Area-wide biological control of disease vectors and agents affecting wildlife

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Summary

Two examples of area-wide programmes, employing the sterile insect technique (SIT), which have eradicated a parasite and a disease vector common to domestic and wild animals are described. New World screwworm (NWS), *Cochliomyia hominivorax*, caused significant morbidity and mortality of livestock and wild mammals in tropical and subtropical areas of America before eradication was achieved in North America using the SIT and other components of an integrated pest management (IPM) programme. Movement of wild as well as domestic animals from an area which is infested with screwworm to a free area requires prophylactic treatment.

Tsetse fly-borne trypanosomosis has an immense influence on the distribution of people and livestock in Africa. The immunotolerance of wildlife to the parasites is an important factor in maintaining some areas livestock free as wildlife refuges. Slaughter has ceased of wild hoofstock species considered to be disease reservoirs for control purposes. The SIT, combined with other IPM measures, has resulted in the eradication of the tsetse fly and trypanosomosis from Zanzibar. Other programmes in Africa are underway.

Microbial 'biopesticides' have also been employed successfully against plant insect pests and some vectors of human disease. It seems likely that for the immediate future, wildlife may benefit from area-wide biological control programmes, intended mainly to protect humans and/or domestic animals.

Keywords

Biological control – Biopesticides – Eradication – Integrated pest management – Myiasis – New World Screwworm – Sterile insect technique – Trypanosomosis – Tsetse flies – Vectors – Wildlife.

Introduction

Elimination of a disease or a disease vector from an entire geographic area has evident value in protecting the wildlife in that area which are susceptible to the disease. Although wildlife are frequently (and sometimes correctly) blamed for being reservoirs of certain livestock or human diseases, examples of cases in which the elimination of a disease in livestock through conventional methods has resulted in health benefits for wild fauna are given elsewhere in this issue.

To date, there are two examples of area-wide programmes which are very broadly termed 'biological control programmes'. These programmes simultaneously subject a parasite or disease vector common to wild and domestic animals alike, to elimination procedures. The technique used, more precisely defined as autocidal control, or the sterile insect technique (SIT), has been employed to eradicate the New World screwworm (NWS) (*Cochliomyia hominivorax*), from North and then Central America to Panama (20). In addition, the tsetse fly (*Glossina* spp.), the biological vector of the very important disease which occurs in Africa, trypanosomosis, was eradicated from Zanzibar island, situated off the east coast of Africa using this technique (1).

New World screwworm was such a constraint to livestock farming in the southern sector of the United States of America (USA) that the disease stimulated creation of the prototype during the 1950s and to date, remains the best example of the most successful application of SIT for animal disease eradication. The technique has subsequently also been used with success for the eradication of certain plant pests, most notably the economically significant Mediterranean fruit fly (*Ceratitis capitata)*, from several areas.

Screwworm eradication

As far as is known, all warm-blooded creatures can be infested with the screwworm, either NWS or its remarkably homologous counterpart in the Eastern Hemisphere, the Old World screwworm (OWS) (*Chrysomya bezziana*). Even minor natural or trauma-induced entry sites, such as the umbilicus of new-born animals, tick bites, lacerations or scratches, etc., offer the living flesh required for nutrition of larvae that hatch after the laying of up to several hundred eggs at the wound periphery by each adult female fly. Enlarged wounds then attract further infestation to gruesome effect, causing significant morbidity and mortality if not treated with larvacide during the seven-day maturation period of larvae before they fall to the ground to pupate.

In those areas in tropical and subtropical America in which NWS has not been eradicated, the disease seasonally invades adjacent areas with great detrimental effect to the wide range of susceptible animals. Old World screwworm has a similar latitudinal distribution and effect in the Eastern Hemisphere. Human cases caused by both parasites, including mortalities, have been described (21, 23).

In North and Central America, estimates of losses to the livestock industry were significant, and programme costs were high (contribution by the USA alone over a period of 40 years amounted to approximately US$750 million) but various cost/benefit ratios calculated for eradication have all been favourable. The development and application of the SIT, as well as programme histories, have been well documented (3, 13). Although to date NWS has been eradicated only with the application of the SIT, other programme elements are also essential to free a significant area from screwworm infestation and then to maintain that free status. Although the term was not used during early phases of the programme, the various simultaneous measures required for success can be summarised as what is now known as integrated pest management (IPM).

Infestation of a very wide variety of wild mammalian species with both NWS and OWS has been documented (11, 23). When NWS was transported to Libya in the 1980s, cases in zoo animals were among the first observed (5). Compared with parts of Asia and Africa, tropical Latin America has a paucity of large herd animals in open savannahs where these animals and perhaps their pathology can be readily observed. Although many different species of wildlife have been infested with NWS, most observations reflecting the important influence of the parasite on wildlife populations have been on white-tailed deer (*Odocoileus virginianus*) in the southern USA before eradication was achieved in that area. Significant mortality (up to 80%) of fawns with umbilical infestation has been recorded, as have additional losses caused by other predisposing conditions, such as tick bites, scratches and lacerations, and antlers in velvet. Although improved management has resulted in an increase in the deer population throughout the USA, screwworm eradication was credited as being an important contributor to the dramatic surge in deer numbers in previously enzootic areas (16). Similarly, the absence of NWS has been blamed for contributing to the explosive growth in the feral swine populations in these areas (6).

The expanding game ranching industry, in which prophylactic wound treatment of free ranging or semi-captive wild animals is impractical, was greatly enhanced by eradication in previously enzootic NWS areas. Similarly, the efforts of both the extensive range ruminant producer and the small part-time livestock owner benefited dramatically (19).

An emergency eradication programme under the auspices of the United Nations was mounted when NWS occurred in Libya (the first incursion outside the Americas) (3). The international feeling was that if the parasite spread, it could, according to the Director General of the Food and Agriculture Organization (FAO), 'have disastrous consequences on livestock, wildlife, and even perhaps to human populations of Africa, the Near East and southern Europe' (19). A genuine fear was that the newly introduced NWS could result in the extinction of the many otherwise severely endangered species in the region (25). The World Conservation Union (IUCN) was one of the many agencies that supported the programme, which fortunately succeeded in eradicating NWS before it could spread from Libya.

Surveillance for eradication purposes, which with domestic animals is normally combined with prophylactic treatment of all animal wounds within and of all animals leaving an infested area, is evidently not practical in free-ranging wild fauna. Screwworm larvae require living flesh for nutrition, and only those found in a carcass of an animal that has died very recently would be appropriate for sampling. Larvae found in living livestock in an eradication programme are identified to differentiate screwworms from secondary blowfly maggots. This is the most important means of defining the geographic limits and intensity of infestation. Although throughout the long eradication programme in North America, traps were primarily used to monitor SIT efficacy, in Libya results of trapping adult gravid (non sterile) female flies correlated well with those measuring distribution by identifying NWS larvae in wounds. As trapping adult flies is very laborious and expensive, it is not normally considered a practical surveillance tool (20).

Animal movement control and quarantine is another essential element for an eradication programme. Free-ranging wild animals may move considerable distances as do flies searching for their appropriate environment (vegetation, animal wounds for gravid females to lay eggs, etc.), factors which evidently contribute to the need for sterile fly dispersion over relatively large areas. Although natural and uncontrollable movements of both wild host and fly have been important considerations for many years, neither has impeded full-scale eradication programmes.

The mechanical transport of the week-long larval stage of screwworms in domestic animal wounds, however, has by far been the main cause of the long distance spread of infestation to new areas or back to areas from which the parasite had already been eradicated. The transport of captive wild animals from infested to screwworm-free areas requires the same straightforward and logical measures (examination, prophylactic treatment of wounds at origin and destination, larvacide dip or spray, etc.) as does that of domestic animals. Used bedding for animals, which is possibly contaminated with viable pupae, should be destroyed at destination (17).

Due to the living flesh requirements of the parasites, restrictions on the transport of meat has not been considered necessary. The high body temperature of birds is thought to impede larval maturation and neither treatment nor movement controls are performed for birds. Unlike some other multi-host ectoparasites of animals, bird migrations are probably epidemiologically insignificant in the spread of NWS.

With SIT application, entire zones are aerially saturated twice weekly with radioactively sterilised flies at high concentrations, benefiting not only livestock and man, but also free-ranging wild animals. Although NWS and OWS evidently occur independently of the presence of domestic animals, no remaining pockets of infestation in wild fauna have been observed in areas in which eradication of NWS has been executed. The SIT against OWS has only been applied experimentally.

Tsetse fly control and eradication

Trypanosomosis maintains large areas of Africa (so-called 'fly belts') free of livestock, and it is presumed that wildlife have developed an evolutionary tolerance to these parasites with which they have cohabited for millennia. Conversely, domestic animal breeds previously unexposed to trypanosomes appear to be more severely affected than those animals which have been in enzootic areas for a long time.

Tsetse fly-borne trypanosomosis exists in almost two-thirds of sub-Saharan Africa. The disease problem is large and the subject complex. No attempt will be made in this brief review to summarise the extensive historical and technical aspects of this disease and its immense socioeconomic impact on the continent. Some trypanosomes directly affect human beings and some severely affect domestic animals, on which many inhabitants in Africa rely for survival. Both effects contribute significantly to the distribution of people on the continent (8).

The wildlife connection with human and livestock trypanosomosis was noted early, as the viral disease rinderpest spread from Asia to eastern and southern Africa during the 1890s, decimating millions of wild ruminants and thus depriving the tsetse fly of its primary hosts. Tsetse flies and trypanosomosis apparently disappeared from many areas until rinderpest subsided and the game animal populations recovered (22).

An important complication for diagnosis in the field and control of arthropod-borne diseases in Africa is that mixed infections frequently occur. More than one trypanosome species may be involved, and also other hemoprotozoans borne by different vectors frequently make definitive diagnoses of certain clinical diseases difficult (12). Traditional diagnostic techniques for direct detection of trypanosomes in blood and lymph nodes have recently been supplemented by indirect fluorescent antibody tests, enzyme-linked immunosorbent assay (ELISA) and molecular techniques (18).

Area-wide elimination of the tsetse vector has occurred in the past with ambitious programmes, most notably in northern Nigeria and southern Africa. Methods of vector and disease control in Africa have included, among other measures, significant manipulation of habitat (bush clearing and game-proof fences), trapping of tsetse flies, depopulation of key wildlife predilection hosts, local targeted and area-wide use of insecticides, chemoprophylaxis, breeding of trypanotolerant animals and experimental immunisation. More recently, after noting the success recorded using the SIT to eradicate NWS in North America, and decades of research on the subject, this technique is now also being applied to the tsetse fly.

Wildlife destruction was carried out primarily in southern Africa on the premise that certain hoof stock (primarily buffalo [*Syncerus caffer*], bushbuck [*Tragelaphus scriptus*], nyala [*Tragelaphus angasii*], kudu [*Tragelaphus strepsiceros*], as well as other antelope and warthogs [*Phacochoerus aethiopicus*]), were the primary reservoirs of trypanosomes, and that their elimination near livestock (hence human) populations would control the disease. Whether or not this action was one of the most important of several measures taken at the time became irrelevant when it was determined that the elimination of indigenous game from an area was environmentally unacceptable.

Trypanotolerance has replaced trypanoresistance as a term describing animal susceptibility to trypanosomosis. Genetic studies corroborated longstanding field observations that certain livestock breeds survived better in tsetse infected areas than others, and that cross-breeding with more susceptible breeds led to intermediate tolerance. Wildlife are trypanotolerant to at least those trypanosomes present in their native geographic range to which they are continuously exposed.

When it was decided to investigate the application of the SIT to control tsetse flies, it became apparent immediately that there were great biological and technical differences relevant to the use of this technique for eradication of NWS and tsetse flies. These differences include the following:

– tsetse flies are vectors of disease while NWS is itself an aetiological agent

– only one species of NWS exists in the entire Western Hemisphere, whereas over twenty species of tsetse fly are found in Africa (many of these species have their own habitat preferences)

– each gravid NWS fly lays hundreds of eggs which can be raised hydroponically by the hundreds of millions, followed by sterilisation of pupae and mass dispersion of the fly, while the female tsetse fly lays only one living larva every week or two in nature.

Commencing in 1994, the results of decades of research were brought into focus in a trial programme using the SIT to eradicate tsetse flies and trypanosomosis from the island of Zanzibar off the coast of Tanzania. In preparation, widespread application of insecticide, as well as fly trapping, were used to suppress the tsetse population to the point where SIT was considered feasible. A sterile fly plant producing 70,000 pupae weekly was developed, and a total of eight million sterile male flies were dispersed over time to overwhelm the residual wild tsetse population. The last wild fly was detected on the island in September 1996 and the last case of trypanosomosis diagnosed a year later. Intensive follow-up not only demonstrated the absence of tsetse flies, but also that no other haematophagous arthropods present transmitted trypanosomes, as is seen with *Trypanosoma vivax* in the tsetse fly-free tropics of the Americas (9).

Efforts by the FAO International Atomic Energy Agency Division to scale sterile tsetse fly production systems to semi-industrial levels are beginning in several countries of Africa. Among these is Ethiopia where eradication activities including the SIT will begin in the southern Rift Valley area in which *Glossina pallipides* inhibits agricultural development (1). It should be emphasised that when targeting tsetse fly and several plant pests for control/eradication, SIT is very important but is still only one of several elements in a multi-faceted offensive required for success in IPM programmes.

Although the results of the Zanzibar trial point towards its technical feasibility, it is an open question whether, considering the many severe problems encountered on the continent, an attempt will be made to eradicate the tsetse fly and trypanosomosis from Africa. Certainly, any such programme would require not only considerable research but also unprecedented international sustained participation and a continent-wide geographic strategy. An economist consultant reporting to the Fifth Meeting of the Programme against African Trypanosomiasis in 1999, estimated that US$20 billion would be required, but that the accruing benefits over the twenty years during which this goal might possibly be accomplished, would be US$50 billion, after which the benefit/cost ratio would of course be increased further. He estimated that widespread but smaller farmer-based efforts would be less effective, even more expensive, less cost-beneficial and then, because eradication would not be achieved, such a programme would continue in perpetuity (4).

That the benefits of SIT to control or eradicate harmful insects have been increasingly recognised is evidenced by the approximately 30 facilities with control scale sterile fly production now in use throughout the world. Successful SIT trials for animal pests have included those for ox warbles (*Hypoderma* spp.) in Canada, the USA and Great Britain (7, 10) and for stable flies (*Stomoxys* spp.) on a Caribbean isle (7).

Biological control

There is a strong environmental incentive to reduce or replace massive pesticide application for area-wide IPM control/eradication programmes by using other measures offering benefits comparable to the SIT, such as species-specific targeting, and no or low residual effects. The value of 'biological insecticides' or 'biopesticides', has been amply demonstrated for several plant pests and, on a more limited scale, some vectors of human disease.

Selected species and strains of *Bacillus* spp. bacteria have dominated this form of biological control of insects. Specific biotoxin-producing strains of *Bacillus thuringiensis* var. *israelensis* or *B. sphaericus* have been used throughout the world to suppress or eliminate the larval stages of mosquitoes, particularly where malaria, filariasis (14) or certain arboviruses are present (15). *Bacillus thuringiensis* var. *israelensis* is also effective against the larval stages of *Simulium* spp., vectors of river blindness in man (onchocerciasis) in tropical Africa, and the cause of severe 'fly worry' in domestic livestock in several regions of the world.

Depending on the specific control programme, chemical larvacides may precede or alternate with the use of *Bacillus*. Host treatment for onchocerciasis or filariasis may also be performed. Studies conducted to date have shown no significant effect of these bacteria and their toxins on vertebrates and only minimal effects on some non-target arthropods and crustaceans. Development of resistance is apparently less of a problem than with chemical pesticides (15). These and other potential problems are continuously being monitored and investigated (24).

Other potential tools which could be used in the future for area-wide biological control programmes against insect vectors/pests of veterinary importance include species-specific sex pheromones, which are presently used as attractants to insecticides for trapping and monitoring and for mating disruption (2). In addition, several parasites and pathogens of vector/pest species are under continuous investigation and are providing promising results.

Hopefully, the not too distant future will witness the development of further biological control techniques of sufficient scope to free entire regions of pathogenic agents or vectors which cause or transmit significant diseases not only of domestic livestock and humans, but also of free-living wildlife, similar to the NWS eradication programme.

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Lutte biologique à l'échelle d'une région contre les vecteurs et les agents pathogènes affectant la faune sauvage

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Résumé

L'auteur décrit deux programmes ayant chacun permis d'éradiquer un parasite et un vecteur affectant les animaux domestiques et sauvages. Ces programmes ont été appliqués à l'échelle d'une région et utilisaient la technique des lâchers de mâles stériles. Les larves de Calliphoridés (*Cochliomyia hominivorax*) ont été à l'origine d'une morbidité et mortalité élevées chez les animaux d'élevage et les mammifères sauvages des régions tropicales et sous-tropicales de l'Amérique, puis la mouche a été éradiquée de l'Amérique du Nord grâce aux lâchers de mâles stériles et d'autres méthodes faisant partie d'un programme de gestion intégrée des nuisibles. Les animaux sauvages et domestiques déplacés d'une zone infestée par *C. hominivorax* vers une zone indemne doivent être soumis à un traitement prophylactique.

La trypanosomose transmise par la mouche tsé-tsé a une incidence considérable sur la répartition des populations humaines et animales en Afrique. L'immunotolérance des animaux sauvages au parasite favorise le maintien de certaines zones, non consacrées à l'élevage, en réserves pour la faune sauvage. L'abattage sanitaire des ongulés, considérés comme des réservoirs de la maladie, a été abandonné. En revanche, les lâchers de mâles stériles de la mouche tsé-tsé, associés avec d'autres méthodes de gestion intégrée des nuisibles, ont permis d'éradiquer la trypanosomose et la mouche tsé-tsé de Zanzibar. D'autres programmes sont en cours en Afrique.

Des « pesticides biologiques » ont également donné de bons résultats contre les insectes nuisibles et certains vecteurs de maladies humaines. Il est probable que dans un futur proche, les programmes régionaux de lutte biologique, essentiellement destinés à protéger l'homme et/ou les animaux domestiques, auront aussi un impact bénéfique sur la faune sauvage.

Mots-clés

Cochliomyia hominivorax – Éradication – Faune sauvage – Gestion intégrée des nuisibles – Lâchers de mâles stériles – Lutte biologique – Mouche tsé-tsé – Myiase – Pesticides biologiques – Trypanosomose – Vecteurs.

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Lucha biológica en zonas extensas contra agentes patógenos y vectores que afectan a la fauna salvaje

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Resumen

El autor describe a modo de ejemplo dos programas de aplicación en zonas extensas de la técnica de moscas estériles, que redundaron en ambos casos en la erradicación de un parásito y un vector que afectaban a los animales tanto salvajes como domésticos. El primero de ellos se refiere a Norteamérica, donde el uso combinado de moscas estériles y otros elementos de un programa de gestión integrada de plagas llevó a la erradicación del gusano barrenador del Nuevo Mundo (*Cochliomyia hominivorax*). Antes de ese programa, el parásito provocaba tasas significativas de morbilidad y mortalidad entre los bovinos domésticos y mamíferos salvajes de las zonas tropicales y subtropicales del continente americano. El desplazamiento de animales salvajes o domésticos de un área infestada a una zona libre del parásito requiere tratamiento profiláctico.

El segundo ejemplo tiene la isla africana de Zanzíbar por escenario. En África, la tripanosomosis transmitida por la mosca tsetsé influye sobremanera en la distribución de la gente y el ganado. La inmunotolerancia de los animales salvajes es un factor importante, pues algunas zonas libres de ganado se mantienen como reservas de fauna salvaje. Se interrumpió el sacrificio de ungulados salvajes considerados reservorios de la enfermedad que venía practicándose como medida de control. Después, combinando la técnica de moscas estériles con otras medidas de gestión integrada de plagas, se consiguió erradicar la mosca tsetsé y la tripanosomosis de Zanzíbar. Otros programas están en marcha en el resto de África.

También se han utilizado con éxito "plaguicidas biológicos" para luchar contra plagas de insectos fitófagos y contra vectores de enfermedades humanas. Parece probable que en un futuro inmediato la fauna salvaje pueda beneficiarse indirectamente de los programas regionales de lucha biológica destinados a proteger al ser humano y/o los animales domésticos.

Palabras clave

Erradicación – Fauna salvaje – Gestión integrada de plagas – Gusano barrenador – Lucha biológica – Miasis – Mosca tsetsé – Plaguicidas biológicos – Técnica de moscas estériles – Tripanosomosis – Vectores.

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References

1. Anon. (2000). – Insect pests – a SITting target? New Agriculturist on-line (www.new-agri.co.uk/99-1/focuson/focuson1.html, accessed on 22 December 2001).
2. Flint H.M. & Doane C.C. (1996). – Understanding semiochemicals with emphasis on insect sex pheromones in integrated pest management programs. University of Minnesota, National Integrated Pest Management Network, Rochester (http://www. ipmworld.umn.edu/chapters/flint.htm, document accessed on 22 December 2001).
3. Food and Agriculture Organization (FAO) (1992). – The New World screwworm eradication program: North Africa 1988-1992. FAO, Rome, 192 pp.
4. Food and Agriculture Organization (FAO) (2000). – Programme against African Trypanosomiasis. *In* 5th Programme Committee Meeting, 22-23 November 1999. FAO, Rome, 24 pp. (www.fao.org/PAAT/PCR5report.doc, document accessed on 22 December 2001).

5. Gabaj M.M., Wyatt N.P, Pont A.C., Beesley W.N., Awan M., Gusbi A.M. & Benhat K.M. (1989). – The SW fly in Libya: a threat to the livestock industry of the Old World. *Vet. Rec.*, **125**, 347-349.

6. Hodge L.D. (2001). – Unwelcome guests 2001, Texas. *Parks Wildl.*, **59** (2), 47-50.

7. Hogsette J.A. & Geden C.J. (eds) (2001). – Research and extension needs for integrated pest management for arthropods of veterinary importance. *In* Proc. Workshop, 12-14 April 1994, Lincoln, Nebraska. Center for Medical, Agricultural and Veterinary Entomology, Gainesville, Florida (http://www.ars-grin.gov/ars/SoAtlantic/Gainesville/cm_fly/Lincoln.html, document accessed on 22 December 2001).

8. Hursey B.S. & Slingenbergh J. (1995). – The tsetse fly and its effects on agriculture in sub-Saharan Africa. *World Anim. Rev.*, **84/85**, 3-4.

9. International Atomic Energy Agency (IAEA)/Food and Agriculture Organization (FAO) (1999). – Insect and pest control. **53**, July.

10. Kunz S.E., Scholl P.J., Colwell D.D. & Weintraub J. (1990). – Use of sterile insect releases in an IPM program for control of *Hypoderma lineatum* and *H. bovis* (Diptera: Oestridae): a pilot test. *J. med. Entomol.*, **27** (4), 523-529.

11. Lindquist A.W. (1937). – Myiasis in wild animals in southwestern Texas. *J. econ. Entomol.*, **30**, 735-740.

12. Mare C.J. (1998). – African animal trypanosomiasis (Nagana, tsetse disease, tsetse fly disease). *In* Foreign animal diseases. United States Animal Health Association (USAHA), Richmond, Virginia, 29-40.

13. Meyer N.L. (1994). – History of the Mexico-United States Screwworm Eradication Program, 1994. Vantage Press, 367 pp.

14. National Research Institute (1996). – Bacteria: a tool in the integrated control of mosquito vectors of diseases. IPM: working for development. *Bull. Pest Manag.*, **7** (http://www.nri.org/IPMForum/ipmwd/issue7/7mossies.htm, accessed on 22 December 2001).

15. New York City Department of Health (NYCDOH) (2000). – Environmental assessment statement: routine comprehensive arthropod-borne disease surveillance and control program. NYCDOH, Bureau of Environmental and Occupational Disease Epidemiology, CEQR No. 00DOH001Y, Attachment A (http://nyc.gov/html/doh/html/epi/wnvnd1.html, document accessed on 15 January 2002).

16. Novy J.E. (1991). – Screwworm control and eradication in the southern United States of America. *World Anim. Rev.*, **10**, 18-27.

17. Office International des Epizooties (OIE) (2001). – International animal health code: mammals, birds and bees, 10th Ed. OIE, Paris, 485 pp.

18. Office International des Epizooties (OIE) (2001). – Manual of Standards for diagnostic tests and vaccines, 4th Ed., 2000. OIE, Paris, 957 pp.

19. Reichard R.E. (1991). – New World screwworm and its appearance in the eastern hemisphere. *World Anim. Rev.*, **1**, 40-47.

20. Reichard R.E. (1999). – Case studies of emergency management of screwworm. *In* Management of animal health emergencies (G. Murray & P.M. Thornber, eds). *Rev. sci .tech. Off. int. Epiz.*, **18** (1), 145-163.

21. Reichard R.E., Vargas Teran M. & Abu Sowa M. (1992). – Myiasis: the battle continues against screwworm infestation. *World Hlth Forum*, **13** (2-3), 130-138.

22. Rossiter P.B. (1994). – Rinderpest. *In* Infectious diseases of livestock, with special reference to Southern Africa (J.A.W. Coetzer, G.R. Thomson & R.C. Tustin, eds). Oxford University Press, Cape Town, Oxford and New York, 735-757.

23. Spradbery J.P (1994). – Screwworm fly: a tale of two species. *Agric. Zool. Rev.*, **6**, 1-62.

24. Stotzky G. (2001). – Toxins of *Bacillus thuringiensis* in transgenic organisms: persistence and ecological effects. National Center for Environmental Research, Office of Research and Development, United States Environmental Protection Agency (EPA), Science to achieve Results (STAR) Program. EPA, Washington, DC, EPA Grant Number R826107 (http://es.epa.gov/ncerqa_abstracts/grants/97/envbio/stotzky.html, document accessed on 22 December 2001).

25. Woodford M.H. (1992). – The potential impact of the New World screwworm, *Cochliomyia hominivorax* (Coquerel) on wildlife in Africa, the Mediterranean Basin, the Near East and Asia. FAO/Screwworm Emergency Center for North Africa (SECNA) report, SECNA/INT/001/MUL. FAO/SECNA, Rome, 27 pp.