access to confident and experienced taxonomic specialists can be vital to implementing fast, cost-effective invasive species management plans.

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Regions: Tropics

Themes: Invasive alien species



The worm that nearly sank the Californian abalone industry

Problem Statement: Abalones are species of the genus *Haliotis* (Gastropoda: Archaeogastropoda: *Haliotis*) that are eaten in many countries. California is an important producer of abalones. In the 1990s farmed abalone in California were found to be growing more slowly than usual with grossly deformed shells. The deformed abalones could not be sold, and as the infestation spread, California's abalone production, worth millions of dollars, was at risk.

Methods: The deformed abalone were found to be infested with a parasite, identified as a little known polychaete worm (Polychaeta: Sabellidae: *Terebrasabella heterouncinata*). The worm does not seriously harm the abalone, but the tunnels it builds deform the snail's shell and cause it to grow more slowly. Information was urgently needed on whether other local mollusc fauna was at risk, and what countermeasures could be taken. The worm's life cycle and its adaptation to parasitism were analysed and, to find out whether the parasite was a native or an introduced species, over 100 abalone shells in the Los Angeles County Museum for Natural History were examined to see if previous generations of molluscs had been affected.

Outcomes and Impacts: None of the museum specimens showed the characteristic tunnels left by the worm, which meant it was not a native but a newly introduced species. A worldwide search in collaboration with curators of other taxonomic collections revealed that the worm originated from Southern Africa. Unfortunately, no natural enemies of the parasite were found. Furthermore, taxonomic and other biological research revealed that infection occurred through the water; it did not require direct contact between the snails. It was therefore recommended to immediately cull all infected snails and annually clean abalone tanks at risk of infestation. More than 1.5 million infected animals were culled. Effective control of the parasitic worm minimised economic losses to abalone aquaculture in California, an industry worth several million dollars per year.

Lessons: International taxonomic research, including the use of archived materials from reference collections, allowed an effective parasite management strategy to be developed.

References: 1: Polychaete infestation disease in abalone: <http://tinyurl.com/27lxx9>. 2: Fitzhugh K, Rouse GW. 1999. A remarkable new genus and species of fan worm (Polychaeta: Sabellidae: Sabellinae) associated with marine gastropods. *Invertebrate Biology* 118: 357-390.

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Regions: Marine

Themes: Invasive alien species, fisheries



Targeting one larvae in nine saves money and protects health and the environment in Argentina

Problem Statement: In Santa Fe, Argentina, farmers often find soil-dwelling insect larvae while planting their cereal crops in winter and early spring. These larvae, or white grubs (gusanos blancos), are considered harmful to their harvest, and insecticides are often used indiscriminately as a preventive measure against the alleged pest. Yet, pesticide use is expensive, potentially harmful to people and the environment, and may also eradicate beneficial insect species.

Methods: A reference collection of arthropods (mainly insects) was established in 1997 at the Rafaela Experimental Station of the National Institute of Agricultural Technology (INTA) in Argentina. This collection was used as the basis for research into the distribution and life cycles of soil-dwelling insect larvae, and into the effectiveness of different pesticides and natural predators in eradicating crop pests during their larval stages.

Outcomes and Impacts: The larvae in the Santa Fe region were identified as nine different species of Coleoptera: Scarabaeidae. Only the larvae of one of these species, *Diloboderus abderus*, cause serious damage to crops. Research based on the correct insect larvae taxonomy, and using information on species distribution gathered from farmers, showed that only 10% of the cereal fields would need insecticide treatment to prevent crop damage. Also, natural predators of these larvae, parasitic wasps, were found to occur in the region. Research revealed that it was best to rely on these for biological control, rather than use pesticides, which may have adverse effects on their populations. The findings were made available to farmers in the form of accessible and simple species identification guides and educational articles on the INTA website, enabling them to target and reduce their use of pesticides, reducing costs, and lessening environmental contamination.

Lessons: Biological reference collections are needed to support the development of agricultural practices that minimise costs and impacts on the environment and human health. Online dissemination of easy-to-use taxonomic and educational products for farmers puts taxonomic research into practice.

References: 1: Read more (in Spanish): <http://tinyurl.com/29t67z>. 2: Identification key of the Scarabidae of the Santa Fe region: <http://tinyurl.com/296cwa>.

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Regions: South America

Themes: Agriculture, conservation



Spotting the assassin in the garden

Problem Statement: The “assassin bugs” and the “ambush bugs” are members of the Reduviidae, a large family of predatory insects. While some species in the family act as biological control agents by feeding on pest insects and thus are regarded as beneficial, other members of this group are disease vectors and occasionally bite humans. The species *Triatoma infestans*, for example, transmits Chagas’ disease. It occurs in low numbers in Argentina but whenever members of the Argentinian public encounter an insect resembling the Reduviidae they are alarmed, often unnecessarily so. Misidentifications frequently lead to a hysterical response in the media, resulting in a generalized fear of all insects, including those that are beneficial for agriculture, the environment and humans.

Methods: A reference collection of arthropods was established in 1997 at the Rafaela Experimental Station of the National Institute of Agricultural Technology (INTA) in Argentina, as a basis for research on the insects of Argentina. INTA collaborated with the ProHuerta (Pro-Garden) programme to set up a website providing information on organic gardening. The site includes a guide to garden insects helping gardeners to differentiate pests from beneficial insects (predators, parasitoids, pollinators and decomposers), and suggesting ways to promote populations of beneficial insects.

Outcomes and Impacts: Local people now have a better understanding of the biology of garden insects, including the Reduviidae, and have begun to appreciate insect diversity. Using the Rafaela insect collection, taxonomists today carry out hundreds of diagnoses each year, identifying species mistaken for pests or causes of parasitosis. Local organic gardeners are now making greater use of natural pest control methods, instead of chemicals, and insect biodiversity is flourishing.

Lessons: Reference collections are an essential resource for knowing and understanding the diversity of beneficial and detrimental garden insects. They also allow taxonomists to produce accessible and simple identification keys and educational materials to support, for example, gardeners, organic agriculture, and the conservation of insect biodiversity.

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- 2: INTA guide on beneficial and pest garden insects: <http://www.inta.gov.ar/extension/prohuerta/info/carpetas/plagasenfermedades/control%20ecologico%20de%20plagas%20en%20la%20huerta-Cordoba.ppt>.

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Regions: South America

Themes: Agriculture, conservation



Guarding against deadly, eight-legged "black widow" immigrants

Problem Statement: In September 1995, a previously unrecorded spider was found in Osaka, Japan. The spider closely resembled the Red Back spider from Australia, one of the notorious and highly poisonous “black widow” species. However, Osaka lies several thousand kilometres away from Australia across the Pacific Ocean and has a much colder climate. Were these really Red Back spiders, surviving a long way north of their usual haunts?

Methods: Taxonomic information on spiders is freely available via the World Spider Catalogue. Informal networks of spider specialists such as the International Society of Arachnology, ISA also exist and all known species of spiders have been catalogued since the 1950s. In Australia, particular efforts were made to make taxonomic information on spiders readily accessible and a CD-ROM on ‘Spiders of Australia’ was published in 2002. With the help of these resources, spider specialists and identification keys, it was possible to verify that the new spider in Japan was the Australian Red Back or Black Widow.

Outcomes and Impacts: The arrival and persistence of the tropical Australian Red Back spider in Japan is highly significant for other countries with temperate climates, indicating that they are not safe from the introduction of tropical, poisonous spiders and adequate preventive measures need to be taken. As climate change pushes temperate climatic zones further towards the poles, such threats will continue to grow. The Australian Red Back is much more resistant to cold than previously believed. In Japan, they survive temperatures below freezing for periods of several days without ill effects and even reach higher population densities than in Australia.

Lessons: Sound taxonomic knowledge combined with freely accessible taxonomic information on spiders and a worldwide network of experts proved essential for swiftly identifying the poisonous spider and developing focused and efficient measures for pest management and public education.

References: Adapted with permission from a case study published by the German Global Taxonomy Initiative programme: <http://www.gti-kontaktstelle.de/cases.html>.

1: International Society of Arachnology, ISA: <http://www.arachnology.org/>

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Regions: Global

Themes: Invasive alien species, health



Taxonomy helps protect CITES-relevant Southeast Asian giant monitor lizards

Problem statement: Southeast Asian water monitor lizards (Varanidae) of the *Varanus salvator* complex are among the largest living lizards of the world. They are top predators in most environments they inhabit in insular Southeast Asia where large carnivorous mammals are missing. At the same time, water monitors are highly exploited for the international reptile leather trade. From Indonesia alone nearly 500,000 specimens are legally exported every year to Europe and the USA and the unreported figure may be much higher. This unsustainable harvest of water monitor lizard populations can lead to the extinction of locally restricted (endemic) species when the taxonomic distinctness of island populations is not recognized.

Methods: Traditionally, Southeast Asian water monitors were regarded as one widespread species with several subspecies. In order to demonstrate the taxonomic distinctness of various island populations, morphological features, such as specific scale counts, morphometric measures and colour pattern features, of numerous preserved voucher specimens from major European natural history collections were investigated. Advanced statistics were applied to the morphological data to separate and delimit distinct monitor species.

Outcomes and impact: The taxonomic investigations revealed that the widespread Southeast Asian water monitors represent a complex of at least seven distinct species. Several of the assumed subspecies are now considered species, and two hitherto unrecognized monitor lizard species were described as new to science. Each species inhabits a much smaller distribution range than *Varanus salvator*. Some are even restricted to single islands, such as the newly discovered *Varanus palawanensis* that is only found on Palawan and its smaller off-shore islets within the Philippine Archipelago.

Lessons: The discovery of new monitor lizard species such as the large-growing *V. palawanensis* clearly demonstrates the need for taxonomic expertise as currently not even the more conspicuous vertebrates on our planet are all known to us. The ability to distinguish CITES-relevant giant monitor lizard species can help to prevent their over-exploitation. Only recognition and protection of distinct species can ensure their persistence.

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Regions: Global, Southeast Asia

Themes: Conservation, trade



What's biting you? The importance of venomous snake systematics in developing antivenoms

Problem Statement: The composition of snake venom varies between different species of venomous snake. Correct species identification is therefore critical to the treatment of snake bites, and the development of effective antivenoms, but is problematic for snakes that form complex groups of rather ill-defined or similar species such as Asiatic cobras (*Naja naja* species complex) and Saw-scaled or carpet vipers (*Echis carinatus* complex).

Methods: Toxinological papers on venoms or bites by Asiatic cobras and Saw-scaled vipers were surveyed. Toxinology is a discipline within the field of toxicology that deals specifically with animal, plant and microbial toxins. Of over 100 papers on Asiatic cobras and Saw scaled vipers that were surveyed; only seven cited any taxonomic works. Based on the information provided in the publications on Asiatic cobras, in only one fifth of these papers could the snake involved be confidently identified. In more than half of the papers on carpet vipers the identifications remain open to doubt

Outcomes and Impacts: Communication between the various groups has been improving, and joint conferences have lead to fruitful collaborations between toxinologists, clinicians and snake systematists. Information on venomous snake systematics is now available online:

<http://biology.bangor.ac.uk/~bss166/update.htm>

Lessons: Improved collaboration between herpetological systematists and biomedical researchers is needed at the research stage to ensure accurate identification of venomous snake species. Improved communication and simple snake identification tools are needed for the public and health practitioners at the point of use of antivenoms.

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Regions: Africa, Asia.

Theme: Health.



Failure to distinguish between two “similar” medicinal plant species costs life in Kenya.

Problem statement: In Kenya, like in many other countries in the world, traditional medicines are an important source of health care. Unfortunately, with the introduction of conventional systems of education, the traditional education systems have been put aside, and there is little training of the young by the experienced, aging practitioners. *Strychnos henningsii* Gilg and *Acokanthera oppositifolia* (Lam.) Codd are two very similar looking medicinal plant species that are both used in traditional medicine. The latter, however, is poisonous and used to prepare arrow poison. In an incidence in 1995, a herbalist mistakenly gave a concoction of it to a patient, who died immediately.

Methods: The case was reported to the police who brought the pieces of stem that had been used by the herbalist to the East African herbarium for taxonomic identification. Additional samples were sent to the government chemist for analysis of the toxicity.

Outcomes and Impacts: The specimens were identified as those of the poisonous *A. oppositifolia*. In the report to the police it was stated that while the tree was very similar to *S. henningsii*, a commonly used medicinal plant in Kenya, the presence of milky latex in the *Acokanthera* would clearly distinguish it from the *Strychnos*. This was used as evidence against the herbalist, who at the time had been arrested awaiting charges on homicide.

Lessons: The safety of herbal medicines is a major concern to both national health authorities and the general public. As the use of herbal medicines continues to expand rapidly across the world, standards and control methods need to be developed, drawing also from taxonomic expertise, to ensure the quality of medicinal plant products.

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Regions: Africa

Themes: Health