PREFACE

Many species of plants, microbes, and animals have been introduced around the world. Species are considered "invasive" or "alien" when they are not native to an area, but become established and cause, or are likely to cause, economic or environmental harm or harm to human health. In this book, the authors present current research in the study of the threats, ecological impacts and control methods relating to invasive species. Topics include thermochemical processing of wood from invasive arboreal species for sustainable bioenergy generation; invasive rodents in the U.S.; invasive Buprestid beetle species monitoring; the invasive beaver castor canadensis of the Tierra del Fuego Archipelago; leaf-cutting ants; invasive species and accurate ecological assessment in freshwater pollution; and the aquarium trade as a pathway for the introduction of invasive species in Mexico.

Chapter 1 – Thermochemical conversion of wood sawdust from two invasive arboreal species (*Prosopis ruscifolia* and *Parkinsonia aculeata)* into valuable products is explored to provide novel possible means of spread control attempting to their use as alternative, easily renewable bio-resources for bioenergy generation and activated carbons production. Rapid pyrolysis of both wood species is examined to assess the feasibility of their conversion into energy products. Yields of the three kinds of pyrolysis products, comprising bio-oil, non-condensable gas, and bio-char, are determined from experiments performed in a bench-scale installation at 500 °C. The wood species noticeably affects yields and distributions of the pyrolysis products. Main physicochemical characteristics and higher heating value (HHV) of the products generated from *Prosopis ruscifolia*, leading to higher bio-oil yield (~42%) than *Parkinsonia aculeata*, are determined. All the products show potentialities for energy applications. The bio-oil, further upgraded, could be employed as a liquid fuel with characteristics similar to those of fuel-oil, whereas the low heating value-gas evolved with pyrolysis course, mostly composed by CO_2, CO, CH_4 and H_2, might contribute to energy sustainability of the process. In turn, the bio-char (HHV≈ 27 MJ/kg) has potential as environmentally friendly solid bio-fuel. Kinetic measurements for the pyrolysis of the two wood species are also carried out by non-isothermal thermogravimetric analysis from room temperature up to 500 °C. An overall first-order decomposition model enables to properly represent kinetic data for both species over the whole temperature range. Differences in pyrolytic reactivity are reflected in the estimated kinetic parameters. On the other hand, use of wood sawdust from the two species as precursor of activated carbons targeted at wastewater treatment is investigated. For this purpose, the phosphoric acid activation process is applied at pre-established moderate conditions (acid/precursor weight ratio of 2, 450 °C, 0.5 h). The

activation atmosphere involved in the thermal treatment stage of the process is *in situ* modified to examine its influence on the development of porous structures, surface chemistry, and adsorptive behaviour of the resulting activated carbons. Either a self-generated atmosphere, flowing air or nitrogen is used. The activation atmosphere and the wood species have a marked influence on the characteristics of the derived carbons. Those developed from *Prosopis ruscifolia* wood in the self-generated atmosphere show higher BET surface area and total pore volume (2281 m^2/g, 1.7 cm^3/g) than the ones obtained under flowing air (1638 m^2/g and 1.3 cm^3/g), although the latter possess a higher total content of surface acidic/polar oxygen groups (2.2 meq/g) than the former (1.5 meq/g). Textural characteristics of *P. ruscifolia*-based activated carbons are superior to those for the carbons developed from *P. aculeata* wood in the self-generated atmosphere (968 m^2/g, 0.70 cm^3/g) and flowing N_2 (1103 m^2/g, 0.75 cm^3/g). These samples have total contents of surface acidic/polar oxygen functionalities of 1.9 meq/g and 1.7 meq/g, respectively. The ability of the activated carbons in removing representative toxic metal ions, oxo-anions, and organic compounds is examined from batch assays using dilute aqueous solutions as models of wastewater. Adsorption isotherms of Cu[II] ion onto *P. ruscifolia*-based activated carbons are determined and properly described by the Langmuir model. Maximum sorption capacity (X_m) for the air-derived carbons (X_m= 0.44 mmol/g) almost duplicates the value for those obtained in the self-generated atmosphere (X_m= 0.24 mmol/g), pointing to a predominant effect of the surface acidic functionalities on metal sequestering behaviour. Adsorption isotherms of salicylic acid onto the air-derived carbons are also ascertained, and satisfactorily fitted to the Langmuir model. On the other hand, effectiveness of the *P. aculeata*-based activated carbons in removing individual nitrate ion, phenol, and methylene blue at pre-established equilibrium conditions is comparatively investigated. High removal levels are attained for the organics (~ 90% and 100% for phenol and methylene blue, respectively), but nitrate removal is low (≤ 40%). Removal effectiveness of these carbons is inversely related to water solubility of the solutes and is slightly affected by the activation atmosphere. Accordingly, effective activated carbons of potential applicability in tertiary wastewater treatment may be developed from the two invasive species, as suitable, alternative precursors, by phosphoric acid activation at moderate conditions.

Chapter 2 – Many invasive rodents have become established in the United States and its territories. The species include several species of *Rattus*, house mice (*Mus musculus*), Gambian giant pouched rats (*Cricetomys gambianus*), ground squirrels (*Spermophilus parryii*), nutria (*Myocastor coypus*) and marmots (*Marmota caligata*). While most were introduced accidently, some were introduced for food or fur. Additionally, some native species of rodents have been placed on islands, at least on a temporary basis, to study rodent species interactions. These rodents have caused serious impacts to native flora and fauna, agriculture, and other resources. They have caused the extinction or many species of birds on insular ecosystems. Although many methods are used to control or eradicate introduced rodents, rodenticides and traps are the main tools. Since the early 1990s, agencies have been eradicating rodents from various islands, primarily for conservation purposes. Of about 27 eradication attempts, 22 (81%) appear to have succeeded with only about 5 failures. For several islands, however, it is too early to determine if the attempted eradication has been successful or not. In the case of failed eradications, rapid re-invasion by rodents from nearby islands may be the reason. Numerous additional eradications are planned. We review the introduced rodent species, their impacts, and eradications, both successful and unsuccessful,

that have occurred in the United States. Most eradications involved the use of the anticoagulant rodenticides diphacinone and brodifacoum. Rodenticides have been applied by hand-broadcast, bait station deployment, and aerial broadcast. We briefly review the strategies and methods used in eradication projects and the efforts to mitigate potential non-target and environmental impacts. Finally, we consider some of the remaining challenges in invasive rodent management and eradication in the United States, including the use of toxicants, land access, public attitudes, resource availability and monitoring difficulties.

Chapter 3 – Buprestid beetles (Coleoptera: Buprestidae), which were previously considered to be minor forest pests, have received substantial attention recently due to the widespread ash tree mortality associated with the North America introduction of the emerald ash borer, *Agrilús planipennis* from Asia. At the same time, geographic expansions of forest buprestid species associated with other hosts have been noticed, causing concern about potentially similar destructive outcomes. Attempts have been made to understand the host-finding and mating behaviors of these forest buprestids in order to develop detection and management tools, with a focus primarily on *A. planipennis*. A complex sequence of chemical and visual signals appears to mediate such behaviors, which has been difficult to mimic in an effective trapping approach. Both sexes appear to be attracted to the tree canopy as a result of host-produced volatile compounds. Once in the canopy, males visually seek and fly directly onto stationary females from a distance of up to 1 meter, an event which immediately precedes attempts to copulate. The subsequent copulation attempts by the males are mediated by sex-specific cuticular hydrocarbon signals. Similar visually-mediated approaches toward dead models have also been observed in other tree-dwelling buprestids such as *Agrilus cyanescens*, *A. subcinctus*, *A. biguttattus*, *A. sulcicollis*, and *A. angustulus*. While the extent of similarities of both visual and chemical signals shared by these species and *A. planipennis* has not been fully explored, it is becoming clear that the visual signal that induces attraction to a female is broadly tuned, exhibiting substantial cross-species attraction. Despite subtle differences in coloration patterns, all of these species generate an intense spectral signal using the refractive properties of repetitive layering of the elytral cuticle. Further investigation into both the means of generation and response to the visual signal, as well as the chemical ecology of these species, may provide advances in trapping technologies for the detection of all tree-feeding Buprestids.

Chapter 4 – The Tierra del Fuego Archipelago (TDFA) contains numerous invasive species, of which *Castor canadensis* is the most abundant and important invasion. Beaver are responsible for the most drastic landscape alteration in Tierra del Fuego since the last glacial age, affecting not only the hydrology and composition of the southern beech forest, but more importantly allowing other exotic species to invade the ecosystem. From 25 pairs intentionally released in 1946, beavers have increased their numbers to a current population size of aprox.100,000 individuals. Here, we present the genetic variability and population structure of 222 mitochondrial DNA beaver samples. We detected 7 D-loop haplotypes, 3 of them resulted the most abundant and distributed all along the archipelago. To analyze the data, TDFA population was subdivided into five subpopulations and a slight structure was found (ϕst =0.169). With these data we also identify management units (MUs) of the invasive beaver in the TDFA. Although, sea water and mountains could be considered barriers for beaver's dispersion, we found no barriers to gene flow within the Isla Grande, which may be due to the complex stream watershed network that allows beavers to easily disperse. These results indicate that the Isla Grande is a single management unit (MU) and every small island

in the archipelago is a separate MU. It is important to consider that successful eradication programs of mammals always were conducted in small islands while invasive populations on larger islands or those that display no distinct structure are more problematic, so the eradication of *Castor canadensis* in the TDFA would be logistically very difficult or perhaps impossible. Therefore, we propose to (1) control the expansion from IG population to others areas through trapping beavers and (2) eradicate beaver populations of the adjacent small islands (small area comparative to Isla Grande) and especially from the continent. If the species is not early removed in the mainland, beavers will begin to invade the Patagonian forests very quickly and its future eradication in these continental areas will be almost impossible. To carry out the control of the species in Tierra del Fuego, is necessary to promote beaver extraction through the commercial trapping in a way to control this species in the short term. To achieve this important point, the classic control scheme must be change it stimulating new business development by incorporating new materials and products to market and also coordinate the participation of public and private actions to exploit species under control. In this work, we state three options for economic use of the beaver: 1) the government could pay a price for killing beavers, 2) to sell/export the beaver fur and 3) to sell beaver´s meat for human consumption. With these three options of beaver exploitation, we believe that the Isla Grande control may be feasible and logistically possible.

Chapter 5 – The fungus-growing ants belong to the genus Atta and Acromyrmex and individuals are causing serious damage to various types of plantations due to the habit of cutting leaves and shoots of economic importance for use in cultivating the garden symbiotic fungus colonies, causing serious damage. The ants attack is harmful at any stage of the cycle, but the damage is greater in the training phase of the plant, when temporarily paralyzes growth. In an attempt to reduce the damage caused by these insects farmers make the control of fire ants through the use of mechanical methods, biological and chemical. The mechanical control is to dig the nest to remove the queen (individual responsible for placing the eggs that give rise to other individuals in the colony), which are larger in size than workers, causing a disruption of the nest, since the queen controls all activities and individuals in the colony. This type of control has been recommended only for newly formed nests, otherwise, the queen will be housed in great depth, making its removal. It should be noted that in practice such control is not a good alternative in commercial plantations due to the large extent of the property. Chemical control can be accomplished by applying powder, liquid insecticide, thermonebulization and granulated bait. The powder is a type of insecticides formulated in solid vehicles, such as talc, and the application is through hand pumps. The death of ants occurs by direct contact with the chemical. However, this type of control has limitations such as the impossibility of penetration of the product in the deepest chambers of nesting adults, and has now been replaced by liquid thermonebulized, through which the product is injected into the nest with the help of hose, and toxic bait, which is considered more efficient due to easy handling, fast action and lower costs. The bait is distributed on the tracks near the colony of ants to be transported into the nest by workers. This method can cause much damage to non-target ants and even other bodies. Finally, it has been used the biological control, which is the introduction of natural enemies in plantations, such as birds, some species of spiders, beetles, mites and even other species of ants, and much research is currently focused on creating natural insecticides that have repellent action or lethal to the ants, such as castor oil, or fungicidal against the garden of fungus that feeds the colony, as is the case of sesame. Studies on the morphology of the reproductive organs of these ants could also be an important

tool in the search for new methods of control. Some studies have been conducted on the morphology of the spermathecae of ants, the body that produces all the elements capable of maintaining viable sperm inside, where it was observed that products circulating in the hemolymph, due to the thin wall thickness of the the spermatheca, also could enter the environment within this structure, where are the sperm and thus affect their viability.

Chapter 6 – Macroinvertebrates are routinely used in the calculation of indices to assess the quality of rivers throughout the world. Macroinvertebrate assemblages have proved themselves to be reliable, cost effective indicators of freshwater pollution, as the relative sensitivities of their members respond to changes in water quality in predictable ways. Such biological monitoring can have advantages over chemical monitoring, as it tends to be cheaper and more reliable over the long term, especially in rivers where water quality can fluctuate dramatically on a day to day basis. However, an increasing threat to accurate biological monitoring comes from invasive species. The rate of freshwater invasions is increasing, with increasing global transport, climate change and environmental degradation all facilitating the arrival of pollution tolerant and often aggressive invaders in many previously undisturbed river systems. Such invasive species can have a major impact on benthic macroinvertebrate assemblage structure and diversity. Macroinvertebrate invaders often radically alter native macroinvertebrate assemblages through biotic interactions, such as competition and predation. In many cases more pollution tolerant invaders can replace more sensitive natives and very predatory invaders can decimate native assemblages as a whole. This has serious implications for accurate biological monitoring and the consequent assessment of the ecological status of invaded rivers. The whole structure of existing water quality indices may need revising to take into account the presence of invasive species within monitored assemblages, such that the accuracy of any derived assessments of water quality can be judged in the context of whether the assemblages generating them contain mainly natives or invaders. In addition, methods of 'biocontamination' assessment, designed to be used alongside current routine water quality indices may represent a simple, cost-effective way to integrate the biological pressure invasives represent, into a country's or region's routine river quality monitoring programme. Such methods should be adopted alongside routine biological monitoring of pollution to provide a more comprehensive estimate of ecological quality status. It is clear that he problems of invasive species and accurate monitoring of freshwater pollution can no longer be ignored.

Chapter 7 – The total ornamental fish industry worldwide (including dry goods) is valued at approximately US $15 billion dollars and it has been estimated that approximately one billion ornamental fish are commercialized every year with a value in the order of US $6 billion dollars. Freshwater species constitute the bulk of the trade; 90 percent of these are obtained from aquaculture and only 10 percent are wild captured. Around 800 to 1000 species and varieties are traded worldwide. Ornamental fish trade has been recognized as an important pathway for the introduction of non native species in several countries and present trends indicate that this pathway may turn into the main source of exotic invasive species in North America. Invasive species are characterized by posing different threats to the environment, the economy and human health. Among the main impacts provoked in the aquatic environment by invasive species are: competition with native species, hybridization, predation, introduction of diseases, habitat disruption and trophic webs modification. The introduction of exotic species has been related to the extinction of 54 percent of aquatic native species worldwide. Overall, 70 percent of the extinctions of North American fishes and 60

percent of those from Mexico are related to non native species, totally or partially. Aquarium trade has shown an accelerated increase during the last decade with a trade value of US $160 million dollars. This increase parallels the boost of exotic species in the country. In fact, in the 80's only 55 non native fish species were registered in Mexico and by 2004 the number raised to 118, of which 67 (58.26 percent) have turned invasive. Several facts contribute to explain this: i) The low amount of varieties cultured in Mexico (61 varieties pertaining to 19 species), compared to the huge number of varieties imported (more than 700 from 117 families), ii) The number of fish imported in Mexico; 40 million ornamental fish are traded annually, of which 45 percent are imported (nearly 18 million fish were imported in 2006) while 55 percent are captive bred iii) there is a lack of official regulations for the establishment and operation of farms producing ornamental fish and for the translocation of ornamental fish within the country. As a result, ornamental fish species have been established in 9 out of 10 continental aquatic regions of Mexico. Some of these species have already severely impacted the environment and the economy in most regions of the country.