

Impact of alien insect pests on Sardinian landscape and culture

Roberto A. Pantaleoni^{1,2,*}, Carlo Cesaroni¹, C. Simone Cossu¹, Salvatore Deliperi², Leonarda Fadda¹, Xenia Fois¹, Andrea Lentini², Achille Loi², Laura Loru¹, Alessandro Molinu¹, M. Tiziana Nuvoli², Wilson Ramassini², Antonio Sassu¹, Giuseppe Serra¹, Marcello Verdinelli¹

¹Istituto per lo Studio degli Ecosistemi, Consiglio Nazionale delle Ricerche (ISE-CNR), traversa la Crucca 3, Regione Balduina, 07100 Li Punti SS, Italy; e-mail: r.pantaleoni@ise.cnr.it

²Sezione di Patologia Vegetale ed Entomologia, Dipartimento di Agraria, Università degli Studi di Sassari, via Enrico De Nicola, 07100 Sassari SS, Italy; e-mail: pantaleo@uniss.it

*Corresponding author

ABSTRACT

Geologically Sardinia is a raft which, for just under thirty million years, has been crossing the western Mediterranean, swaying like a pendulum from the Iberian to the Italian Peninsula. An island so large and distant from the other lands, except for its “sister” Corsica, has inevitably developed an autochthonous flora and fauna over such a long period of time. Organisms from other Mediterranean regions have added to this original contingent. These new arrivals were not randomly distributed over time but grouped into at least three great waves. The oldest two correspond with the Messinian salinity crisis about 7 million years ago and with the ice age, when, in both periods, Sardinia was linked to or near other lands due to a fall in sea level. The third, still in progress, is linked to human activity. Man has travelled since ancient times and for many centuries introduced allochthonous species to Sardinia which radically modified the native flora and fauna, but always at a very slow and almost unnoticeable rate.

The use of sailing or rowing boats, with their low speeds, hindered the transport of living organisms from one place to another. The use of the steam boat, introduced around 1840 but widely diffuse around 1870-1880, opened the doors to more frequent arrivals and also to organisms from the American Continent. This technical innovation had an influence over the whole world economy, with its well-known grain crisis, and coincided in Sardinia with the arrival of Roman dairymen, producers of pecorino cheese and the beginning of the expansion of sheep farming which would continue uninterrupted until the present day. In this period of sudden social and environmental change, an insect was introduced which would turn out to be probably the most economically devastating agricultural pest in Europe: the Grape *Phylloxera*. The vineyard and wine business collapsed first in France then in Italy. The *Phylloxera* arrived in Sardinia in 1883 and wine production crashed a very short time later and only resumed after the distribution of American vine rootstock at the beginning of the 20th Century. From then, vine cultivation in Europe was modified with the essential use of this rootstock.

Since then methods of transport have increased enormously in number and speed. The number of allochthonous and invasive species has increased proportionally: some of them along with exotic plants which are cultivated on the island, others following man in his activities. Often these new pests attack and destroy ornamental plants which have become part of the Sardinian landscape, causing it to change; just as often their presence requires methods of pest management which are different from the traditional methods on specific crops; finally in at least one case (the Asian tiger mosquito) they pose a threat to our health.

KEY WORDS

invasions; dispersion by man; Mediterranean; allochthonous species; history.

Received 12.05.2012; accepted 10.09.2012; printed 30.12.2012

Proceedings of the 1st International Congress “Insularity and Biodiversity”, May 11th-13th, 2012 - Palermo (Italy)

INTRODUCTION

Sardinia is in the centre of the Western Mediterranean, one of the most bio-geographically complex and interesting areas of the Palearctic region. Its natural history is closely linked today with the history of man. Before he arrived, the rhythms of evolution and change in fauna and landscape were synchronised with geological rhythms.

Long periods of standstill were interrupted by some “catastrophic” moments of radical change (Baccetti, 1964; 1983). After the arrival of man, who represents the last of these natural catastrophes, the speed of change was completely modified. The rate of arrival of new species grew exponentially and has probably reached its maximum levels in these years.

NATURAL INVADERS

Geologically, Sardinia is a raft which, for just under thirty million years, has been crossing the western Mediterranean, swaying like a pendulum from the Iberian to the Italian Peninsula. Despite its long never-ending journey the Sardinian terrane still hosts some descendants of the original organisms which were present when it broke away from the continent. Among these animals, a good number of small invertebrates which live in caves and in the soil like the cave ground beetle *Sardaphaenops supramontanus* Cerruti & Henrot, 1956 (Coleoptera Carabidae) (Fig. 1), stand out.

Organisms from other Mediterranean regions have added to this original contingent. These new arrivals were not randomly distributed over time but grouped into at least three great waves. The oldest one corresponds with the Messinian salinity crisis about 7 million years ago. This was the time when the Mediterranean became isolated from the Atlantic and dried up through evaporation. So Sardinia found itself connected to Africa and the northern regions. In this period many of the amphibians and reptiles still present on the island arrived, e.g. the endemic Sardinian Brook Newt *Euproctus platycephalus* (Gravenhorst, 1829) (Urodela Salamandridae) (Carranza & Amat, 2005), and many insects including the lovely orthopteran *Pamphagus sardus* (Herrich-Schaeffer, 1840) (Orthoptera Pamphagidae) (Fig. 2).

The second wave of arrivals came about during the sea-regressions of the ice age, in particular during the sea-regression named “Cassia” by Italian paleontologists, which occurred between one million and eight hundred thousand years ago. In this period animals coming from cold faunas in the north reached Sardinia. The most famous among the vertebrates is the *Prolagus sardus* (Wagner, 1832), a species of rabbit (Lagomorpha Prolagidae) extinct at the end of the XVII century (Smith, 2008).

Among the insects there are some species which are now limited to the peaks of the Gennargentu mountains such as the Winter Moth *Operophtera brumata* (Linnaeus, 1758) (Lepidoptera Geometridae) (Figs. 3, 4) (Hartig, 1976; Cao, 2005). The third wave of arrivals which is still unfinished has only one cause: man. Man caused at first a real mass extinction among vertebrate fauna, mammals were almost completely substituted by species introduced by man. Paleontologists have little doubt in claiming that boar, mouflon, deer, fallow deer and other common animals were brought here by man (Vigne, 1992).

HISTORICAL PERSPECTIVE

In light of this information, the Nuragic cargo ships with a whole collection of domestic animals could be interpreted in a more realistic and less allegorical sense than archaeologists have allowed until now. An impressive ship is the one called “Vetulonia” (Fig. 7) in which we can recognise pigs, rams, a buffalo and a cow, dogs and maybe a cat (Depalmas, 2005). In other cases there are birds which were probably chickens. One species of tortoise (perhaps two), once used as food, was also certainly introduced (Corti et al., 1999; van der Kuyl et al., 2002), as well as the Fat (or Edible) Dormouse, *Glis glis* (Linnaeus, 1766) (Rodentia Gliridae) (Masseti, 2005).

We know little or nothing about the arrival of insects and other invertebrates with man. Almost certainly he arrived with his retinue of synanthropic insects such as cockroaches (Figs. 5, 6) or lice (Robinson, 1996). But he surely also introduced other species in the ballast of ancient ships or with the transport of wood. Among these could have been termites.



Figures 1-7. Some old invaders. Fig. 1. *Sardaphaenops supramontanus* (Coleoptera Carabidae), a cave-dwelling insect belonging to the original contingent of Sardinian Fauna. Fig. 2. *Pamphagus sardeus* (Orthoptera Pamphagidae), a lovely orthopteran belonging to the oldest wave of “invaders” corresponds to the time of Messinian salinity crisis about 7 million years ago. Figs. 3, 4. The Winter Moth *Operophtera brumata* (Lepidoptera Geometridae), a female (3) and a male (4), today limited in Sardinia to the peaks of the Gennargentu mountains, belonging to the second wave of arrivals during the sea-regressions of the ice age. Figs. 5, 6. The Oriental Cockroach *Blatta orientalis* (Blattaria Blattidae), an immature female (5) and a brachypterous male (6), belonging to the organisms dispersed by the ancient man. Fig. 7. Bronze Nuragic cargo ship with a whole collection of domestic animals found in Vetulonia, Tuscany, and deposited at the Archaeological Museum of Florence. Photos by G. M. Delitala (1), M. Romano (2), D. Morel (3), P. Mazzei (4), A. Giannotti (5), and S. Guermanti (6). Figure 7 redesigned from original Leoncini’s draw in Falchi (1887) by Montelius (1924).

In the same way it is possible that the Human Flea, *Pulex irritans* Linnaeus, 1758 (Siphonaptera Pulicidae) was among the synanthropic insects introduced. Many years later, this would serve as a vehicle for the plague which would sweep across

Sardinia several times (Cau & Pozzi, 2003). What is certain is that, apart from the plague, in some thousands of years of trade and travel with the widest range of sailing ships, the increase in the number of species introduced has remained relatively low.

So the Phoenicians, the Punics, the Romans, the Arabs, the Pisans, the Genoans, the Spanish and all the others who travelled around the Mediterranean introduced tens of species to Sardinia which were entirely indifferent to man. They did not alter his crops, attack his farms, or threaten his health. Although there is no certain and documented proof of this phenomenon, the distribution of some organisms seems only to be justified by anthropochory. One of the most interesting cases is the ground beetle *Dicheirotrichus punicus* Bedel, 1899 (Coleoptera Carabidae), found only in Cagliari and in a few stations in North Africa and other Mediterranean islands including Carthage (Gridelli, 1944).

In the first 350 years after America was discovered, along with the numerous crops imported from that continent (potatoes, tomatoes, corn, beans, but also prickly pears, peppers and tobacco) only three insect pests arrived in Europe (Corte, 1991): the Angoumois Grain Moth, *Sitotroga cerealella* (Olivier, 1789) (Lepidoptera Gelechiidae), the Woolly Apple Aphid, *Eriosoma lanigerum* (Hausmann, 1802) (Sternorrhyncha Aphididae), and the Greenhouse Thrip, *Heliothrips haemorrhoidalis* (Bouché, 1833) (Thysanoptera Thripidae).

Things began to change halfway through the 18th century with the introduction of the first steam ships. The American continent suddenly came much closer, just as the Far East and Australia came closer too. Improved shipping connections, with the birth and growth of the railway, had an influence over the entire world economy. The arrival of low cost wheat from America caused a crisis in Europe, forcing whole nations to change their crops. The same crisis caused an enormous flow of immigrants with millions of people who went in the opposite direction seeking their fortune on the other side of the Atlantic.

Sardinia too was the object of epochal changes in the last 20 years of the 1800s (eighteen hundreds). Firstly, through heavy exploitation of forestry, with wide indiscriminate deforestation. At the same time the expansion of sheep farming began, which would continue uninterrupted until the present day with the arrival of Roman dairymen, producers of pecorino cheese. In this period of sudden social and environmental change, an insect was introduced which would turn out to be probably the most economically devastating agricultural pest in Europe and Sardinia: the Grape *Phylloxera*, known

at the time as *Phylloxera vastatrix* Planchon, 1868, and nowadays as *Daktulosphaira vitifoliae* (Fitch, 1855) (Sternorrhyncha Phylloxeridae) (Figs. 8-12).

The Grape *Phylloxera* induces the formation of leaf and root galls on American *Vitis* species. The severe viticultural impact of *Phylloxera* became evident when it was imported into Europe after the 1860s. It devastated the European grape, *Vitis vinifera*, vineyards first in France, then spread across the continent, and finally around the world. The vineyard and wine business collapsed first in France then in Italy (Crovetto & Rossi, 1987). The *Phylloxera* arrived in Sardinia in 1883 and wine production crashed a very short time later and only resumed after the introduction of the practice to graft the susceptible European vine species on rootstock of resistant American vine species at the beginning of the 20th century. From then, vine cultivation in Europe was modified with the essential use of this rootstock (Cau, 1999). Between the commercial introduction of the steam ship and the end of the second World War the scene did not drastically change. Arrivals came in succession at a high rate especially from the American continent, with landings at various European ports and successive diffusion all over the continent.

In Sardinia, the situation is only slightly different. Only few “invaders” never arrived, like the Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say, 1824) (Coleoptera Chrysomelidae) (Fig. 14), a very problematic Solanaceae pest, that was introduced to Europe in 1897 where it established itself from 1920 and came later to Italy in 1944 (Melis, 1950). In 1946, the island was hit by the most violent locust invasion of all time. Wartime, with the abandonment of the countryside, had created suitable conditions for the development of this curse. It was treated mostly with arsenical and organophosphate insecticides (Pantaleoni et al., 2004). But two enlightened entomologists, Guido Paoli and Francesco Boselli, proposed a biological control programme with the introduction of three natural enemies of the locusts present in Italy and absent in Sardinia: two bee-flies (Diptera Bombyliidae) and the beetle *Mylabris variabilis* (Pallas, 1781) (Coleoptera Meloidae) (Paoli & Boselli, 1947) (Fig. 15). The latter in particular, set loose in only 22 locations, has been present all over the island for years (Boselli, 1954; Crovetto, 1966).

For once, a new welcome guest!

With the end of the tragic events of the Second World War, a new means of transport began to develop: the aeroplane. Even more cargo and people started to cross oceans and continents. Journey speeds increased and the number of organisms transported from one country to another increased at the same rate (Pellizzari & Dalla Montà, 1997). The most important points of entry were no longer ports but airports. In Italy, the North East became one of the most frequent points of entry due to the presence of a higher concentration of American military bases.

In Veneto for example, the Sycamore Lace Bug *Corythucha ciliata* (Say, 1832) (Heteroptera Tingidae) arrived for the first time in Europe in 1966 (Servadei, 1966) and the Acanaloniid Planthopper *Acanalonia conica* (Say, 1830) (Fulgoromorpha Acanaloniidae) in 2004 (D'Urso & Uliana, 2004; 2006) and many of the species will be mentioned

further on such as the Leaf-footed Conifer Seed Bug, the *Citrus* Flatid Planthopper, and the Asian Tiger Mosquito.

TODAY

New invasions of insect pests in Sardinia have accelerated dramatically over the last few years. Some particularly harmful species arrived between 1995 and 2000, many after 2000. Often these new pests attack and destroy ornamental plants which have become part of the Sardinian landscape, causing it to change; just as often their presence requires methods of pest management which are different from the traditional methods on specific crops; finally in at least one case (the Asian Tiger Mosquito) they pose a threat to our health. The most significant examples are listed.



Figures 8-12. *Daktulosphaira vitifoliae* (Sternorrhyncha Phylloxeridae) (= *Phylloxera vastatrix* Planchon, 1868). Fig. 8. Opening of the gall on the upper surface of the leaf showing the eggs of the gallecoles. Figs. 9, 10. Gallecole, dorsal (9) and ventral (10) views. Fig. 11. Leaf-galls proliferate on the underside of the leaf. Fig. 12. Section of a gall containing eggs and gallecoles. Photos by C. Cesaroni/ISE CNR Sassari.

Some invaders attack ornamental plants. The *Geranium* Bronze Butterfly, *Cacyreus marshalli* (Butler, 1898) (Lepidoptera Lycaenidae) (Fig. 13), is a native of southern Africa. It was accidentally introduced into the Balearic Island of Mallorca, Spain, probably in 1987, and since then it has spread to the other Balearic Islands (Menorca and Ibiza) and other countries in Southern Europe (Eitschberger & Stamer, 1990; Raynor, 1990; Sarto i Monteys, 1992). The *Geranium* Bronze occurs on cultivated geranium (*Geranium* and *Pelargonium*) species in Europe and can pass through five to six generations per year in Mediterranean locations (Favilli & Manganelli, 2006). Almost all cultivated geranium varieties are at risk and plants can be completely destroyed. In Sardinia it is already found almost everywhere (Contini et al., 2005).

The *Citrus* Flatid Planthopper *Metcalfa pruinosa* (Say, 1830) (Fulgoromorpha Flatidae) originates from South and Central America, and is widespread from Quebec to Brazil. In our country it was spotted for the first time 25 years ago in Treviso (Veneto) (Zangheri & Donadini, 1980) and since then it has spread almost all over the country (Pantaleoni, 1988). The Flatid has been reported on a long list of plants, including many forest trees, orchard and citrus trees, grape and other vines, numerous shrubs, and some herbs. Despite its name it is not frequently found on *Citrus* plants in Sardinia. The Flatid ordinarily does very little damage to plants but its presence is very evident, being revealed by the long, curled filaments of waxy exudate. This woolly material often obscures the nymph producing it (Lucchi, 2000).

The Red Palm Weevil, *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera Curculionidae) (Figs. 17-19) originating in Southern Asia and Melanesia, has been advancing westwards very rapidly since the mid 1980s. It reached the eastern region of Saudi Arabia in 1985. Then it was discovered in Egypt in 1992. In 1994, it was captured in the south of Spain and in 1999 was found in Middle East. The Red Palm Weevil is a large reddish brown beetle about 3 cm long. Usually the damage caused by the larvae is visible only long after infestation, and by the time the first symptoms of the attack appear, they are so serious that they generally result in the death of the tree. In the Mediterranean area the main palm concerned is *Phoenix*

canariensis, the most common ornamental species, but it could attack some other palms (Malumphy & Moran, 2007). In Sardinia, the Red Palm Weevil was discovered in 2007 in Barisardo (Central West Sardinia) on *Phoenix canariensis* plants imported from plant nurseries in the Campania region. It has recently been found also in the urban green areas of Pula (South Sardinia) on palms which came from Sicily and it is expected that it will spread throughout the whole region.

Also pine forests have been affected by the arrival of new pests. In an area of the South West of Sardinia from 2006, the Pine Processionary Moth, *Traumatocampa pityocampa* (Denis & Schiffermüller, 1776) (Lepidoptera Notodontidae), has been found (Luciano et al., 2007). It is considered among the most important limiting factors for both the growth and survival of pine forests in Southern Europe and Mediterranean countries (Laurent-Hervouët, 1986). In recent years, the species has shown a tendency to expand its range to upper latitude and elevation and large outbreak areas have been observed in regions where the pest was absent or rarely recorded (Battisti et al., 2005; 2006). As a consequence, also in Sardinia, the species will foreseeably have a strong socio-economical impact also due to its caterpillars that have tiny sharp barbed hairs and a toxin which can cause irritation and allergic reactions in people and animals (Lamy, 1990).

The Nearctic Leaf-footed Conifer Seed Bug, *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera Coreidae), is considered a severe pest for conifer seed orchards, and it sometimes causes serious alarm when large numbers of adults suddenly invade houses looking for overwintering sites (Bernardinelli & Zandigiacomo, 2001). It is a big insect, the adults are 9-18 mm long. This insect was never recorded for the European fauna, but in 1999 it was first collected near Vicenza (Veneto) (Taylor et al., 2001). Up to now several specimens have been observed in different localities of Italy including Sardinia (Vicidomini & Pignataro, 2007).

We cannot ignore the *Eucalyptus* either. On this originally Australian tree, the Yellow Eucalypt Longicorn, *Phoracantha recurva* Newman, 1840 (Coleoptera Cerambycidae), has recently arrived (Cillo et al., 2006). A wood feeder beetle which is slowly ousting the Common Eucalypt Longicorn, *Phora-*



Figures 13-19. Many kinds of invaders. Fig. 13. The *Geranium* Bronze Butterfly, *Cacyreus marshalli* (Lepidoptera Lycaenidae), a recent “urban” invader from South Africa: two old specimens drinking from the soil moisture. Fig. 14. Colorado Potato Beetle, *Leptinotarsa decemlineata* (Coleoptera Chrysomelidae), an old invader of Europe which never arrived in Sardinia. Fig. 15. *Mylabris variabilis* (Coleoptera Meloidae), a locust enemy introduced into Sardinia from Italy. Fig. 16. *Aedes albopictus* (Diptera Culicidae), an invader with public health implications: adult female. Figs. 17-19. *Rhynchophorus ferrugineus* (Coleoptera Curculionidae), an Asiatic invader that attacks palms: damage (17) and male adult (18, 19). Photos by M. Tomasi (13), E. Musumeci (14), B. de Ruvo (15), S. Deliperi/University of Sassari (17), C. Cesaroni/ISE CNR Sassari (16, 18, 19).

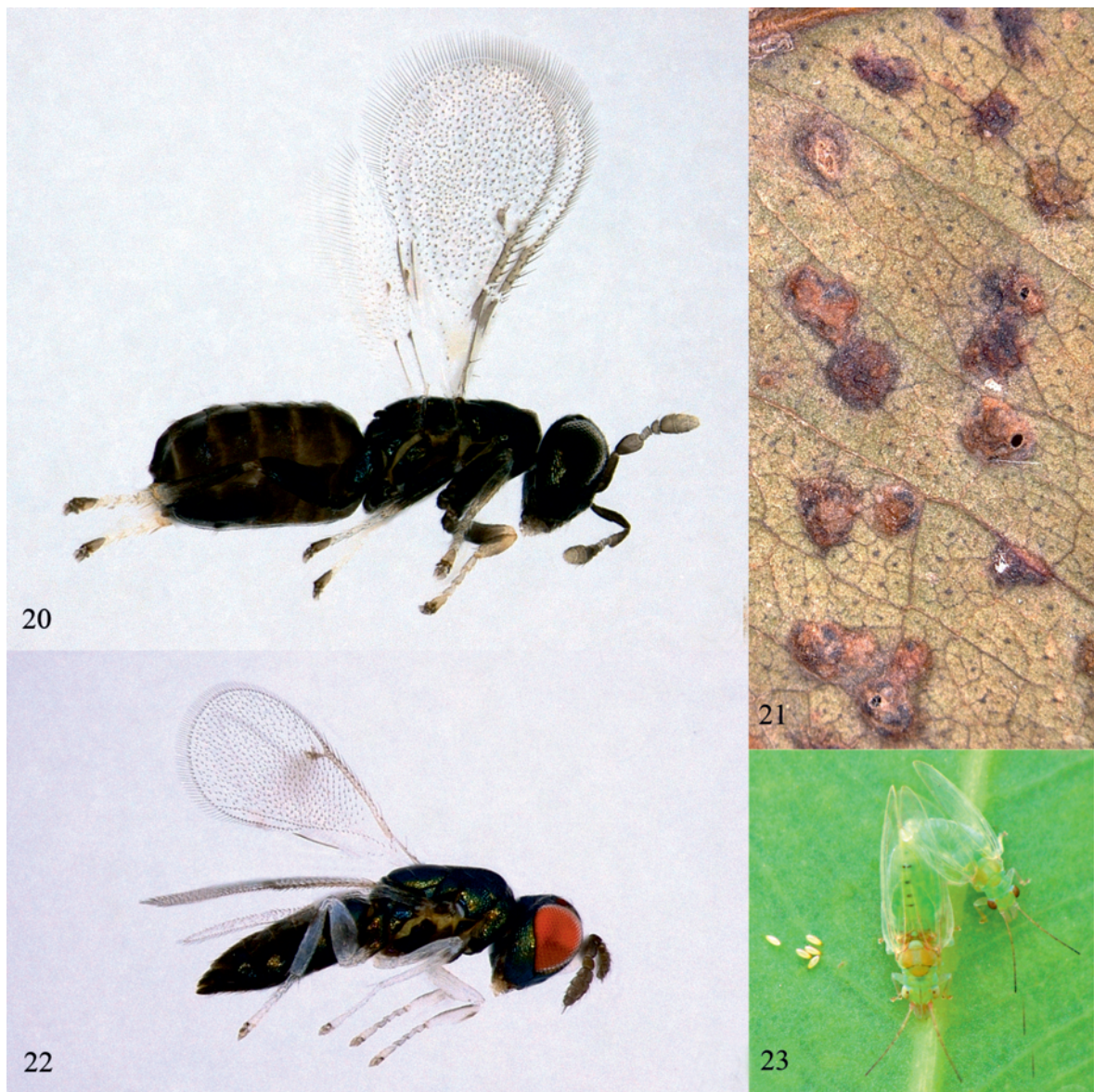
cantha semipunctata (Fabricius, 1775), Australian too, and present in Europe for about thirty years (Tassi, 1970; Cavalcaselle & Contini, 1973). A leaf-galling wasp, *Ophelimus maskelli* (Ashmead, 1900)

(Hymenoptera Eulophidae) (Figs. 20, 21), occurring on *Eucalyptus* in Australia, has been recorded recently in Europe (Protasov et al., 2007) and Sardinia; this species was apparently not associated

with heavy damage to *Eucalyptus* trees, but the adults appear in such large numbers that they disturb people. There have been problems especially in campsites found in *Eucalyptus* woods. One of its parasitoids *Closterocerus* sp. (Hymenoptera Eulophidae) (Fig. 22) has recently been introduced to Italy (Rizzo et al., 2006) and also to the island. In 2010 the invasive Red Gum Lerp Psyllid, *Glycaspis brimblecombei* Moore, 1964 (Sternorrhyncha

Psyllidae) (Fig. 23), has been recorded for the first time in Italy (Laudonia & Garonna, 2010; Peris-Felipo et al., 2011) and the year after in Sardinia (OEPP/EPPO, 2011).

In 2012 its specific parasitoid *Psyllaephagus bliteus* Riek, 1962 (Hymenoptera Encyrtidae) has been detected in Sardinia and Sicily (Floris, pers. com.) probably accidentally introduced together with the psyllid.



Figures 20-23. Insects on *Eucalyptus*. Figs. 20, 21. *Ophelimus maskelli* (Hymenoptera Eulophidae), a gall wasp: female (20) and old leaf galls (21). Fig. 22. *Closterocerus* sp. (Hymenoptera Eulophidae), a parasitoid of the previous. Fig. 23. Red Gum Lerp Psyllid, *Glycaspis brimblecombei* (Sternorrhyncha Psyllidae), the most recent invader on *Eucalyptus* in Sardinia: adults with eggs. Photos by C. Cesaroni/ISE CNR Sassari (20-22), V. Risoldi (23).



Figures 24-28. The Oriental Chestnut Gall Wasp, *Dryocosmus kuriphilus* (Hymenoptera Cynipidae), a parthenogenetic species attacking chestnuts that induces gall formation on shoot tips, leaves and catkins: galls (Fig. 24), section of a gall containing the larva (Fig. 25), magnification of the larva head (Fig. 26), pupa inside the gall (Fig. 27), the specific parasitoid *Torymus sinensis* (Hymenoptera Torymidae) parasitizing a gall (Fig. 28). Photos by M. Verdinelli (24-26), and M. Fara (27, 28)/allISE CNR Sassari.

The Oriental Chestnut Gall Wasp, *Dryocosmus kuriphilus* Yasumatsu, 1951 (Hymenoptera Cynipidae) (Figs. 24-27), native to China but introduced some time ago in Japan, Korea, Nepal (Abe et al., 2007) and eastern parts of the United States (Rieske, 2007), has been discovered in our country, in 2002 in Piemonte (Brussino et al., 2002), then in other Appenine regions. The species was found in the spring of 2007, even in Sardinia in Barbagia di Belvi (Nuoro). It might have been introduced between 2003 and 2005 on some nursery plants which came from Piemonte (Pantaleoni et al., 2007). The gall wasp attacks both the European chestnut and Euro-Japanese hybrids. The development of shoots is extremely limited and fructification is reduced. Chestnut production can record losses of 50-70% (OEPP/EPPO, 2005).

This adversity is therefore extremely serious and could have a negative influence on the local agro-forestry economy of the Barbagia di Belvi area which is closely linked to chestnut cultivation. In order to mitigate gall wasp activity, in 2009, it has been introduced its specific parasitoid *Torymus sinensis* Kamijo, 1982 (Hymenoptera Torymidae) (Fig. 28).

The Asian Tiger Mosquito, *Aedes albopictus* (Skuse, 1894) (Diptera Culicidae) (Fig. 16), is a vector species, which has spread from its original areas in Asia to the rest of the world through shipments of used tires (Eritja et al., 2005). The Asian Tiger Mosquito was detected in Cagliari, in the South of Sardinia, in 1994-95, but the prompt intervention of the local public health agency achieved the eradication of the introduced population (Romi, 1995; Romi et al., 1999). In autumn 2006, the Asian Tiger Mosquito was detected again on the island. It is present in two important port cities, again Cagliari and Olbia in the North-East (Contini, 2007). In the latter location, the Tiger Mosquito seems to have reached a high population density in contrast to the south of the region where the climatic conditions are not so favourable for this species (Cristo et al., 2006). In 2007 an outbreak of Chikungunya fever, carried by Tiger Mosquito, took place in North Italy (Rezza et al., 2007). No prediction can be made about spread and persistence of the virus in Italy. Nevertheless Italy is at risk of infection with arboviruses, such as dengue virus and West Nile virus, which have serious effects on public health.

There are still a lot of insects to mention that are harmful to crops. We will cite only four species as an example. The Western Flower Thrip, *Frankliniella occidentalis* (Pergande, 1895) (Thysanoptera Thripidae), is an important pest insect in agriculture. This species of thrip is native to North America but has spread to other continents via transport of infested plant material (Luciano & Piga, 1988).

The Woolly Whitefly, *Aleurothrixus floccosus* (Maskell, 1895) (Sternorrhyncha Aleyrodidae), is almost certainly native to South America. In the Mediterranean region it was introduced into the Canary Islands in 1959, then Spain and France, before invading mainland Italy in 1970. Now it is kept well under control by several natural enemies, some of which are imported (Delrio et al., 1982; Ortu & Iba, 1985).

The *Citrus* Leafminer, *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera Gracillariidae) (Figs. 29-31), is a small leafmining moth that is a potentially serious pest of *Citrus* native to Asia (Ortu et al., 1995; 2002). The Tomato Borer *Tuta absoluta* (Meyrick, 1917) (Lepidoptera Gelechiidae) is one of the most recent arrivals reported in Europe. This insect, which is especially harmful to the tomato, was found between the winter of 2006 and the autumn of 2008 first in Spain, then in Algeria, Morocco and Corsica, and finally in Sardinia, where it proves to be already widespread on tomatoes and aubergines both in the field and in the greenhouse (Viggiani et al., 2009). The control of all of these species has required (or will require) the use of new management techniques by farmers.

CONCLUSIONS

Man is a tremendous re-mixer of biodiversity, voluntarily and involuntarily. The situation in Sardinia is not very different from the other regions of Italy. Its insularity can either defend the island from new arrivals or make new arrivals more problematic. Our new guests can turn out to be of no importance to human economy or they could deeply affect it. Sometimes the problems are so serious that they entail real changes in habits, traditions and methods like for example the case of the Grape *Phylloxera* and maybe in the future, the Oriental Chestnut Gall Wasp.



Figures 29-31. The Citrus Leafminer, *Phyllocnistis citrella* (Lepidoptera Gracillariidae), a small moth from Asia. Fig. 29. Magnification of the larva. Figs. 30, 31. Mine and larva on the underside of the leaf. Photos by C. Cesaroni/ISE CNR Sassari.

In other words, cultural changes. Other times they could even lead to deeper changes. What will happen to the palm-lined city streets, balconies flowering with geraniums, pine-woods? A great deal will depend on our ability to manage these problems.

ACKNOWLEDGMENTS

We express our deep gratitude to the friends Giuseppe M. Delitala, Bruno de Ruvo, Marcella Fara, Antonio Giannotti, Stefano Guermandi, Paolo Mazzei, Daniel Morel, Enzo Musumeci, Vittorio Risoldi, Marcello Romano, Mirko Tomasi for providing their marvellous photos. We also thank Drs.

Stefania Bagella and Anna Depalmas of Sassari University for useful information on the Nuragic cargo ship “Vetulonia”.

REFERENCES

- Abe Y., Melika G. & Stone G.N., 2007. The diversity and phylogeography of cynipid gallwasps (Hymenoptera: Cynipidae) of the Oriental and eastern Palearctic regions, and their associated communities. *Oriental Insects*, 41: 169-212.
- Baccetti B., 1964. Considerazioni sulla costituzione e l'origine della fauna di Sardegna. *Archivio Botanico e Biogeografico Italiano*, 40: 217-283.
- Baccetti B., 1983. Biogeografia sarda venti anni dopo. *Lavori della Società Italiana di Biogeografia*, 8: 859-870.

- Battisti A., Stastny M., Buffo E. & Larsson S., 2006. A rapid altitudinal range expansion in the pine processionary moth produced by the 2003 climatic anomaly. *Global Change Biology*, 12: 662-671.
- Battisti A., Stastny M., Netherer S., Robinet C., Schopf A., Roques A. & Larsson S., 2005. Expansion of geographic range in the Pine processionary moth caused by increased winter temperatures. *Ecological Applications*, 15: 2084-2096.
- Bernardinelli I. & Zandigiaco P., 2001. *Leptoglossus occidentalis* Heidemann (Heteroptera, Coreidae): a conifer seed bug recently found in northern Italy. *Journal of Forest Science*, 47(Special Issue 2): 56-58.
- Boselli F. B., 1954. Acclimatazione della *Mylabris variabilis* Pall. parassita del *Doclostaurus maroccanus* Thnb. introdotto in Sardegna nel 1946. *Bollettino della Società Entomologica Italiana*, 84: 115-116.
- Brussino G., Bosio G., Baudino M., Giordano R., Ramello F. & Melika G., 2002. Pericoloso insetto esotico per il castagno europeo. *Informatore Agrario*, 37: 59-61.
- Cao O.V., 2005. Segnalazione di *Apocheima hispidaria* (Denis & Schiffemüller) e conferma di *Operophtera brumata* (Linnaeus) per la lepidotterofauna della Sardegna (Lepidoptera Geometridae). *Redia*, 87: 97-98.
- Carranza S. & Amat F., 2005. Taxonomy, biogeography and evolution of *Euproctus* (Amphibia: Salamandridae), with the resurrection of the genus *Calotriton* and the description of a new endemic species from the Iberian Peninsula. *Zoological Journal of the Linnean Society*, 145: 555-582.
- Cau P., 1999. La viticoltura tra Otto e Novecento: dalla fillossera alla vite americana. In: Di Felice M.L. & Mattone A. *Storia della vite e del vino in Sardegna*. Editori Laterza, 288-305.
- Cau P. & Pozzi L., 2003. I segni della vita. Fonti e testimonianze per una Storia Demografica della Sardegna. Regione Autonoma della Sardegna, 82 pp.
- Cavalcaselle B. & Contini C., 1973. Osservazioni preliminari sugli insetti xilofagi dell'eucalitto in Italia. *Bollettino della Società Sarda di Scienze Naturali*, 12: 125-136.
- Cillo D., Leo P. & Sechi D., 2006. Segnalazioni faunistiche italiane 449. *Phoracantha recurva* Newman, 1840 (Coleoptera Cerambycidae). *Bollettino della Società Entomologica Italiana*, 138: 77-78.
- Contini C., 2007. *Aedes albopictus* in Sardinia: reappearance or widespread colonization? *Parassitologia*, 49: 33-35.
- Contini C., Mudu C., Pirodda E. & Senis G., 2005. Sulla presenza in Sardegna del lepidottero Lycaenidae sudafriano *Cacyreus marshalli* Butler, 1898. *Rendiconti Seminario Facoltà di Scienze, Università Cagliari*, 75: 99-104.
- Corte A., 1991. Con le piante arrivano i parassiti. In: Capocaccia Orsini L. & Doria G., 1492-1992. *Animali e piante dalle Americhe in Europa*. SAGEP Editrice, Genova, 193-208.
- Corti C., Masseti M., Delfino M. & Pérez-Mellado V., 1999. Man and herpetofauna of the Mediterranean islands. *Revista Espanola de Herpetologia*, 13: 83-100.
- Cristo B., Loru L., Sassu A. & Pantaleoni R.A., 2006. The Asian tiger mosquito again in Sardinia. *Bulletin of Insectology*, 59: 161-162.
- Crovetti A., 1966. L'acclimatazione della *Zonabris variabilis* Pall. (Coleoptera, Meloidae) in Sardegna 20 anni dopo la sua introduzione. *Redia*, 50: 121-131.
- Crovetti A. & Rossi E., 1987. A survey of the grape phylloxera (*Viteus vitifoliae* (Fitch) problem a century after its introduction. In: Cavalloro R. (ed.) *Integrated pest in viticulture*. Proceedings of a meeting of the EC Expert's Group, Portoferraio, 109-119.
- Delrio G., Ortu S. & Protta R., 1982. Fitofagi di recente introduzione nelle colture agrumicole della Sardegna. *Studi Sassaresi*, 28: 57-64.
- Depalmas A., 2005. Le navicelle di bronzo della Sardegna nuragica. Gasperini Editore, Cagliari, 395 pp.
- D'Urso V. & Uliana M., 2004. First record of *Acanalonia conica* (Issidae) in Italy. Third European Hemiptera Congress, St. Petersburg, Abstracts, 26-27.
- D'Urso V. & Uliana M., 2006. *Acanalonia conica* (Hemiptera, Fulgoromorpha, Acanaloniidae), a Nearctic species recently introduced in Europe. *Deutsche Entomologische Zeitschrift*, 53: 103-107.
- Eitschberger U. & Stamer P., 1990. *Cacyreus marshalli*, a new species of butterfly for the fauna of Europe? *Atalanta*, 21: 101-108.
- Eritja R., Escosa R., Lucientes J., Marquès E., Roiz D. & Ruiz S., 2005. Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. *Biological Invasions*, 7: 87-97.
- Falchi I., 1887. Nuovi scavi della necropoli di Vetulonia. *Notizie degli scavi di antichità: comunicate alla R. Accademia dei Lincei per ordine di S. E. il ministro della pubb. istruzione*, 1887: 472-531 + pl.s XIV-XIX (cfr. pl. XVII).
- Favilli L. & Manganelli G., 2006. Life history of *Cacyreus marshalli*, a South African species recently introduced into Italy (Lepidoptera Lycaenidae). *Bollettino della Società Entomologica Italiana*, 138: 51-61.
- Gridelli E., 1944. In memoria di Angelo Maura. Note su alcune specie di Carabidi della Laguna Veneta. *Memorie della Società Entomologica Italiana*, 23: 55-70.
- Hartig F., 1976. Ein Nachtfang im Winter am Gennargentu (Sardinien). *Mitteilungen der Entomologische Gesellschaft Basel*, (N.F.) 26: 14-19.
- Lamy M., 1990. Contact dermatitis (erucism) produced by processionary caterpillars (Genus *Thaumetopoea*). *Journal of Applied Entomology*, 110: 425-437.
- Laudonia S. & Garonna A. P., 2010. The red gum lerp psyllid, *Glycaspis brimblecombei*, a new exotic pest

- of *Eucalyptus camaldulensis* in Italy. Bulletin of Insectology, 63: 233-236.
- Laurent-Hervouët N., 1986. Mesure des pertes de croissance radiale sur quelques espèces de *Pinus* dues à deux défoliateurs forestiers. I. Cas de la processionnaire du pin en région méditerranéenne. Annales des Sciences Forestières, 43: 239-262.
- Lucchi A., 2000. La *Metcalfa* negli ecosistemi italiani. *Metcalfa pruinosa*: biologia, morfologia, dannosità, controllo. Arsia Regione Toscana, Firenze, 163 pp.
- Luciano P., Lentini A. & Battisti A., 2007. Prima segnalazione di *Traumatocampa pityocampa* per la Sardegna. Proceedings XXI Congresso Nazionale Italiano di Entomologia, Campobasso: 273.
- Luciano P. & Piga A., 1988. Osservazioni su "*Frankliniella occidentalis*" (Pergande) (Thysanoptera: Thripidae) recentemente comparsa in Sardegna. Studi Sassaesi, sezione III, 34 (1992): 87-101.
- Malumphy C. & Moran H., 2007. Red palm weevil, *Rhynchophorus ferrugineus*. Central Science Laboratory. Plant Pest Notice, 50: 1-3.
- Masseti M., 2005. Natural and anthropochorous squirrels and dormice of the Mediterranean region. Hystrix Italian Journal of Mammalogy (n.s.), 16: 3-26.
- Melis A., 1950. Cenni storici sulla comparsa e diffusione della Dorifora (*Leptinotarsa decemlineata* Say) in Europa con particolare riferimento all'Italia. Redia, 35: 185-204.
- Montelius O., 1924. La Grèce préclassique. Vol. I. Kungl. Vitterhets Historie och Antikvitets Akademien. Stockholm : I. Haeggström. 180 pp.
- OEPP/EPPO, 2005. Data sheets on quarantine pests / Fiches informatives sur les organismes de quarantaine: *Dryocosmus kuriphilus*. Bulletin OEPP/EPPO Bulletin, 35: 422-424.
- OEPP/EPPO, 2011. 2011/041 *Glycaspis brimblecombei* occurs in Sardinia, Italy. EPPO Reporting Service - Pests & Diseases, 2: 12.
- Ortu S., Acciaro M. & Cocco A., 2002. Contenimento di *Phyllocnistis citrella* su piante di Agrumi in produzione. L'Informatore fitopatologico, 52: 56-61.
- Ortu S., Delrio G. & Lentini A., 1995. La minatrice serpentina degli agrumi in Italia: *Phyllocnistis citrella* Stainton (Lep.: Gracillariidae: Phyllocnistinae). L'Informatore fitopatologico, 45: 38-41.
- Ortu S. & Ibba I., 1985. *Aleurothrixus floccosus* (Mask), in Sardinia. Atti XIV Congresso Nazionale Italiano di Entomologia: 607-614.
- Pantaleoni R.A., 1988. Modalità d'invasione di un nuovo areale in *Metcalfa pruinosa* (Say, 1830) (Auchenorrhynca Flatidae). Bollettino dell'Istituto di Entomologia «Guido Grandi» dell'Università di Bologna, 43: 1-7.
- Pantaleoni R.A., Loru L., Sassu A. & Loddo C., 2007. Il cinipide del castagno in Sardegna: una nuova preoccupante presenza nella Barbagia di Belvi. Notiziario sulla Protezione delle Piante, 21: 203-206.
- Pantaleoni R.A., Molinu A. & Cesaroni C., 2004. Some aspects of locust control in Sardinia in the first half of the twentieth century / Alcuni aspetti della lotta alle cavallette in Sardegna nella prima metà del XX secolo. In: Molinu et al.. Arsenic Locusts. The control of locusts in Sardinia in the first half of the twentieth century. / Cavallette all'arsenico. La lotta alle cavallette in Sardegna nella prima metà del 1900. Composita Editrice: 17-84.
- Paoli G. & Boselli F., 1947. Introduzione di oofagi del *Dociostaurus maroccanus* Thnb. dalla penisola italiana in Sardegna. Memorie della Società Entomologica Italiana, 26 (sup.): 21-40.
- Pellizzari G. & Dalla Montà L., 1997. Gli insetti fitofagi introdotti in Italia dal 1945 al 1995. L'Informatore Fitopatologico, 47: 4-12.
- Peris-Felipo F.J., Mancusi G., Turrisi G.F. & Jiménez-Peydró R., 2011. New corological and biological data of the Red Gum Lerp Psyllid, *Glycaspis brimblecombei* Moore, 1964 in Italy (Hemiptera, Psyllidae). Biodiversity Journal, 2: 13-17.
- Protasov A., La Salle J., Blumberg D., Brand D., Saphir N., Assael F., Fisher N. & Mendel Z., 2007. Biology, revised taxonomy and impact on host plants of *Ophelimus maskelli*, an invasive gall inducer on *Eucalyptus* spp. in the Mediterranean area. Phytoparasitica, 35: 50-76.
- Raynor E. M., 1990. The occurrence of *Cacyreus* species (Lepidoptera Lycaenidae) in Majorca. Entomologist's Record, 102: 150.
- Rezza G., Nicoletti L., Angelini R., Romi R., Finarelli A.C., Panning M., Cordioli P., Fortuna C., Boros S., Magurano F., Silvi G., Angelini P., Dottori M., Ciufolini M.G., Majori G.C. & Cassone A., 2007. Infection with chikungunya virus in Italy: an outbreak in a temperate region. The Lancet, 370 (9602): 1840-1846.
- Rieske L.K., 2007. Success of an exotic gallmaker, *Dryocosmus kuriphilus*, on chestnut in the USA: a historical account. Bulletin OEPP/EPPO Bulletin, 37: 172-174.
- Rizzo M.C., Lo Verde G., Rizzo R., Buccellato V. & Caleca V., 2006. Introduction of *Closterocerus* sp. in Sicily for biological control of *Ophelimus maskelli* Ashmead (Hymenoptera Eulophidae) invasive gall inducer on eucalypt trees. Bollettino di Zoologia Agraria e di Bachicoltura, 38: 237-248.
- Robinson W.H., 1996. Urban Entomology. Insect and mite pests in the human environment. Chapman & Hall, London, XVI + 430 pp.
- Romi R., 1995. History and updating on the spread of *Aedes albopictus* in Italy. Parassitologia, 37: 99-103.

- Romi R., Di Luca M. & Majori G., 1999. Current status of *Aedes albopictus* and *Aedes atropalpus* in Italy. *Journal of the American Mosquito Control Association*, 15: 425-427.
- Sarto i Monteys V., 1992. Spread on the Southern African Lycaenid butterfly, *Cacyreus marshalli* Butler, 1898 (Lep: Lycaenidae) in the Balearic Archipelago (Spain) and considerations on its likely introduction to continental Europe. *Journal of Research on the Lepidoptera*, 31: 24-34.
- Servadei A., 1966. Un Tingide neartico comparso in Italia (*Corythuca ciliata* Say). *Bollettino della Società Entomologica Italiana*, 96: 94-96.
- Smith A.T., 2008. Conservation of Endangered Lagomorphs. In: Alves et al. (eds.). *Lagomorph Biology Evolution, Ecology, and Conservation*. Springer Berlin Heidelberg: 297-315.
- Tassi F., 1970. Un Longicorne australiano per la prima volta in Italia (Col. Cerambycidae). *Bollettino dell'Associazione Romana di Entomologia*, 24: 69-71.
- Taylor S.J., Tescari G. & Villa M., 2001. A neartic pest of Pinaceae accidentally introduced into Europe: *Leptoglossus occidentalis* (Heteroptera: Coreidae) in northern Italy. *Entomological News*, 112: 101-103.
- van der Kuyl A.C., Ballasina D. L. P., Dekker J.T., Maas H., Willemsen R.E. & Goudsmit J., 2002. Phylogenetic relationships among the species of the genus *Testudo* (Testudines: Testudinidae) inferred from mitochondrial 12S rRNA gene sequences. *Molecular Phylogenetics and Evolution*, 22: 174-183.
- Vicidomini S. & Pignataro C., 2007. *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) in provincia di Salerno (Italia meridionale). *Il Naturalista Campano*, 35: 1-5.
- Viggiani G., Filella F., Delrio G., Ramassini W. & Foxi C., 2009. *Tuta absoluta*, nuovo lepidottero segnalato anche in Italia. *L'Informatore Agrario*, 2: 66-68.
- Vigne J.-D., 1992. Zooarchaeology and the biogeographical history of the mammals of Corsica and Sardinia since the last ice age. *Mammal Review*, 22: 87-96.
- Zangheri S. & Donadini P., 1980. Comparsa nel Veneto di un omottero neartico: *Metcalfa pruinosa* Say (Homoptera, Flatidae). *Redia*, 63: 301-305.