2.3. Impacts and control of invasion

Le Maitre *et al.* (2000) estimated that approximately 10.1 millions hectares of South Africa and Lesotho have been invaded by alien plants in general. Of the eight biomes found in South Africa (see Rutherford *et al*., 2006), the Western Cape Province, which largely comprises the Fynbos biome is the most heavily invaded, particularly by woody shrubs and trees. This is followed by Mpumalanga, KwaZulu-Natal and the Limpopo Province. The largest total invader-transformed areas are those invaded by species of *Racosperma* Mart. (wattles), *Pinus* L. (pines) and *Prosopis* L., and *Lantana camara* L. These invasions deplete water resources (particularly woody invaders), affect delivery of ecosystem goods and services, over-utilise or alter natural resources (e.g. nitrogen addition), shift (often intensify) fire regimes, and affect sand movement and salt concentration (Richardson & Van Wilgen, 2004). Other effects include poisoning, for example *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz (Fig. 13) (= *B. tubiflorum* Harv.) and *B. pinnatum* (Lam.) Oken, succulent members of the Crassulaceae, which are both poisonous when ingested and cause heart failure. The flowers are five times more poisonous than the leaves and the poison can accumulate in body tissue. The impacts are primarily on livestock (Naughton & Bourke, 2005). To date no investigations have been done to measure the impacts of these two alien crassuloid species on the native flora and fauna.

Fig. 13. Ingestion by livestock of the flowers and leaves of *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz can lead to death by poisoning. (Picture by Geoff R. Nichols)

Eradication and control of invasive plants is extremely costly. This may be done either through labour intensive manual clearing, the use of chemicals (e.g. herbicides), or by the introduction of host-specific plant-feeding insects, mites and pathogens from the invader's country of origin, i.e. the plant's natural enemy or enemies, into a new country where the plants have become problematic (biological control or biocontrol) (Zimmermann *et al*., 2004). There is a risk of biocontrols themselves becoming invasive and attacking organisms that were not intended for targeting. The use of biocontrol agents requires very careful research before they are piloted to ensure that undesirable consequences are evaluated and avoided. The price of clearing invasive species may vary depending on the density of the invasion and also on the species being cleared. It was estimated that South Africa allocated approximately R355 million to alien invasive clearing during the 2002/2003 financial year (Marais *et al*., 2004). This highlights the importance of biological control as a comparatively inexpensive and effective means of eradicating alien invasives in the medium- to long-term as the biological control agents inflict damage and cause a decline in population densities, distribution and/or rates of spread of the problem plants. This reduces the costs of other management practices (Zimmermann *et al*., 2004). A total of 111 biological control agents have been released in South Africa against 67 invasive alien plants since 1913. These include 13 succulent species. Eighty-three agents have become established on forty-seven invasive plant species in 14 families. Thirty percent of the released agents inflict extensive damage to the weeds, including 11 succulents. Twenty-five percent resulted in considerable damage and 20% cause a moderate degree of damage to their target hosts (Klein, 2011). Targeting emerging weeds for biological control at an early stage of invasion could considerably increase the chances of success (Olckers, 2004). Preference for biological control agents is also highlighted by the adverse effects of chemical control. The side-effects and impacts on non-target species of the chemical control operations used against prickly pear, jointed cactus and other invasive cacti, for example, were severe. Arsenic pentoxide (sodium of arsenite) was widely distributed to farmers for the control of these cacti between 1893 and 1910. About 425+ tons of arsenic of soda were sold or issued to farmers in the Eastern Cape (Van Sittert, 2002). This most virulent poison was potentially as lethal to farmers' lands, livestock and labourers as it was to the targeted cacti. It caused considerable damage to thorn trees, shrubs, and herbage, as well as the health of livestock and humans while the overall hidden costs were high. Areas of spillage in the natural vegetation were free of all vegetation for more than forty years (Zimmermann, *pers. obs*.). Although the hormone weed killer (2,4,5-T diluted in illuminating paraffin) was less toxic to mammals, it was a potent tree and shrub killer. Between 1958 and 1979, 107 million litres of ready mix herbicide was distributed to farmers for the control of mainly jointed cactus (Moran & Annecke, 1979). This herbicide was later replaced by water based MSMA (Monosodium Methanearsonate, an organic arsenate) which was more selective and caused less harm to the environment. It was issued to landholders on a subsidised basis. Herbicide-dominated eradication of prickly pear took place during 1893 to 1930. Herbicide usage then shifted to jointed cactus between the years 1957 to about 1999 when full reliance was placed on biological control. The farmers were then issued with cochineal instead of herbicide to control the jointed cactus. During the 1970's considerable volumes of herbicides were also issued for the chemical control of the chain fruit cholla (*Cylindropuntia fulgida*). Recently, all support for the chemical control of this most vicious cactus was terminated when a highly successful biological control programme was launched.

3. History of invasive succulent plants in the region

by Helmuth G. Zimmermann

About 55% of all listed invasive plant species in South Africa are of horticultural origin. This is considerably more than the 6%, 11% and 13% that were introduced for forestry, agriculture and as barrier plants respectively (H. Klein, *pers. comm*.). Except for two *Agave* species, a *Furcraea* species (Fig. 14) and two *Opuntia* species (Fig. 15) practically all (about 300–400 species) of the introduced succulents came into the country as ornamentals. There are also a few that arrived in South Africa unintentionally. Presently there are only 24 succulent species on the CARA list (version 6 of 2007) of declared invasive plants. This figure is low compared to the many species that are now naturalised or widely cultivated as ornamentals. Certainly there must be some "sleeper" weeds amongst these that will become invasive in the years to come. Amongst these are several representatives of the Cactaceae, Crassulacaeae, Euphorbiaceae and other families. It is vitally important to identify these potential new invaders at an early stage and to prevent them from reaching harmful population numbers, in addition to preventing the introduction of new potentially harmful species. All these species need to be subjected to detailed risk analyses, which is now a new emerging science in botany (Richardson & Van Wilgen, 2004).

Fig. 14. *Furcraea foetida* (L.) Haw. was introduced into South Africa as a commercial fibre crop, but has escaped into natural vegetation. (Picture by Neil R. Crouch)

Fig. 15. *Opuntia robusta* Pfeiff. was introduced into South Africa as a fodder plant. (Picture by Gideon F. Smith)

According to Glen (2002) there are no less than 183 species in the Cactaceae that are cultivated in South Africa, while some succulent nurseries suggest that this figure is probably closer to 250 species. Except for *Rhipsalis baccifera* (J. Mill.) Stearn subsp. *mauritiana* (DC.) Barthlott (Fig. 16), an epiphyte, all species in the Cactaceae are alien to South Africa. Amongst the many introduced genera there are only a few that include species which have consistently shown tendencies to become invasive, such as *Opuntia*, *Cylindropuntia*, *Cereus* Mill., *Cleistocactus* Lem., *Harrisia* Britton, *Pereskia* Mill. and *Tephrocactus* Lem. Similar patterns are seen in Australia (J.R. Hosking, *pers. comm*.). Amongst the Crassulaceae, the genera *Kalanchoe* Adans. and *Bryophyllum* Salisb. could be identified as posing a threat to our environment because of the large number of species in these genera which show strong tendencies towards invasiveness. In contrast there are no indications, yet, of invasiveness in the genera *Sedum* L. and *Echeveria* DC. with more than 25 widely cultivated species recorded as occurring in South Africa. It is disconcerting that there are 61 and 7 species, respectively, in these two genera recorded as weedy in the Global Compendium of Weeds (Randall, 2010). It is highly probable that from amongst this pool new invasive succulents will emerge.

Fig. 16. *Rhipsalis baccifera* (J. Mill.) Stearn subsp. *mauritiana* (DC.) Barthlott is the only cactus indigenous to South Africa, indeed to Africa. (Picture by Neil R. Crouch)

Species in the genera *Opuntia* and *Cylindropuntia* stand out as being notoriously invasive not only in South Africa, but also in many other countries (Zimmermann *et al*., 2009). They all share certain characteristics which include heavy fruiting, vegetative reproduction, spines, good dispersal mechanisms and lack of natural enemies because of their taxonomic isolation. Not surprisingly it is now virtually impossible to obtain import permits for any species in these genera. The problems concerning Opuntieae are exacerbated where certain spineless cultivars of *O. ficus-indica* (L.) Mill. and O. *robusta* Pfeiff. are permitted because of their agricultural importance as fruit and fodder plants. These spineless cultivars are mutations which are then cloned and used for cultivation. Unfortunately with genetic recombination both species have reverted back to their wild spiny forms (Fig. 17, 18) which then become invasive. In the case of *O. ficus-indica,* this has resulted in a conflict of interest where some encourage and promote the species (spineless form) while others control and try to eradicate the same species (spiny form) (Beinart, 2003). This has serious legal implications as well as restricting the use of biological control which is often the only reasonable option. Resolving such conflicts of interest is difficult (Annecke & Moran, 1978; Middleton, 1999). *Cereus jamacaru* DC. is an aggressive invader in South Africa. In Israel, a member of the *C. hexagonus* complex referred to as *C. peruvianus* (Nerd *et al*., 2002) is cultivated for its fruit. This must be either *C. hildmannianus* or *C. jamacaru*, and it may be only a matter of time before selected cultivars are cultivated in South Africa giving rise to another potential conflict of interest issue.

Fig. 17. *Opuntia ficus-indica* (L.) Mill. plants reverting to the spiny form.
(Picture by Pieter J.D. Winter)

Fig. 18. *Opuntia robusta* Pfeiff. plants reverting to the spiny form.
(Picture by Helmuth G. Zimmermann)

There are several potentially invasive alien succulents sold in nurseries as “sterile” cultivars, for example *Kalanchoe* selections and some *Echeveria* hybrids. This is certainly an option to lower the risk for unintentional invasions provided that the risk for reversion back to the wild forms is minimal. The cooperation of the nursery industry in determining these risks is vital. The Nursery Partnership Programme is aimed at minimizing the risk of releasing potentially invasive ornamentals into the environment. The so-called sterility of cultivars remain open to conjecture though.

Unlike other non-succulent invasive species e.g. in the genera *Campuloclinium* DC. and *Parthenium* L., succulents have generally a long lag phase before becoming invasive. It took close to 150 years for *Opuntia ficus-indica* to reach population levels which became harmful (Annecke & Moran, 1978; Von Sittert, 2002). *Opuntia aurantiaca* was introduced as an ornamental in 1843 but the first records of harmful invasions date from the 1890s (Moran & Annecke, 1979). The lag phase for *Harrisia martinii* (Labour) Britton (Fig. 19) and *Cereus jamacaru*

(Fig. 20) could be around 60 and 40 years respectively (Moran & Zimmermann, 1991a). *Agave americana* L. (Fig. 21) was deliberately introduced and cultivated in the Graaff-Reinet area in about 1850 but the plant has only been added to the CARA list as recently as 1980 (Henderson, 2001). Species with a long lag phase are particularly amenable for the early detection and rapid response programme which was recently launched in South Africa. Other succulent invaders, however, with a short lag phase are amongst the most aggressive species. The chain fruit cholla, *Cylindropuntia fulgida,* was first recorded in South Africa in the 1940s and extensive infestations were already present in the Douglas area during the 1960s. Despite intensive eradication programmes initiated by the Department of Agriculture in the early 1970s, the cactus continued to spread and develop dense populations. Other species in the genus *Cylindropuntia* show very similar tendencies. Unfortunately they are still sold by uninformed nurseries and are common rockery plants.

Fig. 19. *Harrisia martinii* (Labour) Britton had a lag phase of 60 years before it became a problem plant. (Picture by Gideon F. Smith)

Fig. 20. *Cereus jamacaru* DC. had a lag phase of 40 years before it became a problem plant. (Picture by Helmuth G. Zimmermann)

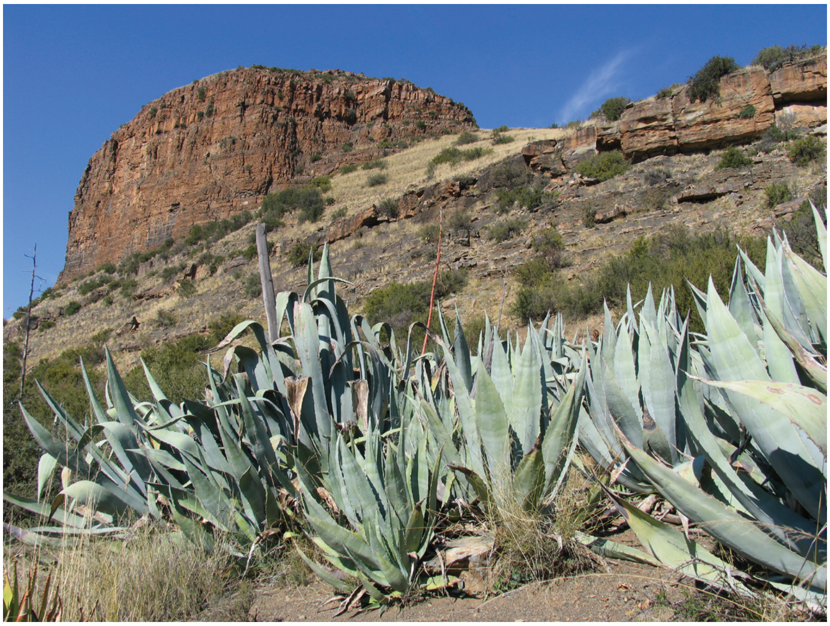

Fig. 21. *Agave americana* L. subsp. *americana* growing near Graaff-Reinet. Plants were introduced to that district in about 1850. (Picture by Neil R. Crouch)

4. Legislation and control programmes to manage unwanted invasions

by Helmuth G. Zimmermann

Nowadays virtually all countries have legislation to prevent the introduction and aid the control and management of unwanted species that impact negatively on agriculture and the environment. Invasive alien cacti in particular, are amongst the organisms that have had the most severe effects on agriculture in South Africa dating back almost 150 years. Legislation dealing with alien plants falls into two categories: (1) Acts that prevent the introduction of potentially invasive alien species into the country and (2) Acts that deal with the management and control of invasive alien plants already established in the country.

4.1. Acts that prevent introduction

There was no legislation prior to 1911 that prevented or controlled the introduction of unwanted organisms into South Africa. Several events or periods between 1652 and 1911 can be identified that were responsible for the introduction of many alien plant invaders. These events are well described by Wells *et al.* (1986). It was during this period, spanning 250 years, that many important cactus and at least one *Agave* species were deliberately introduced as part of the attempts of the European colonists and colonial rulers to "beautify" the colony and to establish new and useful plants species wherever possible. Annecke & Moran (1976), Moran & Annecke (1978) and Van Sittert (2002) give detailed accounts of the introduction and spread of prickly pear (*Opuntia ficus-indica*) and *O. aurantiaca,* the two alien weeds that have impacted greatly on the lives of humans and animals in the Western, Eastern and Northern Cape Provinces. The efforts are well known and documented, of individuals, like Baron Carl Ferdinand Heinrich von Ludwig (1784–1847) who resided in Cape Town and played a key role in receiving exotic plants from contacts in India, Europe and, in particular, Great Britain (often in exchange for members of the Cape flora) (Moran & Annecke, 1978). He has been credited with introducing *Cereus*, *Opuntia aurantiaca* and other *Opuntia* species (Bradlow, 1965). L.W. Sammons reports in Sam Sly's Journal dated October 1843 (see Moran & Annecke, 1978) that "the finest collection in this Colony of Mammillarias, Echinocacti, Cereus – Melocactus, Opuntia etc. lately arrived in Cape Town in the *Bosphorus* from England". The account also mentioned that plants for the Baron came mainly from the estates of Woburn Abbey and Chatsworth, and from the botanical gardens at Kew, Glasgow and Edinburgh. Woburn Abbey was known to have "the finest cactus collections in England". Forbes (1837) lists 315 species of cacti in the collection, including 81 species of *Opuntia* and *O. aurantiaca* is specifically mentioned. Other records of plant exchanges between the Baron and other famous gardens in Britain, e.g. Chiswick Gardens, that were "over-flowing with orchards and cacti" according to Fletcher (cited in Moran & Annecke, 1978), have been recorded. There is thus circumstantial evidence that *Opuntia aurantiaca* (and probably other cacti) arrived in Cape Town perhaps during 1843 and was passed on from the Ludwig's garden to the Cape Town Botanical Garden (not to be confused with the Kirstenbosch National Botanic Garden) between 1848 and

1858. The curator of the garden, J. McGibbon was in touch with missionaries who were often interested in botany and introducing new crops and novelties to their remote mission stations. Strange looking succulents were certainly novelty plants that have attracted much attention.

Text Box 2. Prominent legislation dealing with alien plants in South Africa.

DCA: The Divisional Council Act No. 40 of 1889
APA: Agricultural Pest Act No. 11 of 1911
The Cape Provincial Council Ordinance No. 18 of 1928
The Jointed Cactus Eradication Act No. 52 of 1934
The Weeds Act No. 42 of 1937
The Soil Conservation Act No. 76 of 1969
APA: Agricultural Pest Act No. 3 of 1973
APA: Agricultural Pest Act No. 36 of 1983
CARA: Conservation of Agricultural Resources Act No. 43 of 1983
ECA: The Environment Conservation Act No. 73 of 1998
NEMA: The National Environmental Management Act No. 107 of 1998
NEMBA: The National Environmental Management: Biodiversity Act No.10 of 2004

In summary it can be assumed that many cacti and other succulents from the New World were already introduced and established in South Africa by 1911 and that the spread of two of these, *Opuntia aurantiaca* and *O. ficus-indica,* had already reached alarming proportions in the Eastern Cape which urgently warranted control measures.

The first Agricultural Pest Act (APA), No. 11 was promulgated in 1911 and was aimed primarily at preventing the introduction of agricultural pests. Plants could only be imported into the country under the authority of a permit. The Act also provided special powers to control and eradicate pests of national importance affecting agriculture e.g. locusts. The emphasis was on crop security and protecting agricultural production. By this time the then Cape Province (now the Western, Eastern and Northern Cape Provinces) already had a history of almost 60 years of trying to cope with the serious invasions of prickly pear and jointed cactus and Government officials were sensitised towards other potentially dangerous invasive cacti in general. It would therefore have been difficult to legally introduce further jointed cactus-type plants. This Act was later replaced by the APA, Act 3 of 1973 and later by the APA, Act 36 of 1983 (with at least five amendments) which continued to regulate the importation of all “controlled goods” including plants. Species for introduction are subjected to pre-border and post-border weed risk assessments following guidelines provided by the International Plant Protection Convention (IPPC) (FAO, 2006). As with the previous Act, the emphasis was on protecting agriculture.

It was only after the Convention on Biological Diversity (CBD) was ratified in 1995 that new legislation controlling the importation of potentially invasive species was considered. There are three Acts, all mandated by the Department of Environmental Affairs, that affect the introduction and management of invasive alien species in some or other way with the emphasis on protecting the environment and biodiversity. These are (1) The Environment Conservation Act No. 73 of 1998 (ECA); (2) The National Environmental Management Act No. 107 of 1998 (NEMA) and; (3) The National Environmental Management: Biodiversity Act No.10 of 2004 (NEMBA). Chapter 5 of NEMBA deals specifically and comprehensively with the introduction and management of invasive alien species. The Regulations regarding established plants are based on lists that are divided into specific categories, each with its own particular management prescriptions. These lists match similar lists published under the Conservation of Agricultural Resources Act (CARA). Legal action and financial support to control invasive plants is only possible once a species has been listed. The NEMBA regulations, however, also provide for emergency interventions and for an early detection and rapid response programme to deal with new and emerging issues. New introductions of alien organisms can only occur under the authority of a permit after subjecting the species to an initial and/or a comprehensive risk assessment process. Harmonization between NEMBA and the two agricultural Acts (APA and CARA) regarding invasive plants is required. The environmental Acts are implemented mainly at provincial level while the agricultural Acts are implemented nationally. Two import permits from two different Government Departments will therefore be required in future, based on separate risk assessments, to introduce new ornamental succulents into South Africa.

The control of imported seeds through the postal services remains a challenge though. All seeds of ornamental cacti and many other succulents are small and can easily be sent by conventional air or surface mail. This challenge is compounded by the easy access to seeds through the internet trade.

4.2. Acts that deal with the management and control of invasive plants

There were a few Acts in place during the late nineteenth century that focused specifically on the control of three weeds. These were *Xanthium spinosum* L., *Opuntia aurantiaca* and *O ficus-indica.* Until 1911 *Opuntia ficus-indica* was undoubtedly the plant invader that had had the greatest impact on agriculture and the environment but it was never included in any Act that would assist in its management and control at a national (Cape Colony) level. The reason for this was the conflict of interest amongst landholders regarding the dangers and benefits of prickly pear. The farmers north of the Winterberg/Amatola line could benefit from the prickly pear because the plant was considerably less invasive in the climatically severe, and much colder Upper Karoo while severe invasions occurred south of this line. Until this day there has never been a weed that has generated so many discussions and produced so many reports as the prickly pear. The history of the introduction, invasion, impact and control of prickly pear in South Africa, and the conflicts around its weed status have been documented in detail by Annecke & Moran (1978), Beinart (2003) and Van Sittert (2002). No other plant has contributed more to creating a general awareness concerning the dangers of invasive plants, in particular the dangers of exotic cacti in this country.

Despite several efforts to pass a national law to enforce control measures for prickly pear, during the late nineteenth and early twentieth centuries, this never materialised. The last attempts occurred in 1906 but as in previous cases, the Director of Agriculture again refused to authorise a Prickly Pear Act on grounds that "it would be a hardship to (some) farmers and unfair towards the general taxpayer". Instead, the responsibility for control of prickly pears was devolved to local authorities such as the Divisional Councils. The 1889 Divisional Council Act (amended twice between 1889 and 1910) catered primarily for *Xanthium spinosum* but ignored prickly pear except in two districts where it was proclaimed a noxious weed. The Acts were toothless, were not backed with adequate finances to implement them, had limited powers and contributed little towards solving the prickly pear problem.

There was, however, no conflict of interest with jointed cactus, *Opuntia aurantiaca,* and expensive programmes were put in place to control this plant. The promulgation of the Cape Provincial Council Ordinance No. 18 of 1928 made the control of jointed cactus compulsory. This was followed by the more powerful Act No. 52 of 1934, the Jointed Cactus Eradication Act which placed the responsibility for control on the State Department of Agriculture. Under this Act teams of departmental labourers were employed to assist in the mechanical and chemical control of jointed cactus (Moran & Annecke, 1978; Pettey, 1948). This Act was eventually replaced by the Weeds Act of 1937 which continued to make State subsidies available for the control of mainly jointed cactus. A new subsidy scheme was put in place in 1957 to chemically control jointed cactus, prickly pear, imbricate cactus and chainfruit cholla (previously known as the rosea cactus) and later also other declared invaders e.g. nassella tussock grass. The subsidy scheme was later managed under the Soil Conservation Act of 1969. Eventually the Weeds and the Soil Conservation Acts were replaced by the Conservation of Agricultural Resources Act, better known as CARA (Act No. 43 of 1983) which continued with the subsidy schemes until 1999 when the Working for Water programme took over many of the initiatives on invasive plant control, including those on the invasive cacti.

The objectives of CARA were, *inter alia*, "the protection of the vegetation and the combating of weeds and invader plants". However, this role was to a large extent taken over by NEMBA which purports to "manage and control invasive species to prevent or minimise harm to the environment and biological diversity, and in particular where possible and appropriate, eradicate invasive species that may cause such harm". These two Acts do not only share the same objectives but also share similar lists of invasive alien plants that are declared and subjected to specific control measures. In order to take any action against any invasive plant species it must be listed and must fall into one of three or five categories respectively. The CARA list contains 198 species divided into three categories, each one with its own control and management prescriptions. There are 24 succulent species listed in CARA (version 6 of 2007), 17 of them belonging to the family Cactaceae. The proposed NEMBA list will have close to 345 species divided into five categories. There are over 30 succulent species in this list, 16 of them being cacti. A revised CARA list will reflect the same species and categories.

4.3. Control programmes

Historically, several national campaigns aimed at the control of some cactus and other invaders have been implemented in South Africa. Some date back to the late 19th century when mechanical clearing of invasive prickly pear in the eastern Cape Colony was instigated by the Cape colonial government sometime after 1883 (Annecke & Moran, 1976). This campaign was unsuccessful and was replaced by chemical control based on using a highly poisonous arsenic-based herbicide (arsenite of soda) which remained in use for some 50 years, against both prickly pear and jointed cactus. The environmental impact of this highly toxic compound on plants, animals and humans was horrendous (Van Sittert, 2002). Biological control followed which was shown to be most successful when a cochineal insect, *Dactylopius ceylonicus*, was obtained from India in 1913 which controlled the cactus weed, *Opuntia monacantha* Haw., along the southern coast of South Africa (Fig. 22). This, accompanied by the success of the biological control of *O. stricta* in Australia and supported by public pressure to act on the threat posed by *O. ficus-indica* and *O. aurantiaca*, convinced the minister of Agriculture of that time to embark on a biological control campaign which lasted for thirty years. Two natural insect enemies, the cactus moth, *Cactoblastis cactorum* and the cochineal, *Dactylopius opuntiae*, were introduced in the thirties to control prickly pear and, assisted by hand felling of infested plants, eventually cleared about 80% of the infestations by the late 1950s (Annecke & Moran, 1978). There was a strong lobby of Karoo farmers at the time that vehemently opposed biological control, contributing to a debate which continues to this day (Beinart, 2003). Fortunately it is still possible to successfully cultivate the commercial varieties of prickly pear despite the presence of the two biological control agents that are now regarded as pests in plantations and orchards. A similar successful campaign was also launched at about the same time against jointed cactus, *O. aurantiaca,* using another host-specific cochineal species, *Dactylopius austrinus* originally from Argentina, and introduced from Australia in 1935 (Moran & Annecke, 1978). The introduction of yet another cochineal, *D. tomentosus*, in 1958 for the control of the imbricate cactus, *Cylindropuntia imbricata,* and *C. leptocaulis,* followed (Moran & Zimmermann, 1991a). Recently, equally successful, biological control projects were launched against *Opuntia stricta* and *Cylindropuntia fulgida* using host-specific selected biotypes of *Dactylopius opuntiae* and *D. tomentosa,* respectively (Paterson *et al*., 2011; Zimmermann *et al*., 2004). The cactus mealybug, *Hypogeococcus pungens* (also known as *H. festerianus*), was also successful in controlling rampant invasions of *Harrisia martinii* and *Cereus jamacaru* in the 1980s and 1990s. Other biological control projects implemented against other succulent cacti, however, were less successful, for example *Pereskia aculeata* (Klein, 1999). In general, the track record of biological control against invasive cacti in South Africa is exceptionally good compared to attempts to control invasive representatives of other plant families in the same way. This is partly because of the host specificity of the cactus-feeding natural enemies as well as the fact that, with the exception of a single species of *Rhipsalis* Gaertn.*,* Africa is void of native species in this rather unique family of plants, allowing for a larger selection of host-specific insects to be used.

Fig. 22. About 100 years ago populations of *Opuntia monacantha* Haw. were biologically controlled by releasing a cochineal insect on them. (Picture by Helmuth G. Zimmermann)

Chemical control, using the highly toxic inorganic sodium of arsenite, was the only method available to kill invasive cacti for many years. Since 1957 a new hormone herbicide, 2,4,5-T diluted in illuminating paraffin was supplied to landholders gratis, provided that they used their own labour to treat the cacti. This scheme was primarily aimed at the control of jointed cactus but was later also used against other invasive cacti. 2,4,5-T was later replaced by Picloram which showed serious non-target effects because of the tendency of jointed cactus to grow under trees which are highly sensitive to this product. Currently another herbicide, namely an organic arsenate product, MSMA (monosodium methanearsonate) is registered for the control of cacti (Anonymous, 2004). Most succulents, and in particular cacti and *Agave* species, are very sensitive to any arsenical-based herbicide. MSMA which is relatively less expensive and considerably less toxic than the inorganic arsenites, is effective against all invasive cacti and has less non-target effects on other vegetation. Stem succulents such as prickly pear, *O. stricta* and *Agave* species, are effectively controlled with stem injections of small quantities of MSMA (Zimmermann, 1989). A second, but less effective, herbicide, namely glyphosate, is also registered for the control of some cacti but was never made available in any subsidy scheme.

4.4. Nursery Partnership Programme

Nurseries have been the origin and point of distribution of many invasive plant species in South Africa. There are well over 250 species of cacti, *Agave* and non-native, succulent and non-succulent *Euphorbia* L. cultivated in South Africa (Glen, 2002) most of which are found in, or originated from, the nursery trade (Fig. 23). Fortunately very few of these species show tendencies to naturalise or become invasive. Deliberate introductions by Botanical Gardens and Government departments also provided their share of invasives. It is a formidable but essential task to identify species at an early stage of invasion and then to take quick action. The Nursery Partnership Programme aims to do this by preventing the sale of potentially invasive species. It remains the State's duty to, firstly, prevent the introduction of potentially invasive succulents and secondly, to identify dangerous species already in the country that have the potential to become invasive and then to take quick action. The cooperation of the nurseries is essential in achieving this goal. CARA provides a list of "emerging species" that show tendencies towards invasiveness but which still lack the evidence to be categorised. Some of these species are still found in the nursery trade. The ideal is to convince all nurseries to join the South African Nursery Association (SANA) and to adhere to a code of conduct. Unfortunately there are still far too many nurseries that trade in listed and emerging species and the regulatory arm of the Government is not able to prevent this.

Fig. 23. A wide variety of cactus species are offered for sale in the nursery trade. Some of these may eventually become problematic. (Picture by Helmuth G. Zimmermann)

4.5. Early detection and rapid response programme

"Prevention is better than cure" and this is certainly the case for invasive alien species. It makes economic sense to deal with invasions at an early stage before they are out of control and when they can still be eradicated or contained. Considerable know-how and experience is required to identify those potentially aggressive invaders amongst hundreds of exotic succulent species in cultivation, that could justify a rapid response programme. These decisions are based on detailed risk assessment analyses which are supposed to predict the aggressiveness of an invader. Such an early detection and rapid response programme has recently been launched in South Africa managed by the South African National Biodiversity Institute (SANBI) supported by the Working for Water Programme. Since the inception of the project several new succulents e.g. *Bryophyllum pinnatum* (Fig. 24), *Cylindropuntia fulgida* var. *mamillata, Tephrocactus articulatus* (Pfeiff.) Backeb., *Opuntia salmiana* J.Parm. ex Pfeiff. and *Harrisia balansae* (K.Schum.) N.P.Taylor & Zappi have been identified and are now being targeted for rapid response actions. The Programme relies heavily on the experiences of other countries with similar climates, e.g. Australia, and on the participation of "spotters", the SAPIA programme and interested stakeholders to identify new invaders at an early stage of establishment.

Fig. 24. *Bryophyllum pinnatum* (Lam.) Oken has recently become a pest plant in South Africa. (Picture by Neil R. Crouch)

5. Collecting succulent plants for deposition in a herbarium

by M. Walters

5.1. What is a plant specimen?

A preserved plant specimen is a dried and mounted or pickled voucher that is the botanical world's equivalent to the zoologist's stuffed animals, skins or insect collections that are kept in natural history museums (Fig. 25). Plant specimens are housed in herbaria which are permanent repositories of specimen collections and their associated data.

Fig. 25. A preserved specimen of an indigenous succulent, *Aloe arborescens* Mill., kept in the National Herbarium of South Africa (PRE). (Picture by SANBI)

5.2. How are plant specimens useful?

Herbarium specimens in the vast collections held by Herbaria all around the world are extremely valuable for a number of reasons. Not only are specimens useful when trying to identify plant material, they also provide a record of where and when a particular species was found growing. The information that can be found on the specimen label is valuable too, and may give clues as to, for instance, soil substrate the plant was found growing in. As classifying plants is not a static process, and plant names may therefore change as species concepts change or as new evidence for re-classification is found, specimens can be used to verify past identifications. Label information on herbarium specimens is also used as a way of determining the area of occupancy (AOO) of species, which is an important parameter to determine their conservation status (Red List status) (Hernández & Navarro, 2007). This method results in more accurate, less overestimated determinations of AOO, and will as a result produce more useful and valuable Red List assessments.

5.3. Why bother collecting voucher specimens for exotics?

There are many more ways in which specimen collections are useful, but as far as alien plants are concerned, physical specimens can be of particular use, when investigating points of entry and range expansion of these species over time. They also aid in the development of predictive habitat models that may give clues about habitat preference and potential for future spread.

Most people know better than to touch a cactus with their bare hands. The spines and fine glochids, in the case of representatives of *Opuntia* (prickly pears) and their relatives, found on most species can be very irritating and quite painful when lodged under the skin. So when appeals are made for collecting and pressing these plants, a general lack of enthusiasm is usually shown by professional botanists and by the public alike. Preparing preserved specimens of these plants with their unwelcoming, prickly habit may seem like more effort than it is worth. For this reason, cacti are often not collected and are thus poorly represented in herbaria (Leuenberger, 1987). This is particularly true for southern Africa where, except for one species (*Rhipsalis baccifera* subsp. *mauritiana*), cacti do not comprise part of the indigenous flora and are thus mostly ignored, even by environmental consultants and other specialist collectors. Unfortunately, because of this, potentially valuable information about these plants does not reach the people responsible for monitoring and controlling their spread. The collection of herbarium specimens greatly enhances the quality of invasions biology as a whole by providing study material for current and future studies (Carter *et al*., 2007).

5.4. How to contribute to expanding herbarium plant collections

A basic 3-step process is followed to prepare useful herbarium specimens.

1. Collecting (Fig. 26)
2. Preparation and pressing (Fig. 27)
3. Identification and mounting

5.4.1. Collecting

Selecting the material

When selecting plants for pressing it is important to bear in mind that it is preferable for specimens to have flowers and/or fruit included to aid identification (Leuenberger, 1987; Victor *et al*., 2004). A specimen consisting of sterile material accompanied by the correct information, however, is better than nothing and may be useful in providing pieces of the puzzle for a taxon as a whole. A specimen of, for example, an exotic plant should therefore be made regardless of whether the plant is flowering or not. Adding an illustration (drawing, photograph, print of an electronic image) to the specimen can considerably enhance its value.

In the case of smaller plants, it is best to collect the entire plant, including underground parts, while for larger plants, representative parts should be collected. These should include mature and immature parts, lower and upper leaves, buds and coppice shoots (Victor *et al*., 2004).

Collecting

Once you have selected a plant it is best to place it in a plant press immediately or, if that is not possible, in paper bags. The use of plastic bags is discouraged as it causes sweating in succulent plants, which results in the formation of mould (Burgoyne & Smith, 1998). Large specimens can be bent or cut before placing them in a press. In the case of fat-bodied plants such as cacti, both longitudinal and cross-sections should ideally be prepared, pressed and dried. Care should be taken when working with spiny plants and it is advisable to wear protective gloves. Some plants (like those in the Euphorbiaceae) contain irritant plant sap and contact with the skin, mucous membranes and particularly the eyes should be avoided.

Fruits and flowers, as mentioned, are often critical for correctly identifying plants. This is particularly true for many cactus species, where dissection of the flowers or fruits facilitates correct identification. It is therefore often useful, not only to press, but also to collect whole fruits and flowers. These may be preserved —pickled— in jars with 50–70% diluted ethanol (Leuenberger, 1987).

To prevent the further spread of exotic plants, special care should be taken that no seeds or reproductive parts of the plant is dispersed during and after collecting (Carter *et al*., 2007). This means not only the careful checking of equipment but also clothing and the bottoms of shoes, shoe laces and especially any velcro.

Auxiliary information

Ideally a specimen should be accompanied by photographs of the plant while still growing in its natural habitat. These are valuable complimentary identification tools that provide information on habit or other characters not always visible on dried, preserved specimens (Leuenberger, 1987).