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Economic Impacts of Invasive Alien Species: A Global Problem with Local Consequences

Invasive alien species are increasingly seen as a threat not only to biodiversity and ecosystem services, but also to economic development and human well-being. They reduce yields of agricultural crops, forests and fisheries, decrease water availability, cause costly land degradation, block transport routes and contribute to the spread of disease. They also reduce the effectiveness of development investments by choking irrigation canals, fouling industrial pipelines and impeding hydroelectric facilities. Invasive species therefore contribute to social instability and economic hardship, placing constraints on sustainable development, economic growth, poverty alleviation and food security. Moreover, the spread of invasive species has increased with global trade and development and is likely to be further exacerbated by continuing global change, especially climate change.

To date the majority of figures assessing the economic impacts of invasive species have come from a handful of countries with a predominant focus on agricultural pests.[1] A few aggregate estimates of the full range of environmental, social and economic costs have been posited, but their magnitude signifies the severity of the problem without providing further guidance for policy making.[2] Recently, through the efforts of the World Bank, the Global Invasive Species Programme (GISP) and other partners, economic analysis have focused on the impacts and socioeconomic implications of invasive species for developing countries with particular attention to Africa. For example, the introduction of Nile tilapia for aquaculture has decimated native fisheries; triffid weed causes severe impacts on natural areas as well as cattle ranching; and water hyacinth has negatively affected local fisheries, transport and hydropower.

Despite the growing evidence of the economic impacts of invasive species, the level of awareness amongst decision-makers is still relatively low. It is therefore critical that such assessments be expanded and methodological tools disseminated in order to provide the basic data and information necessary for informed decision-making regarding the prevention, eradication and control of invasive species. The following case studies are a step in this direction:

- Nile tilapia (*Oreochromis niloticus*) – East Africa
- Giant sensitive plant (*Mimosa pigra*) – Zambia
- Triffid weed (*Chromolaena odorata*) – Ghana, South Africa
- Water hyacinth (*Eichhornia crassipes*) – Central African Republic, South Africa
- Larger grain borer (*Prostephanus truncatus*) – Togo, East Africa
- Parthenium weed (*Parthenium hysterophorus*) – South Africa
- Weeping grass (*Eragrostis plana*) – Brazil
- Cactus moth (*Cactoblastis cactorum*) – Mexico

For more information on these efforts, please visit: http://www.gisp.org/publications/economic/

[1] Researchers have estimated the following annual environmental costs of introduced pests: Australia – US $6.8 billion; Brazil – US$ 6.7 billion; India – US$ 25.0 billion; South Africa – US$ 3.0 billion; United Kingdom – US$ 6.6 billion; and the United States – US$ 58.0 billion. Pimentel, D. et al. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. Agriculture, Ecosystems and Environment. 84.

[2] For example, see Pimentel's estimate of US$157 billion in annual impacts in the U.S., and worldwide impacts up to US$1.4 trillion annually – almost 5% of global GDP. See Pimentel 2001; and Pimentel, D. et al. 2004. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics.

NILE TILAPIA (*Oreochromis niloticus*) IN AFRICAN LAKES

NATIVE RANGE OF THE SPECIES

Nile tilapia *Oreochromis niloticus* (L.) naturally occurs in the lower (northern) River Nile system and many rivers of West Africa. It is widely harvested, cultivated and invasive in many continents.

HISTORY OF INTRODUCTION

O. niloticus was stocked on several occasions into several African lakes (Victoria, Chicamba, Kariba) and river systems (Limpopo, Zambezi) for fisheries enhancement, aquaculture and for recreational anglers. It became the most successful of the introduced species as a result of its faster growth rates, wider food spectrum, greater fecundity, wider habitat tolerance and its ability to reach a larger size.

IMPACTS

ENVIRONMENTAL: Inevitably, fish escape into the wild wherever they are introduced, often with severe consequences for native fish fauna. This is particularly the case in Africa, where similar endemic species of *Oreochromis* exist in the majority of river systems and have been greatly depleted, sometimes to extinction, due to invasion by Nile tilapia. An apparently inevitable result of Nile tilapia introduction to a river system or lake in Africa is the complete elimination of indigenous species in the same genus *Oreochromis (*or, sometimes, hybridization with native spcies). In Kenya, almost all native species in the genus were replaced within 30 years of its introduction. Outside Africa, tilapias have had major impacts on ecosystems in Australia, in the Americas, and in Asia. *O. niloticus* is an omnivore which is capable of preying on and competing with other freshwater fish, destroying their habitats (especially nests) and consuming native aquatic vegetation thereby changing the shallow-water ecosystem in their new habitats. In Lake Victoria it has been suggested that *O. niloticus* is responsible for the disappearance or demise of several endemic Cichlidae.

ECONOMIC IMPACTS

Nile tilapia has greatly impacted native fisheries in African countries based on native species in the same genus, as most of the species have been extinguished. Although an increase in earnings between 2 and 12% per fisherman per year (US$ 0.67 to US$ 2.14) was verified from the introduction of *O. niloticus* in Kenya, given the decimation of native fisheries, it cannot be said that the replacement of native species by Nile tilapia has brought any economic advantage. If the costs of prevention measures and control procedures were considered, the introduction of Nile tilapia would imply negative economic results, by far yielding less resources than the continuity of fisheries using native species.

Native fisheries were formerly established in these areas with great potential for sustainable management, with no need for the introduction of non-native species. The cultural impacts of replacing native fishes with invasive species are difficult irreversible, especially as most of the native species have gone extinct.

Sources:
GISP, 2007. The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent. Report prepared by CSIR, South Africa.

The Global Invasive Species Programme

THE GIANT SENSITIVE PLANT (*Mimosa pigra*) IN AFRICA

NATIVE RANGE OF THE SPECIES

Mimosa pigra (Fabaceae; Mimusoideae), thought to be native to tropical Central and northern South America (from Mexico to Brazil), is a large, spiny, invasive shrub of floodplains and both permanent and seasonal wetlands. It has been recorded in parts of Africa for almost 200 years where it is quite widespread.

HISTORY OF INTRODUCTION TO NEW RANGE

The original time and means of introduction of *M. pigra* to Africa is unknown and its long-term presence in some countries is recognised from its traditional names and from its occasional place in folk-law. Mimosa (*M. pigra* is widely known as "mimosa" although there are many other species of the genus, several of which are invasive in other contexts) is spread by seed dispersal when the pods are transported by mobile animals or floodwaters to new (and, especially, disturbed) habitats. Germination mostly occurs after floodwaters (or rains) have subsided and invasion begins when newly-germinated seedlings and shrubs form impenetrable thickets which prevent the growth of other plants beneath them. Records of mimosa's spread and invasion across Africa have increased in the last 20 years – often in response to changes in flooding regimes or other types of disturbance. *M. pigra* is also now recorded as invasive in parts of South-East Asia, Australia, as well as parts of North, Central and South America.

IMPACTS

M. pigra as an invader has serious impacts on both native and farmed biodiversity in Africa where it excludes many plants and animals from its thickets as it spreads across floodplains and wetlands. Some infestations have been recorded to extend over many hundreds of hectares both within and outside protected areas on the Kafue Flats (floodplain) in Zambia. A recent study calculated that the economic cost of this invasion was in excess of US$ 1,350 per hectare to users of the floodplain – including farmers, livestock keepers, fishers, tourist operators and conservation agencies.

Deleterious impacts of mimosa include the changing of floodplain (and sometimes riverine) character resulting in changed flooding and flow regimes with serious implications for water flow and supply, fisheries and biodiversity dependent upon a predictable rise, spread and fall of water. Endangered species such as the Wattled Crane (*Grus carunculatus,* endemic to floodplains in southern and eastern Africa) are seriously threatened by *M. pigra* which has excluded them from traditional feeding and breeding grounds in Zambia, Ethiopia and possibly the Sudan. The same applies to many species of floodplain biota in Africa and the threat increases as mimosa spreads and becomes invasive.

OTHER RELEVANT FEATURES

The process of risk assessment in relation to the future spread of *M. pigra* as an invasive species has been carried out in northern Australia where it has been shown to be a potential problem over at least a further 50,000 km^2. A similar assessment of potential spread in Africa suggested that mimosa may invade at least 100,000 km^2 at least 9 countries in the future and that management (reasonable control using mechanical, chemical and biocontrol options) of such an infestation would cost between zero and US$ 7,600 per km^2. Prevention of spread of mimosa, on the other hand, would cost in the region of US$ 200 km^2.

Sources:
Walden, D et al., 2004. A risk assessment of the tropical wetland weed, Mimosa pira in northern Australia. Supervising Scientist Report, 177, Supervising Scientist, Darwin, NT, Australia, 74pp.
GISP, 2007. Development of case studies on the economic impact of invasive species in Africa: Draft Report – *Mimosa pigra*. Draft prepared by Psi-Delta, Australia, 100pp.

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TRIFFID WEED (*Chromolaena odorata*) INVASIONS IN AFRICA

NATIVE RANGE OF THE SPECIES

Triffid weed (*Chromolaena odorata*) is native to the Americas, from Northern Argentina to Southern Florida, including the Caribbean.

HISTORY OF INTRODUCTION TO NEW RANGE

The modes of introduction are uncertain, but there are two centres of invasion in Africa. While the biotype found in Central Africa arrived via Asia, the Southern Africa biotype came from the Caribbean. The first introduction to West Africa, through Nigeria, occurred in 1937, and the weed spread to all the countries in the region, reaching Liberia and northern Angola by 1990. In South Africa, it reached Durban in the 1940s. It moved North and South and by the 1980s reached the Eastern Cape.

IMPACTS

C. odorata forms dense thickets and reduces crop productivity in agriculture and grazing. It has allelopathic properties, releasing chemicals in the soil to prevent the germination or growth of native plants. It increases the intensity, range and frequency of fires. As density increases, it affects grassland species composition, stops forest succession, and impacts groundwater flows and runoff, with water losses estimated at 68.26 million m^3 per annum in Kwazulu-Natal province of South Africa.

In Ghana, triffid weed occupies 59% of all arable lands. In Ubombo, South Africa, it reduces the carrying capacity of grazing animals by 150%. In West and Central Africa it serves as an alternative host for a pest grasshopper.

The economic costs of undertaking control of triffid weed in natural areas are estimated at US$ 151 to 164 per hectare, depending on the scale of the work. It would therefore take US$ 2 million to clear 4,000 hectares, and up to US$ 24 million to clear 57,000 hectares of natural areas.

In South Africa, on a 13,000 ha government cattle farm with more than 8,000 ha invaded, conservative estimates relating only to clearing the weed for cattle production reach US$ 180 million. This includes controls undertaken over a period of 30 years. The area invaded negatively affects the original production capacity of the farm. If control is implemented for the 8,000 ha, the potential net gain, including control costs, reflects an increase in production by 34%. This represents a gain of US$ 25.6 per hectare per annum due to control efforts.

OTHER RELEVANT FEATURES

Biological control offers the most promising solution for *C. odorata* invasions amongst a range of beetles, flies, butterflies and moths, but research needs to be supported to identify the most efficient species to control this weed.

Sources:

GISP, 2007. The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent. Report prepared by CSIR, South Africa.

WATER HYACINTH (*Eichhornia crassipes*) INVASIONS IN AFRICA

NATIVE RANGE OF THE SPECIES

Water hyacinth (*Eichhornia crassipes*) is a free-floating, aquatic weed from South America.

HISTORY OF INTRODUCTION TO NEW RANGE

Introduction is usually intentional although the exact mode of introduction into Africa is uncertain. It is thought that water hyacinth plants were handed out as gifts during a Trade Fair in St Louis in 1904 and subsequently spread. First recorded in South Africa in 1910, it spread widely and is now recorded from 23 African countries.

IMPACTS

E. crassipes grows rapidly forming expansive colonies of interwoven floating plants, which create impenetrable barriers and obstruct navigation. It impacts all aspects of water resource utilization i.e. fisheries, transport (including the collection of palm wine) and hydropower generation, as well as water supplies (potable water), flood control, irrigation, health (e.g. malaria, bilharzia), ecotourism and water sports. It does have some positive uses (e.g. as stock feed, compost, fibre for paper-making or weaving; filtration and biogas-production), although they are only viable on a small-scale. Large-scale processing is seldom viable as the plant is 96% water and harvesting is very expensive.

There are a number of methods for controlling water hyacinth including: manual or mechanical removal; floating booms to limit spread; application of herbicides; and biological control. Of these, biological control is probably the most important and essential for the long-term, sustainable control of water hyacinth. Five biocontrol agents have been used successfully around the world.

In the Central African Republic, biological control improved annual economic returns from palm wine collection by 1-6% (US$ 2.10 - 7.00) and gill-net fishing by 4-22% (US$ 16.30 - 103.10). Benefit-cost ratios ranged from 5-5.6:1. In South Africa, estimated losses in income from activities impacted by *E. crassipes* total US$ 58,195 annually. These decreased to US$ 7,000 with the immediate implementation of an integrated control programme (i.e., a benefit-cost ratio of 31:1).

The per hectare costs of mechanised and chemical control are relatively low (US$ 36 - 400 per hectare) but cost-effectiveness depends on the size of the area and the goal of the treatment. On a larger area (>100 ha) where the goal is significant reduction, biological control and integrated strategies are more likely to succeed and be cost-effective, even though the upfront investments are also high (i.e. US$ 110,000 - 210,000 annually over 10 years).

OTHER RELEVANT FEATURES

Little data exists on the negative impacts of water hyacinth on biodiversity which is an important area for future research. Similarly, water hyacinth may impact negatively on human health, providing a suitable environment for mosquitoes and other disease-carrying insects and mollusks but it has not been possible to quantify these impacts for lack of data.

The species continues to spread across the larger transboundary lakes and rivers of Africa such that few water systems are now without the “world’s worst waterweed”.

Sources:

GISP, 2007. The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent. Report prepared by CSIR, South Africa.

LARGER GRAIN BORER (*Prostephanus truncatus*) INVASIONS IN AFRICA

NATIVE RANGE OF THE SPECIES

The larger grain borer (*Prostephanus truncatus*) is a species of beetle which is endemic to meso-America, where it has long been known as a pest of maize grain.

HISTORY OF INTRODUCTION TO NEW RANGE

Following its accidental introduction into Africa in the early 1980's, *P. truncatus* has been recorded in 18 African countries and may well have invaded more. Natural dispersal through flight is slow and its widespread occurrence is mainly as a result of trade in maize grain. It was first reported in East Africa (Western Tanzania) in 1980; West Africa in 1984 and southern Africa in 1988, and it is likely that this species will spread to any areas where grains are grown and stored.

IMPACTS

P. truncatus is a major pest of staple food in Africa, especially farm-stored maize and cassava. Its impact is greatest in rural, small-holder farming systems where yield losses range from 23-60% but can be even higher. The pest also deposits excreta on the remaining stored crop rendering the harvest unpalatable for human or animal consumption.

Control of the larger grain borer focuses on reducing its numbers (and therefore its effects) in stores using insecticide mixtures such as permethrin and pirimiphos methyl, or fumigants. In 2006, the annual cost of chemical controls in East Africa was estimated to be $ 18.7 per farm (per hectare) which is prohibitive for most small-holder farmers.

Only one biological control agent, the histerid predator, *Teretrius nigrescens* has been introduced to Africa for the control of larger grain borer. *T. nigrescens* was first released in Togo in 1991 where it was shown to provide a significant reduction in the levels of damage (<80%) and releases of the predator have subsequently been carried out in a number of African countries. Establishment of the biocontrol agent is estimated to cost US$ 218,000 per country per year over 6 years (with additional recurrent costs of US$ 11,780).

Impacts can also be reduced by using modified storage and harvesting techniques such as treating the newly harvested crop with recommended insecticides and/or using a closed storage system (e.g. mud silos, which cost an estimated US$ 151 per farmer for establishment with an annual recurrent cost of US$ 26 per farmer).

Despite the risk of infestation by larger grain borer, clear economic incentives exist for farmers to store their harvested grain, particularly where infestations are more severe.

OTHER RELEVANT FEATURES

The larger grain borer is a pest species and does not have any positive uses. Its eradication is deemed impossible because the borer is able to multiply in natural vegetation. Its depletion of stored foods has brought about reductions in food supply in many rural areas with a consequent expansion of crops into previously wild lands and more use of wild biodiversity for subsistence.

Sources:

GISP, 2007. The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent. Report prepared by CSIR, South Africa.

PARTHENIUM WEED (*Parthenium hysterophorus*) INVASIONS IN AFRICA

NATIVE RANGE OF THE SPECIES

Parthenium weed (*Parthenium hysterophorus*) is an annual multi-branched herb native to tropical and subtropical America.

HISTORY OF INTRODUCTION TO NEW RANGE

The mode of introduction is uncertain, although *P. hysterophorus* was first recorded in Ethiopia in 1968, and in South Africa in 1880. In South Africa, it has only been regarded as invasive since the 1980s in the wake of the "Demoina" cyclone that caused widespread disturbances in native vegetation. More recently, it has been recorded in Madagascar, Mauritius, Mozambique, the Seychelles and Zimbabwe. It is likely present in other African countries given suitable conditions for establishment throughout the tropical and sub-tropical regions of Africa. *P. hysterophorus* was also introduced into Australia as a seed contaminant in the 1950s and is now on the list of declared plants that may not be imported or grown in several states.

IMPACTS

P. hysterophorus is an aggressive pioneer that generally colonizes disturbed areas before encroaching on native vegetation. It has significant impacts on livestock and grain cropping productivity, as well as human health. The weed is toxic to domestic animals and if eaten results in tainted meat. It generates allelopathic effects in the soils, and outcompetes production crops for available nutrients and moisture. *P. hysterophorus* also can cover crops with its pollen, which prevents seed set with productivity losses of up to 40%. In terms of human health, 10-40% of people living in infested areas suffer serious allergies, and the weed has also led to almost epidemic incidences of allergic eczematous bronchial and contact asthma. There is no effective treatment for these ailments other than leaving the infested area.

If *P. hysterophorus* continues to spread uncontrolled in South Africa, expectations calculate that small-scale farmers would likely suffer a decline in total economic returns of 26-41% equivalent to US$87 - 136 per year. Commercial farmers' returns could decline between US$38,818 – 60,957. Cost-benefit analysis suggests that small-scale farmers were slightly worse off for undertaking control measures, although available data was limited. Commercial farmers benefited substantially from implementing control measures with an increase in returns by 49% for immediate control and 13% for instances when control was delayed by 15 years.

OTHER RELEVANT FEATURES

P. hysterophorus can be controlled with conventional herbicides, application of which could double cultivation costs. Contamination of crops with parthenium seeds presents a serious problem regarding its continued spread.

Sources:

GISP, 2007. The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent. Report prepared by CSIR, South Africa.

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WEEPING GRASS (*Eragrostis plana*) INVASION

IN THE SOUTHERN GRASSLANDS OF BRAZIL

NATIVE RANGE OF THE SPECIES

Weeping grass (*Eragrostis plana*) is native to South Africa, where it does not have wide expression, and is not a dominant species.

HISTORY OF INTRODUCTION TO NEW RANGE

E. plana was accidentally introduced into Rio Grande do Sul state, in the south of Brazil, as a contaminant of seeds of an African forage grass, *Chloris gayana*, in 1969, imported from South Africa. As it seemed more resistant to cold and frost than the native grasses, it was cultivated and sold as an exceptional forage grass. By 1979 it had been widely recognized as a very poor forage grass, as the cattle either would not graze on it or would not gain weight, and its use was prohibited by the Ministry of Agriculture. At that time it occupied 20,000 ha. As no control programs were implemented, it grew to 400,000 ha in 1993 and to about 2,000,000 ha in 2007, covering about 20% of the natural ecosystem. Predictions for 2015 are 4,480,000 ha invaded.

IMPACTS

E. plana is strongly dominant and eliminates all other plants from the land it occupies. It is allelopathic, releasing chemicals in the soil to inhibit the germination and growth of native species. It impacts wildlife by not providing food or habitat, and totally changing the natural composition of the grasslands and savannas.

Weeping grass invades the most traditional lands in Brazil for cattle farming – the lands of the gaucho culture in the South, linked to the Argentine and Uruguayan pampas. The cultural impacts of preventing cattle farming in this area are enormous, as being a gaucho is a way of life. When the land is not viable for cattle, farmers often rent the property for alien invasive forest plantations (pines, eucalypts and acacias) or convert to agriculture, destroying biodiversity and the possibility of future restoration. Others abandon the land and move to cities exacerbating problems with poverty, ghettos and delivery of services.

Estimates are that the economic impact of weeping grass invasion on cattle farming leads to a loss of US$ 38.91 per hectare, while non-invaded areas yield a gain of US$ 17.15. The total production losses to the state of Rio Grande do Sul are estimated at US$ 3.4 million in 2005, totaling US$ 29 million between 1995 and 2005. If no control is undertaken, total losses between 1995 and 2015 will total US$ 600 million.

OTHER RELEVANT FEATURES

Biological control would be the only viable alternative to solve this problem, and a research program would cost approximately 1% of the estimated losses per annum.

Sources:
Coelho, R. EMBRAPA Pelotas, Rio Grande do Sul.
Kissmann, K. G. 1997. Plantas infestantes e nocivas. 2 ed. V.1. Sao Paulo: BASF, 569-72.
Rosa, F.L.O.; Ramos, J.V.S.; Ziller, S.R. 2007. The economic impacts of *Eragrostis plana* in Southern grasslands of Brazil. The Nature Conservancy South America Invasive Species Program.

CACTUS MOTH (*Cactoblastis cactorum*) INVASIONS IN MEXICO

NATIVE RANGE OF THE SPECIES

The cactus moth (*Cactoblastis cactorum*) is a native insect from Argentina, Paraguay and Peru, which has been used as a biocontrol agent for several species of cacti (*Opuntia*).

HISTORY OF INTRODUCTION TO NEW RANGE

C. cactorum was used as a biocontrol agent against invasive prickly pear cacti in Australia as well as the Caribbean. It later became established and invasive itself in South Africa, the Caribbean, Hawaii and the gulf states of the U.S. (Florida, Alabama, Mississippi and Texas). In September 2006, it was identified on Isla Mujeres just off the Mexican coast near Cancun, where it was introduced from other Caribbean islands by recent hurricanes. Despite active efforts by federal and non-governmental agencies, the Cactus moth has recently been identified on the mainland most likely transported on local ferries.

IMPACTS

C. cactorum lays its egg sticks on cacti, and emerging larvae feed internally upon the cacti reducing it to a shell. The moths then spread to other plants and swiftly decimate cacti stands. Mexico has a high diversity of *Opuntia* species, some of which are important for local production and consumption. Approximately, 43,000 households are directly involved in *Opuntia* production with others involved in the transport and sale of harvested products. In 2006, national production of nopal was 759,065 tons (valued at US$ 128 million) and prickly pear cactus fruit was 366,381 tons (valued at US$ 71 million).

Increased production costs would likely reduce the number of available jobs and monetary value of the crop with add-on effects throughout communities. Negative employment impacts could increase emigration rates to the U.S., which are already high in the states of Mexico, Morelos, Puebla and Zacatecas. Additionally, the destruction of *Opuntia*, as a staple and national symbol, has nutritional and cultural implications.

In biological terms, *C. cactorum* threatens multiple species of *Opuntia* (Mexico has 56 species of which 38 are endemic) present across 3 million hectares, with consequent impacts on other flora and fauna in those ecosystems.

OTHER RELEVANT FEATURES

C. cactorum can be controlled through the application of insecticides. Current yearly production costs for nopal (a vegetable made from the flattened stems or pads of cactus) range from US$ 2,800 - 5,500 per hectare and cactus fruit from US$ 1,400 - 2,800 per hectare. The cost of insecticide treatments in affected zones could reach US$ 620,000 for nopal and US $2.9 million for cactus fruit.

Sources:

Arroyo, H.S et al. Impacto Economico y Social en Caso de Introduccion y Establecimiento de la Palomilla del Nopal (*Cactoblastic cactorum* Berg) en Mexico (IAEA, 2007).

Soberon, J. The Routes of Invasión of Cactoblastis cactorum. Presentation at the NAPPO PRA Symposium (Puerto Vallarta, Mexico, March 2002).