Published as:
Schembri, P.J. & Lanfranco, E. (1996) Introduced species in the Maltese Islands. In: Baldacchino, A.E. & Pizzuto, A. (eds) *Introduction of alien species of flora and fauna.* [Proceedings of a seminar held at Qawra, Malta, 5 March 1996], pp.29-54. Floriana, Malta: Environment Protection Department; 77pp.

INTRODUCED SPECIES IN THE MALTESE ISLANDS

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INTRODUCTION

The aim of this paper is to review the situation regarding the introduction of non-native species of flora and fauna into the Maltese Islands and their surrounding waters. The introduction of non-native species is not a new phenomenon -- indeed it is a natural process in ecosystems, particularly island ones. Most oceanic islands are initially colonised by species coming from 'overseas'. Those invaders that manage to gain a foothold and survive to breed and spread, eventually become the native biota. Invariably this biota will evolve characteristics that adapt it to the particular environment it is now living in, which may be substantially different from that of its native environment. Some island populations will eventually become so different from their 'exotic' ancestors that they become new species in their own right -- species that occur only on the particular island on which they live, that is, endemic.

Continental islands, such as the Maltese Islands, are somewhat different since they may become connected to the continental mainland during sea-level lows, allowing easy access of mainland biota. During sea-level highs, the islands become cut off from the mainland and the biota becomes stranded. For example, in the case of the Maltese Islands, they received their initial biota when they were connected to the Sicilian mainland towards the end of the Miocene, and then became separated at the beginning of the Pliocene, some five million years ago (THAKE, 1985; GIUSTI *et al.*, 1995). For those species with limited powers of dispersal, the island populations continue to evolve independently of their mainland ancestors, and here too endemic forms may arise. Superimposed on this, there is an influx of those mainland species which manage to cross the water.

All intermediate stages between initial invader or coloniser and full endemic species exist, and the different degrees of adaptation and accumulation of unique characters are often given names: variant, race, ecotype, subspecies. Even after an island has accumulated a set of colonisers, the process does not stop there. Islands are dynamic systems, the rate of invasion slows down but never stops. New colonisers continue to arrive. For islands with a 'mature' biota, many of these invaders will not succeed in establishing themselves, however, some occasionally do. What happens then depends on the particular circumstances of the invader and the invaded ecosystem, as well as on chance. In general, the new invader may die out within a short time, or it may establish itself for a time and then die out, or it may find a vacant niche and spread, or it may compete for a niche already occupied by a native species. If it manages to outcompete the native, then it will displace it, and eventually cause its extinction from that particular ecosystem. Things are not really that simple, however, and there are other possibilities as well as intermediate cases.

If invasion by aliens is a natural phenomenon, especially on islands, why then the concern. This question can be answered at many levels, but the most basic is that whereas the rate of natural invasion is low for long-established ecosystems which are in equilibrium with their physical and biological environments, human agency has in many cases greatly increased the

rate of invasion by aliens, often to levels that are orders of magnitude above the norm. Moreover, human agency has also allowed invasion by species which, under ordinary circumstances, would probably never get the opportunity to invade. This may be an interesting biological experiment to some, but to others it represents the disruption of a system which has been shaped by thousands of years of evolution. In some cases it also causes the displacement and extinction of unique variants or races, resulting in an irreparable loss of genetic diversity. Even when the effect of invasion is not so drastic, it causes a reduction and dilution of the biotic complement of an ecosystem -- from the human point of view, a loss of the natural heritage. There are many other effects: invaders may be pathogenic, or they may act as vectors for pathogens, or they may become pests, or they may seriously compete with species of economical importance. The fact that introduced exotics are operating outside their normal ecosystems, and therefore outside the various brakes and checks which normally limit their population growth, means that the chances of uncontrolled irruptions are greatly increased.

We do not intend to review the whole question of introduced species or the associated ecological and evolutionary theory. Neither do we want to give a catalogue of species which have, or are presumed to have been, introduced into the Maltese Islands, or to treat in detail conservation aspects of the invader question. Rather, the purpose of this paper is to give an overview of the situation in the Maltese Islands in order to provide the background on which to base any further action.

DEFINITIONS

In the above paragraphs, deliberate use was made of a number of terms common in the literature on introduced species: introduction, invasion, alien, exotic, indigenous and many others. There does not appear to be universal agreement on the definition of these terms, in spite of a number of attempts. Often some of these terms are used interchangeably, leading to a certain amount of confusion, especially to workers outside the field. For this reason it is important to define the various terms as used in the present work.

An **indigenous** (or native) species is one which occurs naturally in a particular place, in our case, the Maltese Islands.

An **exotic** species is one which does not form part of the original biota of a defined geographical area.

An **introduced** species is an exotic which enters an ecosystem through human agency, whether the introduction is accidental or deliberate; according to this definition, those few exotic species which have reached the Maltese Islands through natural means (for example, the date palm *Phoenix dactylifera* which is apparently transported to the islands by birds migrating from North Africa [MIFSUD (S), 1995]) are not ‘introduced’ and are not considered further in this review.

An **adventive** species is an exotic which is capable of reproducing without deliberate human intervention outside its native range.

A **naturalised** species is an adventive which has become firmly established outside its native range.

A **casual** is an adventive species which establishes short-lived populations outside its native range or which only appears sporadically due to chance germination or, in the case of animals, of accidental imports which find their way outside their native range but which are unable to become established.

This term **alien** is used interchangeably for ‘exotic’ and ‘adventive’.

There are of course a number of problems with these definitions. One of the main ones is that the biota of the Maltese Islands, in common with that of most other islands now consists of species which reached the islands spontaneously, and those which were originally introduced

by man, but such a long time ago that they are now fully integrated in local ecosystems -- so integrated in fact, that had they to be removed, the ecosystem would suffer profound changes. In some cases, it is not even certain that these species were introduced by man, and it is only circumstantial evidence which suggest this. Clearly, such species are not comparable to recently introduced ones which are still not in equilibrium with the local ecosystem and which might never become integrated. Many such species are plants introduced in antiquity, and botanists refer to such species as **archaeophytes**. The next problem is of course when does an introduced species become an archaeophyte. The majority of European botanists accept the end of the 15th Century as the cut-off point. There does not seem to be an equivalent terminology for animals, although the term '**archaeozoic**' would suggest itself. Plants which have been introduced after the end of the 15th Century are referred to as **neophytes**; the equivalent term for fauna would be '**neozoic**'. It is interesting to note that one of the most successful aliens in the Maltese Islands, the prickly pear *Opuntia ficus-indica* was introduced to Andalusia on the return of Columbus' first expedition in 1493, and was rapidly diffused throughout the Mediterranean basin, including the Maltese Islands (LE HOUÉROU, 1992). Whether this species is considered an archaeophyte or not is a moot point.

A second problem is the special case of **Lessepsian immigrants**. These are those species of Indo-Pacific origin that entered the Mediterranean from the Red Sea through the Suez Canal when this was opened in 1869 (POR, 1978). This immigration is very interesting from the biogeographical point of view since it is practically unidirectional towards the Mediterranean. It has been termed Lessepsian after the French engineer and diplomat Ferdinand de Lesseps who was largely responsible for development of the Suez Canal. By definition, all Lessepsian immigrants are introduced species since they entered the Mediterranean through human agency, albeit indirect. To date, some 300 different species have penetrated into the Mediterranean and established themselves, mostly in the Levantine Sea, although a few have penetrated further west and some have reached Sicily and the Maltese Islands.

Lessepsian immigrants are not considered further here, except for those species which after their initial colonisation of the eastern Mediterranean then spread through human agency, for example, via shipping, the aquarium trade or through deliberate introduction.

MODES OF INTRODUCTION

There are many ways in which non-native species can enter ecosystems through human agency. In the particular case of the Maltese Islands the following mechanisms are known or are suspected to have operated.

- Deliberate introduction for agriculture and aquaculture

In the mid-1970s, attempts were made to start an aquaculture industry in the Maltese Islands. Apart from a private company culturing mussels and oysters, the University's Fort St. Lucian Marine Station set up experimental oyster cultures at Marsaxlokk Bay, Mistra Bay and Rinella. Species known to have been imported for these farms were *Mytilus galloprovincialis*, *Ostrea edulis* (both of which occur naturally in the Maltese Islands) and *Crassostrea gigas*; spat of the last two were imported from Anglesey, Wales (AGIUS *et al*., 1978). *Mytilus galloprovincialis* and *Ostrea edulis* occur in the Mediterranean, however, *Crassostrea gigas* is native of north-eastern Asia from where it has been transported world-wide for aquaculture purposes, including many sites in the Mediterranean (ZIBROWIUS, 1991). It is interesting to note that although all these aquaculture ventures came to an end in the late 1970s, specimens of *Crassostrea gigas* are still occasionally met with in the wild along the Maltese coast (MALLIA 1991), suggesting that this species has managed to establish small breeding populations locally. Similarly, practically all species of agricultural crops are met with as casuals growing on disturbed ground.The sulla *Hedysarium coronarium*, grown for fodder, is now firmly naturalised.

- Deliberate importation for commercial purposes

+ Ornamental plants

Use of ornamental plants goes back to antiquity. Some ornamental species, particularly those hailing from regions with a Mediterranean climate, may become more or less naturalised. Several examples of such escaped ornamentals exist in the Maltese Islands. The most notorious is the castor oil tree *Ricinus communis*, which has become firmly established and, apart from disturbed habitats, also invades watercourses and other natural communities.

+ The aquarium trade
Helisoma duryi is a freshwater planorbid gastropod whose natural range is the southern parts of the United States of America. It is extensively used in the aquarium trade and has been introduced into Brazil, Denmark, England, France, Spain, Italy, the Canary Islands, Israel, Northeast Africa, Egypt, Tanzania, Mauritius and Oceania; it has also been introduced into the Maltese Islands, presumably deliberately as an aquarium snail, but locally, apart from aquaria, it is found in private and public garden ponds, for example, at the Argotti Gardens in Floriana and at San Anton Gardens (GIUSTI *et al.*, 1995). In 1986, a large population of this species was discovered in the wild in the freshwater stream at Wied il-Luq, Buskett. This population was still thriving in 1987 but disappeared in 1988, probably because during the hot summer of that year the stream at Wied il-Luq dried up completely (GIUSTI *et al.*, 1995; SCHEMBRI [PJ], 1995). Another exotic freshwater gastropod, *Physa acuta,* now found in many natural freshwater habitats in the Maltese Islands, was probably also originally introduced as an aquarium snail (GIUSTI *et al.*, 1995).

● Deliberate importation for scientific purposes

+ Botanical gardens
Botanical gardens are perhaps the most important potential sources of plant (and animal) introductions, receiving, as they do, seeds and plants from all over the world. There is a tendency for some of these to escape within the precincts of the garden although very few (in the case of Malta) have managed to travel much further. Yet the two most widespread and troublesome weeds of the Maltese Islands owe their origin to this source. The cape sorrel *Oxalis pes-caprae*, now the commonest plant in the Maltese Islands, was introduced in the beginning of the 19th Century (HENSLOW, 1891) while *Aster squamatus*, probably the most successful weed, seems to have been introduced in the 1930s. In fact it does not feature in BORG's (1927) flora or its supplement (1936).

● Deliberate introduction for biological control programmes

The ladybird *Rodolia cardinalis* is a common species in the Maltese Islands (SCHEMBRI [S], 1993). This beetle was originally described from Australia and it has been imported into South Europe, North and South America, North and South Africa, Java, China and Japan, mainly as a biological control agent for scale insects. It was originally introduced into Malta from Portici (Naples) in 1911 in an attempt to control infested gardens at St.Julians (BORG [J], 1922; SCHEMBRI [S], 1993).

In the past ten years a number of exotic insects, mostly parasitic hymenoptera, were introduced as part of biological control programmes. These include *Dacnusa sibirica* and *Diglyphus isaea* for the control of leaf miners; *Encarsia formosa, Eretmocerus californicus* and *Macrolophus caliginosus* for the control of the sweet potato whitefly *Bemisia tabaci*, *Cales noacki* for the control of the citrus whitefly *Aleurothrixus floccosus*; *Orius Laevigatus*, *Orius insidiosus* and *Amblyseius cucumeris* for the control of thrips and, in the case of the last named, also for red spider mite; *Aphidius colemani* and *Aphidoletes aphidimyza* for the control of aphids in greenhouses; and *Phytoseiulus persimilis* for the control of red spider mite (MIFSUD [D], in press).

Another two exotic parasitic hymenoptera, *Encarsia lutea* and *Eretmocerus mundus*, have apparently been accidentally introduced with the exotic sweet potato whitefly *Bemisia tabaci*, itself accidentally introduced and now an established and important pest in the Maltese Islands (MIFSUD [D] *et al.,* 1995).

Bumble bees (*Bombus terrestris* [David DANDRIA, personal communication, 1996]) are also imported for use as pollinators (ZAMMIT, 1994). The only local species of bumble bee, also

Bombus terrestris, has apparently declined in recent years, to the point that in 1989 it was listed as vulnerable in the *Red data book for the Maltese Islands* (SCHEMBRI [S], 1989); now, however, the bumble bee population has increased again, probably due to augmentation by imported bees which 'escape' into the wild (David DANDRIA, personal communication, 1996).

● Accidental importation with other species

A number of important pests have been introduced in this way. Thus the cottony cushion scale insect *Icerya purchasi*, a dangerous pest of citrus and other fruit trees, first reached Malta from Sicily in 1907 with imported ornamental plants (BORG [J], 1922). Much more recently, a number of exotic pests have been accidentally introduced into the Maltese Islands, including the citrus whitefly *Aleurothrixus floccosus* introduced around 1985, the sweet potato whitefly *Bemisia tabaci* introduced around 1993, species of *Liriomyza* leafminers, the thrips *Thrips tabaci*, *Frankliniella occidentalis*, and *Phyllocnistis citrella* (MIFSUD [D], 1995;1996; David DANDRIA, personal communication 1996).

A number of exotic species which have now become established to varying degrees in the Maltese Islands appear to have been originally introduced with plants, or with soil or leaf litter, imported from overseas. For example, GIUSTI *et al.* (1995) list a number of species of terrestrial snails which they consider to have reached the Maltese Islands in this way, including: *Pomatias elegans* and *Discus rotundatus*, which are only found at San Anton Gardens; and *Vallonia pulchella* and *Cecilioides jani*, found in private gardens and in agricultural areas.

Gibbula cineraria is a common East Atlantic trochid gastropod occurring from Norway to Gibraltar. In the Mediterranean it only occurs in the extreme West along the Spanish coast where it penetrates through the Straits of Gibraltar. In 1976 two living adult specimens were collected from the floating cages of an oyster farm at Mistra Bay, Malta (SCHEMBRI [PJ], 1979). These specimens were very probably introduced with oyster spat, which was imported from Anglesey, Wales, where *Gibbula cineraria* is very common (SCHEMBRI [PJ], 1979).

Keeping aquaria has become a very popular hobby locally and a large number of aquatic species are imported to supply this demand. As invariably happens in such cases, accidental introductions also occur. For example, the authors know of a species of exotic freshwater parasitic leech and an exotic freshwater encrusting bryozoan, both as yet unidentified, that are frequently found in heated freshwater aquaria. Also frequent is the *Chantransia* stage of a red alga, possibly a species of *Batrachospermum*. A species of *Nymphula*, an aquatic moth of the family Pyralidae is occasionally imported with freshwater plants and temporarily establishes itself in tropical freshwater aquaria (Stephen SCHEMBRI, personal communication, 1996).

● Accidental importation with food or other natural products

+ Weeds imported with birdseed and crop seeds
Birdseed often includes a number of contaminant species. The birdseed species themselves escape, for example, canary grass, *Phalaris canariensis* is more or less naturalised, while foxtail millet *Setaria italica*, and common millet *Panicum miliaceum*, often occur as casuals. Among the contaminants one may mention *Centaurea diluta*, a western Mediterranean species, which has become more or less naturalised in disturbed areas at least since the 1960s. A putative hybrid between this and the native *Centaurea nicaensis* was seen once at Manoel Island. Most weeds of cultivated ground, such as species of *Amaranthus*, poppies *Papaver* spp. and cornflag *Gladiolus italicus* were originally imported with crop seeds.

+ Accidental importation with domestic animals
Given modern quarantine requirements for animals imported into the Maltese Islands, such an avenue of introduction is not very likely, however, in the past, certain exotic species appear to have been introduced in this way. For example, an exotic species of leech (according to SCHEMBRI [PJ], [1986] possibly *Limnatis nilotica*) used to occur in public animal drinking troughs at Birkirkara in the 1930s; these leeches originated from the inside of the mouth and nasal passages of cattle imported from North Africa which used these drinking troughs as they

were being driven in the streets (George ZAMMIT MAEMPEL personal communication in SCHEMBRI [PJ], 1986)

+ Accidental importation with ornamental plants
Importation of ornamental plants has increased greatly to meet the expanding demand. The imported plants often arrive with accompanying species. Most of these can only survive in a greenhouse. Some of the commoner accompanying species are *Cardamine hirsuta* (which also occurs, very rarely, as a true native), the liverwort *Marchantia polymorpha* and the mushroom *Leucocoprinus birnbaumii*. The most recently noticed 'import' is gallant soldier *Galinsoga parviflora*, which seems to be a good candidate for naturalisation on disturbed ground. Exotic animals are also sometimes imported with ornamental plants, for example, the giant terrestrial flatworm *Bipalium kewense* (LANFRANCO [E], 1975).

+ Accidental importation with wood products
Imported wood, either as logs, firewood or timber products seems to be an excellent vehicle for transporting exotic species into the Maltese Islands. For example, SCHEMBRI [S.] & SAMA (1986) list at least four species of cerambycid beetles apparently imported into the Maltese Islands with wood products, including: *Rosalia alpina*, a European species whose larvae feed on beech, imported with ash logs (BORG [J], 1939); *Morimus asper*, a common Italian species whose larvae feed on poplar and elm, imported into the Maltese Islands with firewood at Marsa (BORG [J], 1939); and *Cordylomera spinicornis*, a West African species collected from Santa Venera from imported logs (SCHEMBRI [S.], 1975). It is interesting to note in passing that some cerambycid beetles are serious pests of cultivated trees, for example, in the Maltese Islands, species of *Cerambyx* (BORG [J], 1922; SALIBA, 1963; SCHEMBRI [S.] & SAMA, 1986).

Recently, from a consignment of tropical logs imported from Africa, four species of Nititulidae, one of Cerambycidae, one of Bostricidae (all Coleoptera) and one of Sirphidae (Diptera) were collected.

● Accidental introduction due to shipping.

This can occur in two ways: (1) sessile species foul the hulls of ships, drilling platforms or other structures, and vagile species cling to the fouling communities; such species are transported to new environments with the ship or with towed structures; and (2) species which are taken on board with ballast water and are then liberated into a new environment when the ballast is discharged.

+ Fouling
Megabalanus tintinnabulum is a large species of barnacle which is an important fouling organism on ships' hulls, and which is frequently found on vessels entering the Mediterranean from the Atlantic; it is common on ships entering the Malta dockyards for repairs, but it has never been found in the wild in local waters. There are a number of geographical races of *Megabalanus tintinnabulum* and the one which has been found on ships entering Malta is *Megabalanus tintinnabulum tintinnabulum*, whose natural area of distribution is the Atlantic coast of Africa from Gibraltar to Capo di Buona Speranza (RELINI, 1980).

+ Ballast
In 1977 two species of marine bryozoans not previously recorded from the Mediterranean were discovered fouling the cages of an oyster farm at Rinella (AGIUS *et al*., 1977). One of these, *Celleporaria pilaefera* is an Indo-West Pacific species, while the other, *Celleporaria aperta*, has a world-wide warm-water distribution. It is thought that both species reached the Maltese Islands via shipping, especially since Rinella is located in the most important harbour in the Maltese Islands.

Prionocidaris baculosa is a sea urchin which occurs in the Indian Ocean where it is very common. In 1976 an adult specimen was collected from the ballast tank of a ship undergoing repairs in the Malta Dockyards (SCHEMBRI [PJ], 1978). It seems certain that larvae of this species entered the ship's tanks when this took on ballast water, presumably in the Indian Ocean, and these larvae then metamorphosed and grew in the ballast tank.

- Accidental importation with cargo

A documented case of introduction of an exotic species with cargo is the following. A lizard identified as *Agama agama* was found hiding amongst crates of imported beer being unloaded from a lorry at Marsa in 1979; a second as yet unidentified specimen of *Agama* also probably introduced with cargo is presently at the National Museum of Natural History (SCHEMBRI & SCHEMBRI, 1984). *Agama agama* is a native of Africa where it is a common and widespread species and where it lives in dry rocky habitats with low-growing vegetation often close to built-up areas. Such habitats are common in the Maltese Islands and it is quite possible for this species to establish itself locally as has happened in the case of the chameleon and, as some authorities think, in the case of the Algerian whip snake *Coluber algirus* and the cat snake *Telescopus fallax.* According to BORG [J] (1939) both species were introduced into Malta with shipments of firewood during the first World War and became established in the vicinity of the then fuel-yard at Floriana. However, the evidence for introduction is mainly circumstantial: for both species Malta is outside the main area of distribution, and locally early records were from Northeast Malta, where Floriana is situated. On the other hand, both snakes have retiring habits and easily confused with other species, so they may have been more widespread than thought and the cat snake at least may possibly be indigenous (SCHEMBRI [PJ], 1984).

- Discarding into the environment of deliberately imported species.

Examples of exotics introduced in this way include mosses and algae (together with accompanying microscopic biota) used as packing material, and species used as live bait for fishing, or as live food for captive animals. Larvae of the beetle *Tenebrio molitor* imported as live food are known to have been discarded into a local valley, whereas dried (but still living) mosses are imported for use as 'vegetation' on Christmas cribs and are then discarded after the crib serves its purpose. These last are unlikely to ever establish themselves since most of the species involved require acidic substrata and colder winters.

In June 1964, a British services medical officer released three eyed lizards, six European green lizards and two Greek tortoises in Gozo in an attempt to naturalise them (LANFRANCO [G], 1964). None of these managed to become established.

- Escape from captivity, for example from menageries or aquaria.

There are no known Maltese examples of this, although the chameleon (*Chamaeleo chamaeleon*) may qualify. However, a recent spectacular case is that of the green alga *Caulerpa taxifolia*. This tropical species apparently escaped from the aquaria of the Oceanographic Museum in Monaco around 1985; it has since spread to colonise the coasts of France and Italy (MEINESZ & HESSE, 1991) and, more recently, Spain and Croatia (ANON, 1995).

In 1955 some individuals of the snake *Natrix natirx persa* were found at Floriana a couple of weeks after an Italian circus troupe which had been performing in the area had left (Guido LANFRANCO, personal communication, 1996).

- Expansion of the range of Lessepsian immigrants.

The phenomenon of Lessepsian immigration has already been discussed. A number of Lessepsian immigrants now occur in Maltese waters and it is not clear whether this represents a natural expansion of their Mediterranean range or whether they have been transported to the central Mediterranean through human agency.

The best known example is that of the sea-grass *Halophila stipulacea.* This Red Sea species is thought to have entered the Mediterranean after the opening of the Suez Canal in 1869 and has since spread westwards, possibly partially under its own steam but very likely aided by shipping. It reached the Maltese Islands around 1970 (LANFRANCO [E], 1970) and more recently, the eastern coast of Sicily (BILIOTTI & ABDELAHAD, 1990).

A less known example from the animal kingdom is *Bursatella leachi,* a large opisthobranch gastropod common in the Red Sea. This species was first recorded from the Mediterranean

(Turkey) in the early 1960s (SWENNEN, 1961) where it has now successfully colonised the entire eastern basin as far west as Sicily and Malta (ZIBROWIUS, 1991). The first specimens recorded from the Maltese Islands were collected from the Grand Harbour in 1969 (BEBBINGTON, 1970).

CHARACTERISTICS OF ALIEN SPECIES

Invasion of an ecosystem by exotic species proceeds in four phases: (1) arrival; (2) establishment; (3) spread; and (4) persistence (MOLLISON, 1986). The different modes of arrival have been discussed above. Not all exotic species which arrive into a new ecosystem establish themselves; in fact most introduced species never do. Similarly, not all exotics which establish themselves spread; many remain limited to marginal habitats. Again, it is very few exotics which manage to persist for long periods of time (millennia). Is there any way of predicting the potential of any given exotic species for successful establishment and spread?

Successful invaders do appear to share a number of characteristics. According to WILLIAMSON & BROWN (1986) these include: (1) the absence of natural enemies; (2) a large capacity for dispersal; (3) an opportunistic life-history strategy (i.e. r-strategy); and (4) the presence of an ecological niche which is unoccupied. (For a more comprehensive list, see DI CASTRI, 1990.) Although it is not necessary for all these conditions to be met for an introduced species to become established, they do permit us to predict which species are more likely than others to become established and to take precautions against this happening, the most obvious one being not to allow such species to enter in the first place.

Perhaps one of the best local examples of species which satisfy all these criteria and which are very successful aliens are rats. Two species occur: the brown rat *Rattus norvegicus* and the black rat *Rattus rattus*. The former is a native of southern Asia and the latter of Southeast Asia, however, they have been introduced world-wide by man (MICHAUX *et al*., 1990). In the Maltese Islands both species seem to have been introduced sometime between the late Bronze Age and Phoenician times, the black rat appearing first, followed by the brown rat (STORCH, 1970). The dispersive abilities and opportunistic nature of both species are well known; locally no equivalent animal has been found in Holocene deposits so presumably the niches currently occupied by the two species were empty, and, being of Asian origin, these species are presumed to have had no natural enemies in local ecosystems, or if they did, the rats' high biotic potential would render these controls unimportant .

To the four characteristics listed above may be added another one: many successful introductions appear to have first occurred in ecosystems which are not in equilibrium or which are stressed, for example, agroecosystems, habitats suffering from periodic disturbance, habitats undergoing succession, harbours, lagoons, estuaries and polluted environments. Most such ecosystems tend to have a low diversity and weak interspecific interactions, and seem to be more susceptible to invasion than species-rich systems with well established species interactions. Again, this observation provides a clue as to which ecosystems are particularly prone to invasion and to keep a lookout on such habitats.

In fact a large proportion of the flora of disturbed areas is made up of presumed exotic species. Some species are not very particular as to the type of habitat, examples being *Oxalis pes-caprae* and *Aster squamatus*, although the latter has a preference for soils which are relatively humid and which are somewhat sheltered. These are the type of plants which are most likely to invade natural habitats as the species mentioned have indeed done. Other species are more particular. Thus *Nicotiana glauca* grows almost exclusively on building rubble and in rubble filled crevices. Such species are environmentally 'safe' although *Nicotiana* occasionally has some nuisance value when it grows in the crevices of walls and fortifications. Disturbed areas close to the sea are the preferred habitat for the tree mallow *Lavatera arborea*, which is a native of the Mediterranean area but most probably an introduction insofar as the Maltese Islands are concerned. The tree mallow does not seem to pose an environmental problem, however the kaffir fig *Carpobrotus edulis*, a South African succulent widely cultivated as a ground cover, often 'escapes' from disturbed areas and can grow on cliffs, which are possibly the most important habitat in the Maltese Islands. Many

exotics are associated with cultivated fields and large gardens. These include several species of *Amaranthus*, natives of the Americas, which have increased considerably over the years. Again such species seem to be environmentally 'safe' but, of course, pose problems from the point of view of agriculture.

Of natural ecosystems, some are by nature highly labile and/ or are much subject to human interference. A particular case in point are the valley watercourses, all of which are highly disturbed. This has resulted in a considerable loss of indigenous biodiversity but has permitted the establishment of some adventive species. Notable examples are *Xanthium strumarium* which forms dense populations at Wied il-Qlejgha, and *Paspalum paspaloides* in places such as Wied il-Lunzjata (Gozo), Marsa and San Martin. Saline marshes are likewise subject to much human intervention and some have been invaded by weedy species, most especially the ubiquitous *Aster squamatus* which seems to have a high salt tolerance.

Invaders, or at least plant invaders, appear to have a somewhat extended latent period from the time of their introduction to the time when they become invasive (see LE FLOC'H [1991] and examples therein). This means that an alien, which may barely have established a foothold and which is unimportant now, may become invasive later if environmental conditions change.

EFFECTS OF INTRODUCED SPECIES

There is now a vast literature on the effects of introduced species on the host ecosystem. Most introduced species do not become established and therefore have no effect on the host ecosystem; SIMBERLOFF (1981) estimates that some 80% fall in this category. For those that do become established, it is customary to describe their effect as positive or negative, however, it must be kept in mind that 'positive' and 'negative' refer to the human perception of things -- for the introduced species, any range expansion or increase in population is positive and for a species that suffers a reduction in population size no matter how small, as a result of the introduction, the effect is negative.

In some cases the introduced species finds an unoccupied niche in the host ecosystem and integrates well with the existing communities, without causing any apparent disruption to existing biodiversity or ecosystem processes. Such an introduction may be called 'neutral'. A Maltese example of such a neutral introduction is that of the Mediterranean chameleon (*Chamaeleo chamaeleon*). The local population owes its origin to Protestant ministers who some time between 1846 and 1865 brought specimens from North Africa, presumably as 'pets', and released them in the gardens of a large house at St.Julians, which later became the Jesuit College of St.Ignatius; this house no longer exists but from St.Julians the chameleon has spread and it now occurs in the wild all over Malta and also in Gozo (GULIA, 1890; DESPOTT, 1915; BALDACCHINO & SCHEMBRI, 1993). This internal spread was partly natural and partly due to man as the chameleon has a high curiosity value and is frequently taken when encountered and kept as a 'pet'. At one time it was also sold in the Valletta open air market and elsewhere. Given the large number of persons based in Malta but who regularly work for long period in North Africa, it is also possible that there have been multiple introductions of this species. The chameleon is now a fully naturalised and established species in the wild and in some parts of the islands it is actually a common species. Its introduction does not seem to have had any negative impact on local biota or ecosystems. This is probably because there is no other local species which occupies its arboreal niche.

It must be kept in mind that even though the introduction is neutral in the sense explained above, it still represents a contamination of local biodiversity with a foreign element, even if the element in question here is a Mediterranean species that occurs on the mainland nearby and which may conceivably have reached the islands autonomously at some time in the future. Some people might also argue that local biodiversity may be augmented or 'improved' by finding vacant niches and introducing 'neutral' species. (Many suggestions for deliberately introducing species into the Maltese Islands in order to 'improve' our biota have been made, for example see VON BAUMGART-PSAYLA, 1985). Such a course of action is dangerous. Quite apart from the controversial issue of whether the natural complement of species

occurring locally needs to be improved or not, our knowledge of the functioning of local ecosystems and of their component niches is too fragmentary to allow us either to decide which niches are vacant or not, or to predict the end result of any such introduction into a supposedly vacant niche, particularly since the introduced species may turn out to occupy a different ecological space in its new environment than that in its home environment where it is subjected to a vastly different set of interspecific interactions and possibly also physical factors.

The introduction of an exotic species into an apparently vacant niche may turn out to have quite unexpected effects. The literature is replete with examples of well-intentioned introductions which have turned out to be total disasters. One such is the cane toad *Bufo marinus* introduced into Australia to control insect pests in the canefields of Queensland. The toad had no significant effect on the pests but became a voracious predator of native insects, lizards, snakes and small mammals, as well as a threat to native predators due to its poisonous skin secretions; it is now widely distributed in north-eastern Australia and is considered a serious pest (COMMON & NORTON, 1992).

The case of New Zealand is particularly instructive. New Zealand has no native mammals, except for bats, and birds occupied all the ecological niches which mammals occupy elsewhere. Once New Zealand was settled by Europeans, numerous so called acclimatisation societies were established. These organised the shipment of animals into New Zealand, looked after them on arrival, and distributed them round the country. The objective of these societies was to 'enrich' the land, which had very few fauna familiar to Europeans, with animals. Thus, red deer and hares were introduced in 1851, rabbits and fallow deer in 1864, and hedgehogs in 1870; in 1867 ferrets were introduced in order to keep the rabbit population down! (O'BRIEN, 1981). By the early 1880s, rabbits had become a major pest and stoats, weasels and more ferrets were imported in an effort to control them (O'BRIEN, 1981). Many other animals were deliberately introduced over the years; some did not establish themselves, but others have become naturalised and are now common. This massive invasion of exotic species into the country had a profound effect on the native ecosystems and biota: vegetation communities have been highly modified by grazing, the invertebrate fauna has become depleted, populations of native freshwater fish, amphibians and reptiles have declined, and a large number of native birds have either become extinct or are severely endangered (O'BRIEN, 1981). Australia has a similar history (GROVES & BURDON, 1986). It is perhaps significant to note that these two countries now have the strictest controls on the introduction of exotic species in the world!

It should also be emphasised that chance plays a significant role in determining the fate of an introduced species (DI CASTRI, 1990); often circumstances combine to favour the establishment and spread of introduced species in ways which are impossible to predict. An illustrative example of this is the case of the faya tree (*Myrica faya*) in Hawaii (VITOUSEK, 1986; BEARD, 1990). This tree is a native of Madiera, the Azores and the Canary Islands and it was introduced into Hawaii by immigrant workers in the 1920s. The faya has escaped from cultivation and has become a pest as it outcompetes native species of flora, particularly the ohia tree (*Metrosideros polymorpha*) and its complex of understory shrubs. There are several reasons for the successful establishment of the faya. One is that this species is well adapted to live in nitrogen-poor volcanic soils as it has symbiotic nitrogen-fixing bacteria in root nodules, unlike the native ohia; the faya is also faster growing than the ohia and it produces allelochemicals which inhibit the growth of other vegetation in its vicinity. Another reason for the success of the faya is that its seeds are dispersed by the Japanese white-eye, an Asian bird which was brought to Hawaii as a cage-bird during the early part of the century and then escaped and rapidly established itself in the wild. White-eyes eat the berries of the faya tree and pass the seeds undigested when they perch on trees and shrubs. Thus they deliver the seeds to the most suitable place for germination, in the shade of ohia trees. Such unpredictable interactions between different aliens are by no means uncommon. Also in Hawaii, the alien trees strawberry guava (*Psidium cattleianum*) and banana poka (*Passiflora mollissima*) are dispersed by feral pigs (SMITH, 1985), while in the Galapagos Islands, the introduced common guava (*Psidium guajava*) is dispersed by introduced cattle (BRAMWELL, 1979). The fleshy fruits of these trees are eaten by pigs or cattle who pass the seeds undigested through their guts and deposit them with their faeces, thus providing them with organic fertiliser; in the case of pigs, their rooting activities also clear away vegetation thus the

seeds of the aliens are delivered to a most suitable place for germination (SMITH, 1985). All three species of aliens displace the native flora.

Some introductions are beneficial from the human point of view, where beneficial usually means economic benefit. For example, in the Levant Sea, Lessepsian immigrant fish now account for some 13% of the fish fauna of the region; some of these are commercially important and Lessepsian immigrants accounted for about 16% of the Mediterranean fish catch of Israel during 1980-1982 (BEN-TUVIA, 1985). Similarly, the Lessepsian immigrant prawns *Penaeus japonicus* and *Penaeus monoceros* now make up most of the prawn catches along the Egyptian and Israeli coasts (GALIL, 1986).

Maltese examples of such 'beneficial introductions' abound. Practically all deliberate introductions into the Maltese Islands were made because whoever was responsible for the introduction perceived some benefit. The following are some examples.

All species of crops were originally exotic. Although many crop species, particularly herbaceous ones, have been so modified by cultivation as to be unable to compete in the wild, practically all have been reported as casuals and some may be nearly or completely naturalised. An example is the sulla *Hedysarum coronarium*, itself a true native of the Mediterranean, which is widely grown as a fodder crop. It has also escaped and is now one of the dominant species of clay slopes. Also, it is not unusual to find tomatoes *Lycopersicon esculentum* growing wild, while some of the less common crops tend to make successful colonisers, an example being the camomile *Matricaria recutita*. Woody crops tend to be less modified by cultivation and thus may become fully naturalised. Most archaeophytes fall in this category, indeed hardly any useful tree which now grows wild is really indigenous. This includes the carob *Ceratonia siliqua,* fig *Ficus carica,* and almond *Amygdalus communis*. Sisal *Agave sisalana* was introduced in 1900 for a short-lived sisal industry, and mulberry *Morus alba,* was introduced to breed silkworm and supported a cottage industry (BORG [J], 1915; 1927; BORG [B], 1959). The sisal has become fairly well naturalised but the mulberry only rarely spreads by natural means.

Prickly pear *Opuntia ficus-indica* was introduced into the Maltese Islands around the beginning of the 16th Century for its fruit and for use as a fodder and hedge plant. This species has become fully naturalised and has escaped from cultivation is some places, especially where agriculture has been abandoned. The main environmental problem is that it readily colonises maquis communities and, more seriously, cliffside communities, which carry most of the endemic and Tertiary elements of the flora.

The marine equivalent of the importation of crop species is the importation of species for aquaculture. The importation of *Mytilus galloprovincialis*, *Ostrea edulis* and *Crassostrea gigas* for aquaculture trials (AGIUS *et al*., 1978) has already been mentioned. Other imported species currently being cultured in Maltese waters are sea bass *Dicentrarchus labrax* and sea bream *Sparus aurata* (MEILAK, 1995). ZIBROWIUS (1991) has given a thorough review of alien species introduced into the Mediterranean as a result of aquaculture. Exotic species have also been introduced into the Maltese Islands with aquaculture organisms (see above), more will probably be in the future.

Domestic animals are also imported, although in the case of 'traditional' species this has been going on since antiquity. Thus BOESSNECK & KÜVER (1970) report the remains of goat, sheep, cattle, pig, cat, pigeon and chicken from the prehistoric layers of the Ghar Dalam deposits. Some of these domestic animals have had a profound effect on local ecosystems, even if technically they have remained in captivity (for example, goats and to a lesser extent sheep through their grazing and browsing activities respectively [see below]); others have escaped from captivity and have established feral populations (for example, the rabbit) with equally severe effects (see the case of St.Paul's Islands, below). New types of domestic animals are occasionally imported. For example, some years ago a consignment of giant African snails *Achatina* sp. was imported to start a snail farm. The potential for escape, with all the associated problems always exists.

Importation of ornamental plants is one of the main sources of recruitment for potentially adventive species. The species causing most problems is castor oil *Ricinus communis,* but numerous other species can be mentioned including tobacco tree *Nicotiana glauca*, and the common hedge shrub *Pittosporum tobira*, which is now firmly naturalised and on the increase, especially in garigue communities on karstlands between Sliema and St. Pauls Bay. Herbaceous ornamentals such *Freesia refracta*, *Chasmanthe aethiopica*, marvel of Peru *Mirabilis odorata* and *Mirabilis jalapa,* and garden nasturtium *Tropaeolium majus* are also naturalised.

Trees used in afforestation can have considerable impact on the ecosystem irrespective of whether or not they become naturalised. The main problems have been caused by the blue wattle *Acacia cyanophylla*, which was planted extensively during the 1960s and 70s, often in natural habitats on slopes and along valleys. The acacia is capable of regenerating from seed and has also become invasive. The ecologically important sand dune of Ghadira has been practically obliterated by the spread of this species. Species of eucalyptus, particularly *Eucalyptus camaldulensis* and *Eucalyptus gomphocephala* have also been planted extensively, again in natural contexts. Although there are no reliable records of eucalypts regenerating from seed or otherwise, they are still ecologically harmful because they drain soil water and because their leaf litter prevents other species from growing due to chemical exudates.

Ornamental street trees do not usually have a direct impact on natural ecosystems. Some, however, have escaped. Thus the tree of heaven *Ailanthus altissima*, is naturalised in several disturbed areas while false pepper *Schinus terebinthifolius* is now firmly naturalised in a few localities such as Wied Harq Hamiem (STEVENS, 1995) and Wied il-Lunzjata (Gozo) and seems to be steadily increasing. *Pistacia atlantica*, originally imported as a stock for pistachio nut *Pistacia vera*, has also escaped and tends to grow on fortifications.

Another example of beneficial introductions are organisms used for biological control. Maltese examples have been discussed above. There is no evidence that any of these have caused any problems in local ecosystems, although no form of assessment of ecological impact has been made.

Some introductions are of course necessary and nobody would argue that crop plants or domestic animals or aquaculture species should be extirpated from the islands simply because they are not part of the indigenous biota, or that for the same reason no biological control agents or ornamental plants or other economically important species should be introduced. On the other hand, some species introduced for economic reasons do have the potential for causing great disruptions to existing ecosystems should they be introduced into the wild or escape from captivity. Luckily there are no local examples of this (although the goat may qualify) but examples from elsewhere are plenty. A classical example is that of the rabbit *Oryctolagus cuniculus*, originally a native of Spain, that was introduced into Australia with devastating results (MYERS, 1986).

The point therefore is that economic benefit alone is not an overriding criterion for introduction. New crop species, domestic animals, pets, ornamental plants, biological control agents and other beneficial species should only be introduced after an assessment of the risks involved is made. For example, rabbits are certainly beneficial as edible animals, but would it be advisable to re-introduce rabbits into St Pauls Islands (from where they have apparently been exterminated due to a disease epizootic) given the huge effect they have on the vegetation, and hence the whole ecosystem, of these islands? In fact, since rabbits were eliminated from St Pauls Islands, the vegetation has started to proceed up the successional series.

Introduced species could also have negative effects on the host ecosystem. There is probably more literature on this aspect of introductions than on any other, which is hardly surprising since people are usually alerted to the effects of introduced species when the ecosystem around them starts changing and they are adversely affected by the change. Examples of such negative impacts on local ecosystems include the following.

A number of serious agricultural pests have been introduced into the Maltese Islands over the years (for examples see BORG [J], 1922; SALIBA, 1963; MIFSUD [D], 1995). Two such

recent introductions are the citrus whitefly *Aleurothrixus floccosus* introduced around 1985, and the sweet potato whitefly *Bemisia tabaci* introduced around 1993; the former has become an important pest of citrus trees in the Maltese Islands, while the latter is a serious pest of tomatoes and other greenhouse crops since it is a vector for the tomato yellow leaf curl virus (TYLCV) as well as other viruses (MIFSUD [D], 1995; David MIFSUD, personal communication 1996; David DANDRIA, personal communication 1996).

The Argentine Fire Ant *Iridomyrmex humilis* is a widespread species, occurring on all three main islands of the Maltese group, and one whose distribution seems to be extending SCHEMBRI [S.] & COLLINGWOOD (1981). That this is an introduced species into the Maltese Islands is not in doubt, however, it is not known when it arrived, from where, and how. This species originated from Argentina but it has now been introduced into numerous countries in many of which it has become a serious pest; for example, in the Hawaiian islands, this ant has been shown to have negatively affected the endemic arthropod fauna (LOOPE, 1995), while in the United States it damages crops and destroys native ant species (EHRENFELD, 1970). The effects of the Argentine Fire Ant on local ecosystems is not known because no studies have been made. However, given that locally it is a common and widespread species, that its mode of life is very similar to that of a number of indigenous ant species, and that it is known to be a successful competitor, it is likely to have had some impact and there are some indications that it has displaced native species of ants (SCHEMBRI [S.],1984). One of us (EL) in fact enumerated eight different species of ant from his garden before *Iridomyrmex humilis* gained a foothold in the 1960s to early 70s and eliminated all these in a period of less than 10 years.

The goat was introduced into the Maltese Islands in antiquity (remains of goat were recovered from the prehistoric layers of the Ghar Dalam deposits [BOESSNECK & KÜVER, 1970]). As in other Mediterranean countries, this animal has had a profound effect on the natural vegetation and the ecosystems of the Maltese Islands, being responsible for degrading the landscape, impoverishing the flora (and consequently the fauna), and increasing runoff and erosion due to its browsing activities. The goat is a highly adapted browser with a remarkable agility, flexible diet, a relatively low water need, and a specialised digestive tract which allows it to thrive on low-quality browse which cattle or sheep would not be able to survive on (LE HOUÉROU, 1981). With the changing socio-economic situation in the Maltese Islands during the past fifty years, goat herding has become much less important, and now virtually inexistent; this has had a beneficial effect on the vegetation which is regenerating in over-browsed areas and in others is developing from steppe to garigue or maquis (SCHEMBRI & LANFRANCO, 1993).

Oxalis pes-caprae, the cape sorrel, is a native of South Africa and was introduced in the Maltese Islands towards the beginning of the 19th Century allegedly by Carlo Giacinto (Carolus Hyacinthus), a Genoese carmelite monk who was also curator of the botanical gardens at Floriana. This plant escaped and within a few decades had also escaped from Malta and become naturalised throughout the whole Mediterranean coast (HENSLOW, 1891) and subsequently along the Atlantic coast as far north as South Devon (STACE, 1991). The main environmental problem is that Cape sorrel has insinuated itself into natural ecosystems and has possibly been the cause of the reduction in populations of certain local species. Strangely enough, an endemic variant of a small broomrape, *Orobanche muteli* f. *melitensis*, originally a parasite of a variety of legumes, switched host and now grows almost exclusively on the roots of cape sorrel.

Aster squamatus, a native of the Americas, seems to have escaped from the Argotti Gardens (personal communication from the late Carmelo PENZA, head gardener at Argotti), possibly in the late 1930s, seeing that BORG [J] (1927) does not include it in his flora or its supplement (1936). It is now one of the most common weeds in the Maltese islands.

Ricinus communis, the castor oil tree, was originally imported sometime in the 19th Century as an ornamental and, possibly, because of its medicinal value. It has now become one of the most problematic weeds since it tends to invade valley watercourses where it competes very effectively with the indigenous vegetation.

Some introduced species, although not presently a nuisance, have the potential for becoming so. For example, *Crepidula fornicata* is a marine prosobranch gastropod native to the Atlantic coast of North America. From there it was introduced with oysters to the southern coast of England from where it spread, mainly as a result of transport of oysters, to colonise the western coast of Europe and the northern shores of the western Mediterranean (ZIBROWIUS, 1991). This species is a serious nuisance to oyster and mussel cultures since it competes with these bivalves for space and food. In 1973 a beached specimen of *Crepidula fornicata* was collected from Marsaxlokk Bay, and in 1975 live specimens were collected with oysters from Marsamxett Harbour (CACHIA, 1981). CACHIA presumed an accidental importation by shipping, however, importation with oysters and mussels used for aquaculture is also possible. At present, *Crepidula fornicata* seems to occur at low population densities in Maltese waters, however, if bivalve cultures become important locally, this species has the potential to become a serious pest, as has happened elsewhere.

CONCLUSION

The introduction of exotic species into ecosystems, whether deliberate or accidental, has been a side-effect of human expansion probably since the earliest of times. In the Maltese Islands, exotic species have certainly been introduced since the islands were first colonised. For example, the 'cultural layers' of the Ghar Dalam deposits have yielded the remains of black rat, brown rat, house mouse, cattle, sheep, goat, pig, cat, and chicken, amongst others (BOESSNECK & KÜVER, 1970; STORCH, 1970; 1974), while the remains of wheat, barley and lentils were found in deposits from the Ghar Dalam phase of Maltese prehistory (HELBAEK, 1966).

Locally, the trend is for this phenomenon to increase as commercial activity increases, transportation becomes more efficient and accessible to a wider variety of people, and the general standard of living increases -- it appears that many people have acquired a taste for keeping exotic fauna and flora (for example, the Environment Protection Department has received applications for the importation of more than fifty different species of exotic animals, mostly reptiles and amphibians but also spiders, scorpions, land crabs and others, since regulations concerning trade in species of fauna and flora came into force in 1992 [Alfred E. BALDACCHINO, personal communication, 1996]).

Of the hundreds of species which have been introduced into the Maltese Islands over the millennia, relatively few have managed to establish themselves and become fully naturalised. Some of those that have become adventive, however, have had significant impacts on local biota and ecosystems. These serve as examples of what could happen to the presently existing ecosystems if new exotic forms invade and establish themselves.

Generally, undisturbed ecosystems are inherently resistant to invasion by exotics (MOONEY & DRAKE, 1987; DI CASTRI, 1990), and LE FLOC'H (1991) has shown this to be true also for Mediterranean ecosystems. However, this capacity is reduced in ecosystems which are disturbed, especially if the disturbance is frequent and rapid (DI CASTRI, 1990). This is usually the case with human activity and for Europe it has been shown that the number of neophytes in different areas is strongly correlated to the intensity of human activity (SYKORA, 1990). Anthropogenic activity as an ecological factor is especially important where ecosystems and habitats are small-scale and therefore easily affected even by minor interventions, such as in the Maltese Islands. Most exotic species which have become established in the Maltese Islands have first gained a foothold in such disturbed ecosystems, for example, in inhabited areas, in gardens, in fields, in land cleared of its natural vegetation cover, and in harbours. Disturbed and stressed ecosystems are therefore the ones to watch especially for initial establishment of exotic species.

Given that the opportunities for exotic species to reach the Maltese Islands have increased, and that many local habitats are disturbed or stressed, the chances of an invading exotic successfully establishing itself are now much greater. The fact that the number of naturalised exotics in the Maltese Islands is less than in most areas of the Mediterranean, should not lead to complacency. This is possibly due mainly to the low water availability and secondarily to the

high soil pH, however, there are many species being introduced whose own native habitats show these characteristics.

Two principles should guide local authorities concerned with preservation of local biodiversity: the principle that prevention is better than cure, and the precautionary principle. Once an exotic species becomes established, it is very difficult to remove; it is therefore better to be proactive and prevent establishment, rather than to be reactive and try to eliminate invaders after establishment. The precautionary principle suggests that in the absence of certainty, it is best to err on the side of caution. Thus an exotic species which has established itself elsewhere in the Mediterranean region may or may not do the same if introduced locally, however, it is best not to take the chance!

Nothing new is being said here because such actions are regularly taken locally with respect to agriculture and animal husbandry. Thus imported plants require a phytosanitary certificate and some imported animals require to be kept in quarantine. While such measures are mainly aimed at preventing the introduction of diseases or pests affecting domestic plants and animals and at protecting human health, it is now also important to protect local biodiversity and ecosystems. Existing regulations therefore need to be augmented and extended accordingly.

What is done is done -- long established introduced species are now part of the ecosystem, no matter whether this is perceived as positive or negative and are difficult or even impossible to eliminate. It is not being suggested that archaeophytic and archaeozoic species should be eliminated, as they now form an integral component of local biodiversity. Neither is it being suggested that long-established species (although not archaeophytic and archaeozoic) that have no observable negative effects on the ecosystem should be eliminated (e.g. chameleon, introduced snakes, some plants). However, in the case of recently introduced species which are having clear-cut negative effects and which have still not gained a strong foothold on the islands, removal is possible and should be pursued.

It is important to select those exotics which are capable of invading natural communities and to devise ways of controlling them. Particular attention should be paid to species of plants native to regions with the Mediterranean type of climate (e.g. Cape Province of South Africa, south-western Australia, central California, central Chile). If introduced such species are more likely to become invasive aliens than others as they are already pre-adapted to the climatic regime prevailing in the Maltese Islands. Indeed, some of the most successful aliens which have become established locally originated from Mediterranean-type climatic zones, for example *Oxalis pes-caprae* and *Carpobrotus edulis* (both from the Cape Province of South Africa), and *Acacia* spp. and *Eucalyptus* spp. (both from Australia).

In some cases (e.g. *Oxalis pes-caprae*) eradication of exotics may seem an impossible task but perhaps a study of the ecology of the invader may reveal means of biological control (for example, in the case of *Oxalis pes-caprae* by encouraging growth of the broomrape which parasitises it). In other cases, invasive species may be selectively removed. Thus *Carpobrotus edulis* poses a threat to cliff communities - which are those that are floristically the most important and most intact - and should be removed from such sites. Care should be taken not to plant exotic species in or immediately adjacent to natural communities.

Removal of such aliens from natural communities should also be undertaken with care. Thus, in some cases (e.g. *Ricinus communis*), it is better to remove the plants gradually since the sudden obliteration of a large population may expose undergrowth species to an environmental shock.

It is especially important to guard against the importation of alien stock of indigenous species because while conspecific these would rarely be genetically identical since geographical races tend to evolve; our particular stocks are therefore unique genetic entities. One should also be careful when introducing species closely related to native ones since these may hybridise and pollute the local gene pool. Thus, the local race of the house sparrow *Passer hispaniolensis* has been shown to be a hybrid between *Passer hispaniolensis hispaniolensis* and the Italian sparrow *Passer domesticus italie* (SULTANA & GAUCI, 1982). *Passer domesticus* originally emanated from Asia and progressively colonised Europe (NIETHAMMER, 1969).

On the other hand, some species have become so rare, in some cases reduced to single specimens, that it might be desirable to import the species from places which are biogeographically as close to us as possible (e.g. south-eastern Sicily) since, while we may resort to micropropagation, we would still be dealing with a single clone, prone to genetic erosion. It may also prove desirable to introduce, again from suitable sources, species which have been completely lost.

Finally we must guard against introduction (deliberate or accidental) of species which have the potential for causing great disturbance to local ecosystems and biodiversity and which have already invaded other Mediterranean countries with devastating effects, for example, the 'assassin weed' *Caulerpa taxifolia* and the japweed *Sargassum muticum* which are causing great concern in neighbouring countries. In this context it is interesting to note that the Environment Protection Department has received a request for permission to import live *Caulerpa taxifolia* originating from Singapore for sale to aquarists (Alfred E. BALDACCHINO, personal communication, 1996).

The release of genetically modified organisms (GMOs) in the environment poses another potential threat to natural ecosystems and their biota (WILLIAMSON, 1988, RCEP,1989). GMOs are organisms in which the genetic material has been altered in a way that does not occur naturally by mating or recombination, that is, they are 'genetically engineered'. While GMOs have been produced and used in laboratory and other contained environments for the past 25 years or so, in recent years a number of releases of GMOs into the environment have taken place and many others are planned. Such releases have points of similarity with the introduction of alien species, and should be done with caution and only after a detailed assessment of the risks involved (SIMONSEN & LEVIN, 1988; TIEDJE *et al*., 1989). While no adverse effects to the environment have been reported from what releases of GMOs have taken place to date, this does not mean that there is no danger and guidelines, codes of practice and strict regulations concerning the release of GMOs into the environment exist in many countries (see for example OECD, 1986; Council Directives 90/219/EEC and 90/220/EEC of the European Communities [EEC, 1990a, b]). However, further discussion of this is beyond the scope of the present paper.

ACKNOWLEDGEMENTS

We are grateful to a number of persons who have generously helped us in the preparation of this paper by supplying information and in other ways, particularly Alfred E. BALDACCHINO, David DANDRIA, Guido LANFRANCO, David MIFSUD, and Stephen SCHEMBRI. This work was supported by research grants from the University of Malta for which we are also grateful.

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