Chapter 3
Domestic Regulatory Framework and Invasive Alien Species in China

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Editor's Note China has become a significant participant in international agricultural trade during the past 15 years. Regulatory activities in China have not been widely understood by the international community of agricultural trade and travel. Yet China has an important role to play in international Plant Biosecurity. The following chapter outlines some of the significant elements of Chinese Plant Biosecurity as an example of domestic regulatory work within one bureaucratic framework. Each country must construct its own domestic (internal) programme based upon its unique circumstances. Structure and administration of these programmes can vary among countries. Regulatory officials of all domestic programmes should understand and appreciate the complexities of regulatory programmes among their trading partners and work cooperatively to improve management of Invasive Alien Species.

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3.1 Official Control: Regulations and Bureaucracy (Zhi-Hong Li)

3.1.1 Introduction

The first reported instance of using legal means to control plant pests occurred in 1660 when the government of Leon, France attempted to eradicate barberry in order to prevent Wheat Stem Rust disease caused by *Puccinia graminis* Pers. (Xia 2002; Li et al. 2004; Xu 2008). The earliest suggestion of plant quarantine in China was proposed during 1916 by Dr. Bingwen Zou, the pioneer and founder of Plant Pathology in China (Chen and Huang 1992). Zou explained the importance of plant quarantine and emphasized four elements of the management of plant diseases (exclusion, eradication, protection and immunization) (Chen and Huang 1992). During 1927–1929, a paper titled "Plant Quarantine" was published in three parts by Dr. Fengmei Zhu (Chen and Huang 1992). The publication emphasized the significance and basic methods of plant quarantine. Zhu advocated import quarantine to prevent plant-pest introduction and protection of domestic agriculture and forestry. He also emphasized that export quarantine would increase overseas customers' confidence and promote international trade. These collective actions were regarded as the scientific foundation of plant quarantine in China. In December 1928, the Ministry of Agriculture and Minerals published 'Regulation for Agricultural Products Inspection' in an attempt to prevent Cotton Bollworm, *Pectinophora gossypiella* (Saunders), from becoming established in China. This is the first official regulation for plant quarantine in China (Chen and Huang 1992). During 1928, Agricultural Products Inspection Services were established in Shanghai, Guangzhou and Tianjin. These services were mainly responsible for the import quarantine of cotton and the export quarantine of plant products to the UK and USA.

"Plant quarantine" is intended to prevent the introduction and/or spread of quarantine pests in China. Plant quarantine and invasive species management activities have been developed in China during the past 80 years. Three Ministries and their branches are responsible for executing plant quarantine regulations (see below).

3.1.2 Legal System

National regulations, international agreements and bilateral/ multilateral agreements form the legal system of plant quarantine in China. Among national regulations, "Law of the People's Republic of China on the Entry and Exit Animal and Plant Quarantine", "Regulations on Plant Quarantine" and related lists of quarantine pests play a very important role in the international and domestic phytosanitary activities.

For international agreements, as a member of FAO and WTO, China conforms to the principles of IPPC, SPS Agreement and Agreement on Technical Barriers to Trade (TBT Agreement) (see Chaps. 2 and 9). During the past 10 years, and following membership in the WTO, China has executed more than 600 bilateral or multilateral agreements related to SPS and TBT measures.

"Law of the People's Republic of China on the Entry and Exit Animal and Plant Quarantine" became effective in 1992. This law now includes eight chapters under the titles "General Provisions", "Entry Quarantine", "Exit Quarantine", "Transit Quarantine", "Quarantine of Materials Carried by Passengers or by Post", "Quarantine of Means of Transport", "Legal Responsibility", and "Supplementary Provisions". In the General Provision, the law was formulated to prevent infectious or parasitic diseases of animals, diseases, insect pests and weeds dangerous to plants, and other harmful organisms from spreading into or out of China. The law also protects crop production, forestry, animal husbandry, fisheries and human health, and promotes foreign economic relations and trade. To execute this law effectively, "Regulations for the Implementation of the Law of the People's Republic of China on the Entry and Exit Animal and Plant Quarantine" came into force during 1997. In these regulations, Import Permits for Entry, Exit and Transit Quarantines, Quarantine of Materials Carried by Passengers/Post, Quarantine Transport, and Quarantine Inspection Supervision were regulated in detail.

"Regulations on Plant Quarantine" was circulated by the State Council in 1983, and amended in 1992. The regulations include 24 Articles and indicate that the agricultural and forestry departments under the State Council are in charge of the plant quarantine work throughout China. The agricultural and forestry departments of Provinces, Autonomous Regions and Municipalities control plant quarantine work in their own domains. The agricultural and forestry departments of Provinces, Autonomous Regions and Municipalities may develop quarantine catalogues for their own regions. Imported seeds, seedlings and other propagating materials must be isolated for trial planting. Plants are released for planting only after they have been observed, tested and shown to be free of quarantine pests.

China maintains three national lists of plant quarantine pests. The lists are periodically revised and used by quarantine officers. All lists are circulated by the government to all members of FAO, WTO and related organisations. The public can read and download all the lists from the relevant website. The newest lists are compared especially with the number of different kinds of quarantine plant pests (Table 3.1).

3.1.3 AQSIQ, MOA, SFA and Branches

China's plant quarantine includes one Ministry and two ministerial administrative organizations under the State Council. General Administration of Quality Supervision, Inspection and Quarantine of the PRC (AQSIQ) and its branches control plant quarantine work at ports throughout the country. The Ministry of Agriculture

Table 3.1 Plant quarantine pest lists of People's Republic of China

PRC list	Year	Pest species	Pathogen species	Insect and snail species	Weed species
Entry quarantine pests	2007	435	242	152	41
Agricultural quarantine pests	2009	29	17	9	3
Forest quarantine pests	2008	21	7	13	1

(MOA), State Forestry Administration (SFA) and their branches control domestic agricultural and forest plant quarantine work respectively.

AQSIQ monitors product quality, standard metrology, entry-exit commodity inspection, entry-exit health quarantine, entry-exit animal and plant quarantine, import-export food safety, certification and accreditation, standardization, as well as administrative law-enforcement (http://english.aqsiq.gov.cn/). AQSIQ maintains 19 Departments including the Department of Supervision on Animal and Plant Quarantine. This department is responsible for: (1) Studying and preparing provisions and regulations involving entry-exit of animals and plants, (2) Studying and preparing lists of prohibited animals and plants, (3) Organizing inspection, quarantine and supervision of entry-exit animals, plants, and animal/plant products, (4) Administering inspection and quarantine of entry-exit genetically modified organisms (GMOs) and their products, (5) Collecting information on animal and plant epidemics outside China and organizing the implementation of Risk Assessment and emergency precaution measures, and (6) Administering registration and approval of entry-exit animal and plant inspection and quarantine. AQSIQ has established 35 Entry-Exit Inspection and Quarantine Bureaus (CIQs) in China's provinces, autonomous regions and municipalities, with approximately 300 branches and more than 200 local offices across the country. AQSIQ has more than 30,000 employees operating in commodity distributing centres at sea ports, land ports and airports. The WTO/TBT and WTO/SPS National Enquiry Points of the People's Republic of China are also located within AQSIQ.

The Ministry of Agriculture (MOA) is responsible for national development of agriculture and the rural economy. MOA includes 11 Departments, 6 Bureaus, and a Permanent Representative Office to the UN FAO (http://english.agri.gov.cn/). The Department of Crop Farming Administration (DCFA) is responsible for domestic agricultural plant quarantine work. Primary functions of DCFA include: (1) Administration of plant quarantine, (2) Organize drafting and implementation of laws, regulations and related standards for plant quarantine, (3) Implementation of IPPC, (4) Draft and negotiate inter-governmental agreements on plant quarantine, and (5) Enact and circulate decrees of prohibited plants. In each Province, Autonomous Region and Municipality, a general station of plant protection and/or quarantine is maintained to resolve agricultural plant quarantine affairs locally.

The State Forestry Administration (SFA) is responsible for national development of forestry and forest economy. SFA includes eight Departments and a Bureau (http://english.forestry.gov.cn/). Department of Afforestation and Greening (Office

of the National Afforestation and Greening Committee) is responsible for domestic forest plant quarantine work. The functions of this Department include seven aspects: (1) Quality control of seeds and seedlings, afforestation, management of national seeds and forestry operations, (2) Ensuring the prevention of water loss and soil erosion by biological measures such as planting trees and grasses, (3) Monitoring the cultivation of various types of public welfare forests and commercial forests, (4) Organizing and directing forestry pest control, quarantine and forecast, (5) Directing and supervising nationwide voluntary tree-planting, urban and rural greening activities, (6) Stipulating policies and measures in forestry sector for tackling climate change and supervising their enforcement, and (7) Performing specific tasks assigned by the National Afforestation Committee. In each Province, Autonomous Region and Municipality, a general station of forestry protection operates to regulate forest plant quarantine affairs.

The Ministry of Environmental Protection (MEP) of the PRC administers environment protection including biodiversity and invasive species management (http://english.mep.gov.cn/). MEP guides, coordinates and supervises ecological conservation and biological species activities. This includes organizing and coordinating the conservation of biodiversity. The Department of Nature and Ecology Conservation in MEP is the office of Biodiversity Conservation and the office of National Biosafety Management.

3.1.4 Summary

China has more than 80-years of experience in plant quarantine. The Chinese government has always placed high priority on the development of agriculture since establishment of the PRC. With the development of international trade in horticulture and plant commodities, China is placing more attention to plant biosecurity. This priority is realized in the management of plant quarantine involving invasive species. Based on the three levels of China's legal system, the international collaboration between China and other members of WTO and FAO, and the domestic collaboration among AQSIQ, MOA, SFA, and MEP, the management of plant biosecurity has achieved more transparency and harmonization.

3.2 Technical Support: Academies and Universities (Zhi-Hong Li)

3.2.1 Introduction

Plant quarantine and invasive species management are based on technical support, especially for Pest Risk Assessment, inspection and identification, eradication and

treatment, supervision and monitoring. In China, at least three national academies and more than 50 universities are researching techniques and educating students on plant biosecurity. Notable among these institutions are the Chinese Academy of Inspection and Quarantine (CAIQ), Chinese Academy of Agricultural Sciences (CAAS), Chinese Academy of Forestry (CAF), China Agricultural University (CAU), Zhejiang University (ZU), Nanjing Agricultural University (NAU), and Beijing Forestry University (BFU). Considerable contributions of technical support and professional education for plant quarantine and invasive species management are provided by these institutions.

3.2.2 CAIQ, CAAS and CAF

Chinese Academy of Inspection and Quarantine (CAIQ) is a national scientific research body for social benefits. CAIQ was established in 2004 with approval of the State Council. CAIQ was created from two former institutes: The China Import and Export Commodity Inspection Technology Institute and the Animal and Plant Quarantine Institute of General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). The scope of CAIQ is research mainly on the application of science and technology in inspection and quarantine, as well as relevant basic, high-tech and soft science research. The focus is on solving emergency and basic scientific problems. CAIQ also provides technical support to the policy-making of inspection and quarantine for the national government. Eleven institutes and three centres are affiliated with CAIQ (Table 3.2).

China maintains as least 35 technology centres within CIQs. Among these, the Institute of Plant Quarantine and the Institute of Equipment Technology play an important role in technical support of plant quarantine and invasive species management. The journal 'Plant Quarantine' (established in 1979) is maintained by CAIQ. Papers published in Plant Quarantine include new reports and research developments related to exit-entry plant quarantine, domestic agricultural and forest plant quarantine issues.

CAAS was established in 1957. It is the national agricultural research organisation directly affiliated to the MOA. CAAS has the strategic task of serving nationwide agriculture, rural development and empowering farmers with science and technology (http://www.caas.net.cn/engforcaas/index.htm). CAAS concentrates on strategic and applied research solving scientific problems of national or regional importance. CAAS maintains 38 research institutes located in 17 Provinces, Autonomous Regions and Municipalities. The Institute of Plant Protection (IPP) plays an important role for technical support of invasive species management, especially in recent years (http://www.ippcaas.cn/ippc/ippcaas_e/ippcaas_e.htm). The mission of IPP is to study and seek resolution of theoretically and economically important problems involving plant pests and pesticides. The Chinese Society of Plant Protection is responsible for IPP, in which the Sub-society of Biology Invasion was established

Table 3.2 Research institutes and research centres of CAIQ

Institute/centre	Acronym	Responsibility
Institute of Food Safety	IFS	Hazardous compounds analysis and metabolic mechanism, species identification and genetic modified organism (GMO) safety, food safety information and technical support
Institute of Plant Quarantine	IPQ	Early warning and emergency response of plant pathogenic microorganisms and quarantine pests, and epidemic monitoring
Institute of Animal Quarantine	IAQ	Animal infectious diseases and epidemiology
Institute of Health Quarantine	IHQ	Exotic infectious disease, ports safety, pathogenic microbiology
Institute of Industrial and Consumer Product Safety	IICPS	Safety and quality safeguard for light industrial products, toys and textile products
Institute of Chemicals Safety	ICS	Safety and quality safeguard for daily used chemical product
Institute of Mechanical and Electrical Product Safety	IMEPS	Safety and quality safeguard for electric/electronic products
Institute of Equipment Technology	IET	Quarantine treatment and equipment, on-site rapid inspection and quarantine technology
Institute of Tobacco Safety and Control	ITSC	Safety and quality safeguard for tobacco products
Institute of Food Risk Management and Application	IFRMA	Food safety risk management policy and technical regulation
Institute of Strategy for Inspection and Quarantine	ISIQ	Comprehensive, look-forwarding and basic scientific theories, development strategies and relevant long-term mechanism
Agro-product Safety Research Centre	ASRC	Safety and quality safeguard for agricultural products
Data Centre of Inspection and Quarantine	DC	Information collection and analysis on inspection and quarantine
CAIQ Test Centre	TEST	Third-party inspection and quarantine test according to ISO/IEC17025

in 2009 in response to increasing plant Biosecurity needs. The Biosafety Research Centre of MOA in IPP focuses on research of invasive pests in China.

CAF (established in 1958) is the national forest research organisation directly affiliated with SFA, and is based on the former Central Research Institute of Forestry (established in 1953) (http://www.forestry.ac.cn/). CAF includes 29 research institutes, centres and organisations located across 18 Provinces, Autonomous Regions and Municipalities. Among these Institutes, the Research Institute of Forest Ecology, Environment and Protection (RIFEEP) conducts research on forest plant biosecurity. RIFEEP contributes to the technical support of forest quarantine and in recent years has focused more on invasive species management (http://www.ifeep.cn/).

3.2.3 Higher Education of Plant Protection and Forestry

The higher education of agriculture in China has a history dating from 1905. It is regarded as the basic and significant field of higher education with sustainable development. Plant Protection and Forestry have a close relationship with plant biosecurity for undergraduate and graduate levels. With the development of plant biosecurity and social demands, Plant Quarantine and Invasive Pest Management now receive more attention within higher education in China. Most universities with Plant Protection and Forestry have majors related to Plant Quarantine and Invasive Pest Management for undergraduates and/or postgraduates.

To promote higher education, 'Project 211' and 'Project 985' were implemented by the PRC Ministry of Education (MOE) in 1995. Project 211 is responsible for constructing nearly 100 universities during the twenty-first Century. Its main goal is to establish Higher Institutes and Key Disciplines during the twenty-first Century. Project 211 has improved education quality, scientific research, administrative standards and operational efficiency. Project 985 aims to construct first-class universities, establish world-class research groups, explore new administrative systems and operational mechanisms. Currently, 113 universities are supported by 'Project 211'; 39 distinguished universities are supported by 'Project 985'. This constitutes only 6.6 % and 2.3 % respectively of more than 1,700 universities, colleges and institutes in China.

Table 3.3 compares majors and/or research directions during 2010 related with plant biosecurity in universities supported by 'Project 211'. Three trends are apparent: (1) Plant Protection and Forestry are very popular majors for undergraduates. (2) Plant Pathology, Agricultural Entomology and Insect Pests Control, Pesticide, and Forest Protection are traditional majors for postgraduates. (3) Some universities establish majors or directions of plant quarantine, forestry quarantine and/or invasive species management for undergraduates and postgraduates, e.g. China Agricultural University, Zhejiang University, Nanjing Agricultural University, Southwest University, and Beijing Forestry University among others.

3.2.4 Research Projects

Most research projects related to plant biosecurity in China are supported by the government. During the past 10 years, China has significantly increased funding in support of research on plant quarantine and invasive species management. Projects include the National Basic Research and Development Programme (973) (http://www.973.gov.cn/English/Index.aspx), the National High-Tech Research and Development Programme (863), the National Key Technological Research and Development Programme, the projects of public industry research, the projects of Natural Science Foundation of China (NSFC), the ministerial and provincial

Table 3.3 Degree majors in 2010 related with plant biosecurity at primary universities in China

Universities	Support from 211 project	Support from 985 project	Major for bachelor's degree	Major for master's degree	Major for Ph.D. degree
China Agricultural University	Yes	Yes	Plant Protection	Plant Pathology	Plant Pathology
				Agricultural Entomology and Insect Pest Control	Agricultural Entomology and Insect Pests Control
				Pesticide	Pesticide
				Plant Quarantine and Agricultural Ecology Health (with direction of plant quarantine)	Plant Quarantine and Agricultural Ecology health (with directions of pest risk analysis, quarantine identification and treatment)
Zhejiang University	Yes	Yes	Plant Protection	Plant Pathology	Plant Pathology (with directions of plant quarantine, invasive biology)
				Agricultural Entomology and Insect Pest Control (with direction of Biosecurity and Management)	Agricultural Entomology and Insect Pest Control (with directions of plant quarantine, Invasive Biology)
				Pesticide	Pesticide
Northwest Agricultural and Forest University	Yes	Yes	Plant Protection	Plant Pathology	Plant Pathology
			Forestry	Agricultural Entomology and Insect Pest Control	Agricultural Entomology and Insect Pest Control
				Pesticide	Pesticide
				Plant Protection Resource Utilization	Plant Protection Resource Utilization
				Pest Management Ecological Engineering	Pest Management Ecological Engineering
				Forest Protection	Forest Protection
Sun Yat-Sen University	Yes	Yes	Biology Science	Agricultural Entomology and Insect Pests Control (with direction of Biology Invasion and Control)	Agricultural Entomology and Insect Pests Control
Shanghai Jiaotong University	Yes	Yes	Plant Biology Technology	Plant Pathology	Pending
				Pesticide	

(continued)

Table 3.3 (continued)

Universities	Support from 211 project	Support from 985 project	Major for bachelor's degree	Major for master's degree	Major for Ph.D. degree
Lanzhou University	Yes	Yes	Grass Science	Plant Pathology	Pending
Jilin University	Yes	Yes	Plant Protection	Plant Pathology	Pending
				Agricultural Entomology and Insect Pests Control	
				Pesticide	
Nanjing Agricultural University	Yes	No	Plant Protection	Plant Pathology (with direction of Plant Quarantine and Invasive Biology)	Plant Pathology
					Agricultural Entomology and Insect Pest Control
				Agricultural Entomology and Insect Pest Control (with direction of Invasive Biology and Biology Control)	Pesticide
					Plant Quarantine and Biosecurity (with directions such as Alien Invasive Pathogen Quarantine and Control, Alien Invasive Species Risk Assessment, Alien Insect Pests Invasive Ecology, Alien Insect Pests Control, Alien Pathogen Pests Control, GMO Testing and Security assessment)
				Pesticide	
Huazhong Agricultural University	Yes	No	Animal and Plant Quarantine	Plant Pathology (with direction of Plant Quarantine)	Plant Pathology (with direction of Plant Quarantine)
				Agricultural Entomology and Insect Pest Control	Agricultural Entomology and Insect Pests Control
				Pesticide	Pesticide
Southwest University	Yes	No	Plant Protection	Plant Pathology	Plant Pathology
				Agricultural Entomology and Insect Pest Control	Agricultural Entomology and Insect Pest Control
				Pesticide	Pesticide

				Biosecurity (with directions of Biology Invasion, Dangerous Disease Diagnosis Technology, Pests Monitoring and Control, GMO Biology Risk Assessment)	Biosecurity (with directions of Biology Invasion, Dangerous Disease Diagnosis Technology, Pest Monitoring and Control, GMO Biology Risk Assessment)
Hainan University	Yes	No	Plant Protection	Plant Pathology Agricultural Entomology and Insect Pest Control (with directions of Invasive Species Prevention and Control) Pesticide Forest Protection	Molecular Plant Pathology Crop Insect Pest (with direction of Insect Ecology; Invasive Biology)
Guangxi University	Yes	No	Plant Protection (with direction of Plant Quarantine)	Plant Pathology Agricultural Entomology and Insect Pest Control Pesticide	Plant Pathology Agricultural Entomology and Insect Pest Control Pesticide
Guizhou University	Yes	No	Plant Protection	Plant Pathology Agricultural Entomology and Insect Pest Control	Plant Pathology Agricultural Entomology and Insect Pest Control
Beijing Forestry University	Yes	No	Forestry Forest Resources Conservation and Recreation	Forest Protection (Forest Quarantine)	Forest Protection (Forest Quarantine)
Northeast Forestry University	Yes	No	Forestry Forest Resources Conservation and Recreation	Forest Protection	Forest Protection
Northeast Agricultural University	Yes	No	Plant Protection	Plant Pathology Agricultural Entomology and Insect Pest Control Pesticide	Pending

(continued)

Table 3.3 (continued)

Universities	Support from 211 project	Support from 985 project	Major for bachelor's degree	Major for master's degree	Major for Ph.D. degree
Suzhou University	Yes	No	Horticulture	Agricultural Entomology and Insect Pest Control	Pending
Huazhong Normal University	Yes	No	Biology Science	Agricultural Entomology and Insect Pest Control Pesticide	Pending
Sichuan Agricultural University	Yes	No	Plant Protection Forestry Forest Resources Conservation and Recreation	Plant Pathology Agricultural Entomology and Insect Pest Control Pesticide Forest Protection	Pending
Ningxia University	Yes	No	Plant Protection	Agricultural Entomology and Insect Pest Control Pesticide	Pending
Shihezi University	Yes	No	Plant Protection	Plant Pathology Agricultural Entomology and Insect Pest Control Pesticide	Pending

research projects and the international collaboration programme. Data on the CAIQ website (2004–2008) show it has undertaken 222 national research projects of high academic level, valued at a total of 160 million RMB.

3.2.5 Summary

Support by CAIQ, CAAS, CAF and many universities (CAU, ZU, NAU, and BFU) for plant quarantine and invasive species management has engaged critical research and higher education in China. With continuing support from government, the study of plant Biosecurity, emphasizing plant quarantine and invasive species management, is acquiring significant biological and ecological information and progress toward exclusion, management and eradication of Invasive Alien Species.

3.3 Quarantine Techniques, Standards and Application (Shui-Fang Zhu)

3.3.1 Introduction

Pest Risk Analysis supports the work of the domestic quarantine system involving entry of plants and plant products (Chap. 9). Detection and identification are daily tasks in the front line of port quarantine (Chaps. 12 and 13). The detection and identification conclusions drawn from the intercepted exotic pests diseases and weeds serve as an important foundation for carrying out Pest Risk Analysis and formulating quarantine policies. Accurate identification of IAS also is critical for quarantine treatment, because under many circumstances only after detecting and identifying the exotic species could the specific quarantine treatment be implemented. Quarantine treatments refer to measures with official license aiming at killing, removing or rendering infertile quarantine pests (Chap. 10). Treatments include various technical procedures adopted towards goods/products/commodities/containers infested with pests. Quarantine actions include disinfection and disinfestations, return of shipment, destruction of material, port transferring, change of use and restriction of utilization. Plant quarantine must monitor and detect new epidemic situations within the country, province or region and promote emergency plans to expeditiously contain or eradicate newly discovered IAS incursions. Quarantine actions should also monitor the distribution trends of quarantine pests present in parts of the country or region, and thus provide a scientific basis for decision-making for entry and exit plant quarantine and prevent specific pests from exiting and re-entering. Facing today's economic globalisation, the frontier quarantine assumes the double responsibilities of preventing exotic pest from entering and exiting as well as guaranteeing the efficient import and export of agricultural trade (Zhu et al. 2004a, b).

3.3.2 Pest Risk Analysis and Pest List

Early in 1981, the former Plant Quarantine Institute of Ministry of Agriculture (the predecessor of Plant Quarantine Inspection Institute of CAIQ) implemented evaluation of quarantine for dangerous pests. Subsequently, the Institute completed topics of 'Study on Quarantine Pest Risk Analysis' and 'Quantitative Risk Assessment of Pests' in succession, and introduced quantitative assessment methods such as agroclimatic analogical distance, ecoclimatic assessment model, geographical information system, Monte-Carlo simulation and risk simulation experiment study, by means of which the Institute analysed the suitable areas in China for important quarantine pests. Some of these quarantine pests include *Ceratitis capitata* (Wiedemann), *Tilletia controversa* Kühn, *Bursaphelenchus xylophilus* (Steiner & Bührer) Nickle, *Erwinia amylovora* (Burrill) Winslow et al. and *Sorghum halepense* (L.). These assessment methods applied to quarantine pests provided the scientific basis for macro decision-making of plant quarantine.

The 'Chinese Entry and Exit Animal and Plant Quarantine Risk Analysis Committee' was established in April 2002. The Committee is comprised of senior experts from relevant departments of the State Council, institutions of higher learning, scientific research institutes, quality inspection system and relevant social groups. The Committee studies and discusses major issues about Risk Analysis of entry and exit animal and plant quarantine in China. The Committee also deliberates on important Risk Analysis reports of entry and exit animal and plant quarantine. The two national standards for risk analysis, 'Technical Requirements for Pest Risk Analysis of Entry and Exit Plants and Plant Products' (GB/T 20879-2007) and 'Work Guidelines for Pest Risk Analysis of Entry and Exit Plants and Plant Products' have been issued and implemented in 2007 and 2008 respectively. The basic principles of these two national standards adopt by equation of the international standards such as ISPM 02, 11, 19 and 21.

Pest Risk Analysis (Chap. 9) is initiated mainly under the following circumstances: (1) Creating or revising quarantine pest lists; (2) Importing or exporting plants and related products; (3) Introducing certain pests for special demands; and (4) Intercepting new exotic organisms. 'Revision of Quarantine Pest List of Entry Plants' was completed in 2006. In 2007 the new 'Regulated Plant Pest List of P. R. China' was issued and the taxa of quarantine pests increased from 87 to 436 (Bulletin MOA 2010; Chen 2009). Currently, Hong Kong and Macao are formulating lists of plant quarantine pests. In 1993 the former Plant Quarantine Institute of Ministry of Agriculture presided over completion of the first Chinese PRA report: 'Risk analysis report of importing American plum'. Subsequently, more than 200 Pest Risk Analysis reports have been completed in China. With the expansion of import and export trade, the number of risk analysis reports initiated has increased yearly. Risk Analysis provides the scientific basis for plant quarantine negotiations with foreign countries and relevant decision making.

3.3.3 Pest Inspection and Testing

The number of exotic pests intercepted by China is increasing yearly (Wan et al. 2009a, b). The prevention and control of exotic pests has become a global public security issue correlated with economic globalisation. In 2005, Chinese ports intercepted more than 2,000 taxa (Genus/Species) of plant pests in more than 100,000 consignments. In 2012, as many as 300,000 consignments and 4,300 taxa (Genus/Species) of invasive alien pests were intercepted. To improve the effectiveness and strengthen the appraisal, evaluation and supervision of port quarantine work, Department of Animal and Plant Quarantine of the State General Administration for Quality Supervision issued the *Assessment Index System of Plant Epidemic Situation Interception*. This included entry pest interception, export violation notification and importance assessment of relevant work which aims at further strengthening the effectiveness of interception work of exotic pests.

The substantial increase of exotic pest interceptions at frontier ports is credited to the improvement and standardization of detection technology and methods. The current identification work mainly involves insects, weed seeds, nematodes and parts of fungi. The work centres upon morphological identification using microscope observation and computer network technologies (remote identification). CAIQ researched and developed a remote pest identification system which integrated various software and hardware resources related to port quarantine such as microscopic image acquisition devices, synthesis module of photos with enhanced depth of focus, remote video conference system, auxiliary pest identification system and records management of identification. This system can realize many practical functions related to pest identification such as remote real-time microscopic video communication, on-line experts' audio/video identification direction, computer auxiliary identification and identification records management and so on; it can also satisfy the business demands of port quarantine tasks from observation, identification and recheck of samples to reporting and filing the intercepted epidemic situation (Chap. 12).

The detection and identification of bacteria, viruses, fungi, insect eggs and larvae, sibling species, subspecies and ecotypes depends on molecular techniques including serological techniques, various PCR technologies, chip technology, gene cloning and sequencing analysis technology (Zhu et al. 2004c; Chen and Zhu 2008; Huang et al. 2011; Zhao et al. 2011; Zhang et al. 2010, 2011) (Chap. 13).

China has formulated and issued more than 300 national and industry standards and operation regulations of 'Entry Plant Quarantine Pests'. In addition, Chinese experts have also actively participated in formulating and revising several ISPM standards.

3.3.4 Pest Treatment

Quarantine treatment plays a vital role in preventing entry or exit of invasive alien species as well as guaranteeing that import/export trade can proceed unimpeded

(Chap. 10). The primary quarantine treatment technologies adopted by China include: fumigation treatment, heating-cooling treatment, radiation treatment, isolated quarantine, detoxification treatment and chemical treatment as well as special equipments, together with pest-free production areas, or with pest-free places of production, or with pest-free production site. Quarantine treatment requirements for most import/export products have been established. Nevertheless, new quarantine treatment standards are always under review and new quarantine treatment technology/methods are under research and development.

3.3.5 Pest Survey, Monitoring and Alert Response

Survey and monitoring are the basis for timely detection of IAS, establishing effective prevention and control measures and reporting epidemiological conditions that help prevent pests from exiting China. Each year the state allocates special funds for entry-exit plant quarantine departments to carry out routine survey and daily monitoring of pests of domestic and international concern. Target insect pests include *Cydia pomonella* (L.), *Liriomyza trifolii* (Burgess), *Leptinotarsa decemlineata* (Say) and Tephritidae. Monitoring occurs near the ports, in distributing centres of imported goods and export facilities. These efforts are the foundation of China's national monitoring system. Monitoring of Tephritidae in China began in 1994, The *State Technical Guide for Tephritidae Monitoring* was formulated subsequently, and has passed through several revisions. Tephritidae monitoring shows that various flies of quarantine concern (such as *Ceratitis capitata* (Wiedemann)) have not become established in China. Survey efforts reveal the distribution of Tephritidae in China and provides the scientific basis for plant quarantine negotiations with other countries and lays foundation for promoting the establishment of Tephritidae-free areas in northern China.

China continually evaluates real-time information of epidemic situations occurring in other countries. This is combined with information on pests intercepted at China's seaports and monitored on the basis of Risk Analysis. This surveillance system enables China to release alert information of epidemic situations in China.

During the past few years, China has strengthened the scientific and technological research in pest monitoring and alert with some notable achievements (Chap. 11).

3.3.6 Summary

The inspection and quarantine departments in China have constructed a framework and technological support system involving Risk Assessment, IAS detection, monitoring, emergency alert and quarantine treatment of exotic pests and diseases. Quarantine Departments have played an important role in preventing the entry/exit of pests and improved the efficiency of import/export trade. Nevertheless, many problems remain unresolved, so investment in science and technology should be increased and the cooperation among trading nations should be strengthened.

3.4 Invasive Alien Species and Research in China (Fang-Hao Wan)

3.4.1 Introduction

The spread of invasive alien species in China is significant and has become a nationwide problem, costing taxpayers hundreds of billions of RMB in environmental degradation, lost agricultural productivity, increased health problems, and expensive prevention and eradication efforts (Wan et al. 2008a). Some IAS have been introduced intentionally and are highly valued by humans (e.g. agriculture, aquaculture and ornamental species). Nevertheless, many other species are introduced as by-products of human activity, especially increasing international trade and travel. Since 2001 when China entered the World Trade Organisation, IAS-related problems have become progressively more acute for humans and entire ecosystems

To establish an effective prevention and control system for IAS, many entomologists and ecologists in China pay more attention to basic and applied scientific research relating to IAS, with strong support of the Chinese government. During the past 10 years scientists have made significant progress on IAS research in China. Here we review the current status and trends of occurrence and scientific research on invasive species.

3.4.2 Invasive Alien Species in China: Current Status and Trends of Occurrence

Species type and habitat distribution: Analysis of literature records and field data to 2012 reveals more than 600 alien species in agriculture, forestry and aquatic ecosystems in China. These IAS include 277 terrestrial plant species (45.9 %), 112 terrestrial invertebrates (18.6 %) as well as microorganisms, aquatic invertebrates, aquatic plants, fishes, mammals, amphibians, reptiles and birds (Fig. 3.1).

Alien species invade almost all ecosystems in China, including farmlands, forests, grasslands, bushes, wetlands, inland waters, oceans and human habitation (Fig. 3.2). Most invasive species are likely to flourish in man-made habitats. About 43.4 % invasive species occur in arable lands and botanical gardens, 34.1 % in seriously disturbed habitats such as buildings and road construction areas, and 17.8 % in orchards and plant nurseries, followed by natural terrestrial ecosystems and aquatic ecosystems.

Our data shows diverse IAS (microorganisms, plants and animals) have unique distribution patterns. Weeds comprise most of the invasive alien plants and typically occur in human-disturbed habitats. Insects top the invasive animals and typically occur in farmlands, forest and orchards.

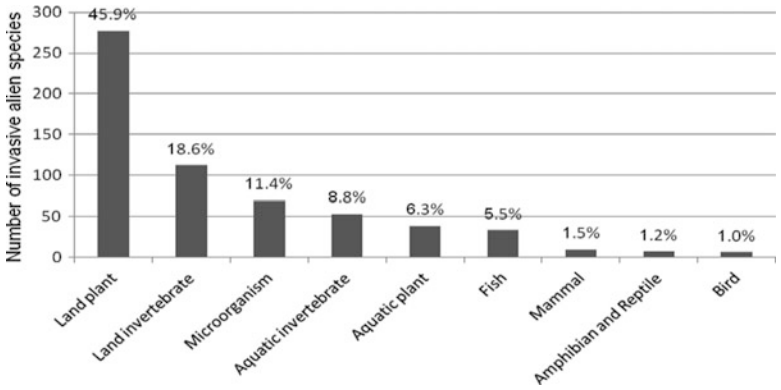

Fig. 3.1 Numbers and percentages of various categories of invasive alien species in China (Wan, unpublished)

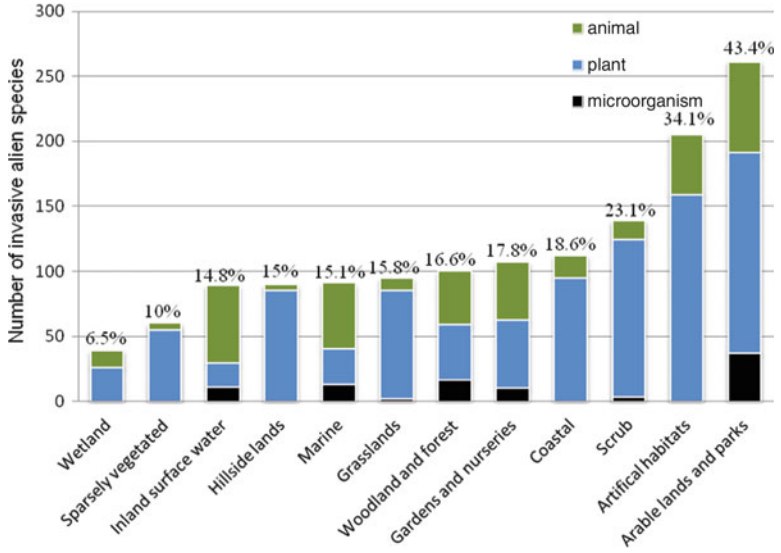

Fig. 3.2 Numbers of introduced invasive microorganisms, plants and animals and percentage of the total number of invasive alien species in different habitat. Total of percentages across habitats is more than 100 % because some species can be assigned to more than one habitat type

3.4.3 Chinese List and Databases of Quarantine Pests and Important Invasive Alien Species

The Chinese Import-Export Plant Quarantine List has been amended six times since 1954, most recently in 2007. The list contains 435 quarantine pests, including 146 species (/genus-level) of insects, 6 species of mollusks, 125 species (/races)

of fungi, 58 species (/race) of prokaryotes, 20 species (/genus-level) of nematodes, 39 species of viruses and viroids and 41 weed species (/genus) (See Bulletin 862, Ministry of Agriculture – People' Republic of China). New detection techniques and national/ industry standards of 34 plant diseases in the new quarantine pests list were established, including five bacterial diseases, 12 fungal diseases, 6 nematodes and 11 viral diseases (Table 3.4, Wan et al. 2009a, b).

With IAS research and data becoming more important, a few noteworthy databases have been built by Chinese research institutes and universities. These include: The Chinese Invasive Alien Species Database (www.invasivespecies.org.cn/wzjs/index.asp), Chinese Agricultural Pest Information System (www.agripests.cn), and the Chinese Invasive Alien Plant Information System (www.weed.njau.edu.cn/exowort/exoweeds.htm). The Chinese Invasive Alien Species Database was established by the Institute of Plant Protection (IPP) of the Chinese Academy of Agricultural Sciences (CAAS) and Centre for Management of Invasive Alien Species of Ministry of Agriculture (MOA). The IAS databases are extensive, important and provide detailed information for more than 600 IAS in China. Information includes the Chinese name, Latin name (scientific name), English name (common name), taxonomic status, morphological features, biological characteristics, photos, introduced time and place, introduction pathways, invasion pathways, potential distribution and/or spread regions, prevention methods, control and management methods, etc. The IAS databases have an internet message-board and anyone can remote search and upload or download information after registration.

For IAS management and control efficacy, an IAS list was prepared by IPP, CAAS. Of primary concern is the 'List of the Worst IAS in China' (Table 3.5), identifying species that must be controlled. The list includes the worst IAS in agricultural, forestry, wetland and freshwater ecosystems. The most notable IAS are highlighted in red.

3.4.4 Scientific Research on Invasive Species in China

Scientific research in most fields can be classified into "basic research" (including theory or mechanism researches) and "applied research" (including new methods, technology or regulation). According to different invasive processes (introduction, establishment, lag phase, dispersal and outbreak), research on IAS in China is sorted into five topics:

- Early-warning and invasion pathways,
- Population formation and development,
- Interaction and competition between IAS and host or native species,
- Response mechanisms of ecosystem,
- Technologies and methods for prevention and control of IAS.

Table 3.4 Quarantine diseases with detection technique standards established in China

Disease types	Organism	Code of detection standard
Bacterial	*Curtobacterium flaccumfaciens* pv. *flaccumfaciens*	SN/T1586.1-2005
	Acidovorax avenae subsp. *citrulli*	SN/T1465-2004
	Ralstonia solanacearum race 2	SN/T1390-2004
	Pantoea stewartii pv. *stewartii*	SN/T1375-2004
	Xanthomonas axonopodis pv. *Vasculorum*	SN/T1400-2004
Fungal	*Tilletia controversa* Kuhn, TCK	GB/T 18085-2000
	Tilletia indica	SN/T 1127-2002
	Verticillium albo-atrum	SN/T 1145-2002
	Peronospora hyoscyami f.sp. *tabacina*	GB/T 18086-2000
	Ceratocystis fagacearum	SN/T 1271-2003
	Ophiostoma novo-ulmi	SN/T 1272-2003
	Cephalosporium maydis	SN/T 1900-2007
	Diaporthe phaseolorum var. *Meridionalis*	SN/T 1899-2007
	Monilinia fructicola	SN/T 1871-2007
	Peronosclerospora (Ito)	SN/T 1155-2002
	Mycosphaerella fijiensis	SN/T 1822-2006
	Phytophthora sojae	
Nematode	*Radopholus similis*	SN/T 1505-2005
	Globodera rostochiensis	SN/T 1723.2-2006
	Globodera pallid	SN/T 1723.1-2006
	Bursaphelenchus xylophilus	SN/T 1132-2002
	Heterodera schachtii	SN/T 1140-2002
	Ditylenchus angustus	SN/T 1136-2002
Virus/viroid	*Prunus* necrotic ringspot virus, PNRSV	SN/T 1618-2005
	Cacao swollen shoot virus, CSSV	SN/T 1617-2005
	African cassava mosaic virus, ACMV	SN/T 1616-2005
	Carnation ringspot virus, CRSV	SN/T 1612-2005
	Southern bean mosaic virus, SBMV	SN/T 1611-2005
	Potato mop-top virus, PMTV	SN/T 1135.3-2003
	Arabis mosaic virus, ArMV	SN/T 1150-2002
	Tobacco ringspot virus, TRSV	SN/T 1146-2002
	Potato yellow dwarf Nucleorhabdovirus	SN/T 1135.2-2003
	Coconut lethal yellowing phytoplasma	SN/T 1579-2005
	Coconut cadang-cadang viroid, CCCVd	SN/T 1580-2005

Basic Research. Basic Research includes activities that increase understanding of essential principles. Basic Research is not intended to yield immediate commercial benefit. However, in the long term, it is the source for many commercial products and applied research. Hence, as a novel research domain, Basic Research is necessary on IAS in China. During the past 10 years, the Chinese government has funded many projects and launched many programmes to support the basic research of invasive species. This work has focused on the four key scientific issues, including the relationship of IAS between invasive potential and successful invasion, IAS population expansion and dispersal, IAS ecological adaptation and evolution, response mechanism of IAS on ecosystem. Most of these research

Table 3.5 List of the most significant invasive alien species in China

Latin name	Common name
Insects	
Aleurodicus dispersus Russell	Spiraling Whitefly
Bactrocera cucurbitae (Coquillett)	Melon Fly
Bemisia tabaci (Gennadius)	Tobacco Whitefly
Carpomya vesuviana Costa	Ber Fruit Fly
Cosmopolites sordidus (Germar)	Banana Root Borer
Cylas formicarius (Fabriaus)	Sweet Potato Weevil
Dendroctonus valens LeConte	Red Turpentine Beetle
Frankliniella occidentalis (Pergande)	Western Flower Thrips
Hemiberlesia pitysophila Takagi	Japanese Pine Needle Scale
Leptocybe invasa Fisher & LaSalle	Blue Gum Chalcid
Liriomyza huidobrenisis (Blanchard)	South American Leaf Miner
Liriomyza sativae Blanchard	American Serpentine Leaf Miner
Oracella acuta (Lobdell) Ferris	Loblolly Pine Mealybug
Quadrastichus erythrinae Kim	Erythrina Gall Wasp
Rhabdoscelus lineaticollis (Heller)	Asiatic Palm Weevil
Rhynchophorus ferrugineus (Olivier)	Red Palm Weevil
Trialeurodes vaporariorum Westwood	Greenhouse Whitefly
Other animals	
Achatina fulica Bowdich	Giant African Snail
Pomacea canaliculata (Lamarck)	Golden Apple Snail
Trachemys scripta (Thunberg)	Brazilian Slider
Bacterium	
Clavibacter michiganensis subsp. *sepedonicus* (Spieckermann *et* Kotthoff) Davis et al.	Bacterial Ring Rot of Potato
Fungi	
Cronartium ribicola J. C. Fischer	Soft-pine Stem Blister Rust
Phytophthora infestans (Mont.) de Bary	Soybean Blight
Virus	
Southern rice black-streaked dwarf virus	SRBSDV
Nematode	
Bursaphelenchus xylophilus (Steiner *et* Bührer) Nickle	Pine Wood Nematode

(continued)

Table 3.5 (continued)

Latin name	Common name
Plants	
Aegilops squarrosa L.	Tausch's Goatgrass
Alternanthera philoxeroides (Mart.) Griseb.	Alligator Weed
Ambrosia artemisiifolia L.	Ragweed
Ambrosia trifida L.	Giant Ragweed
Cenchrus pauciflorus Bentham	Field Sandbu
Eichhornia crassipes (Martius) Solms-Laubach	Water Hyacinth
Eupatorium adenophora Spreng.	Crofton Weed
Eupatorium catarium Veldkamp (*Praxelis clematidea* R.M. King)	Praxelis
Eupatorium odoratum L.	Fragrant Eupatorium Herb
Flaveria bidentis (L.) Kuntze	Coastal Plain Yellowtops
Mikania micrantha Humboldt, Bonpland et Kunth	Mile-a-minute Weed
Parthenium hysterophorus L.	Grayule Parthenium
Solanum rostratum Dunal	Buffalo Bur Nightshade
Solidago canadensis L.	Canada Goldenrod
Spartina alterniflora Loiseleur	Smooth Cord-grass
Spartina anglica C. E. Hubbard	Common Cord-grass

programmes were supported by the National Natural Science Foundation of China (NSFC) and the National Basic Research Programme ("973" Programme).

The National Natural Science Foundation of China (NSFC). The China NSFC, established under State Council ratification in 1986, is an increasingly important governmental funding source for sponsoring China natural science research. The NSFC supports research projects usually including Young Scientist (funded to 48,000 USD), General Programme (funds 95,000–130,000 USD) and Key Programme (funds more than 320,000 USD). By 2010, about 300 invasion biology research projects had been sponsored by the NSFC, with accumulative funding exceeding 14 million USD. Analysing NSFC's published data (1999–2010) shows that programmes funded by NSFC dramatically increased basic research of biological invasions. In 2008, 35 projects were active with cumulative expenditure of 1.8 million USD. In 2010, 61 projects were funded with 2.9 million USD (Fig. 3.3).

The National Basic Research and Development Programme ("973" Programme). This Programme is China's on-going national keystone basic research programme. It was approved by the Chinese Government in 1997 and is organized and implemented by MOST. The strategic objectives of the 973 Programme are to strengthen the original innovations and to address the important scientific issues concerning the national economic and social development at a deeper level and wider scope to improve China's capabilities of independent innovations and to provide scientific support for the future development of the country. Generally, every project can obtain support of 3.2–4.8 million USD over 5 years.

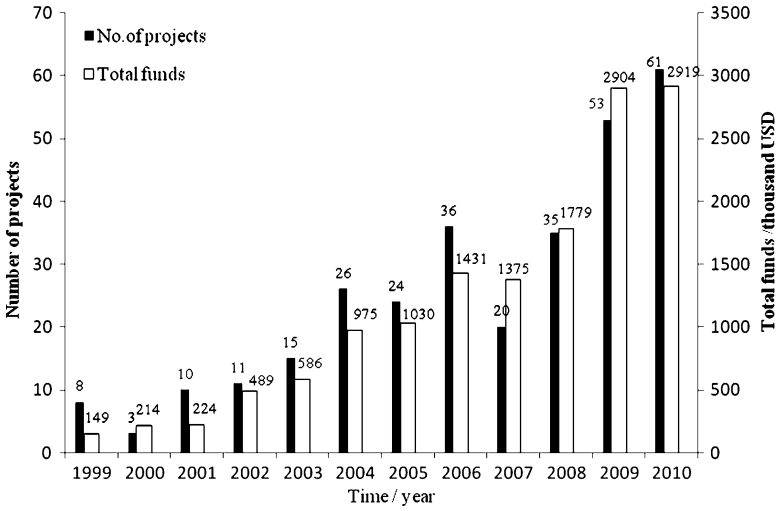

Fig. 3.3 Number of projects funded and expenditure on research into biological invasions in China by the National Natural Science Foundation from 1999 to 2010

Since 2003, several "973 programmes" have conducted basic research on invasion mechanisms of IAS and applied research related to prevention and management techniques involving IAS. The total budget has been over 16 million USD. The most significant work involves a two-phase 10-year research project: "Invasive biology and control strategy of alien species in agriculture and forestry". The second phase "Invasive mechanisms and management of major alien species" involved core scientific issues: (a) Population establishment and expansion of IAS (Doc. State Council 2003; Wan et al. 2002); (b) Ecological adaptation and rapid evolution of IAS (Wan and Guo 2007); (c) Invasion impacts on ecosystem structures and function (Wan et al. 2005, 2009a, b, 2011b, c). This project has engaged a series of "greatest risk" IAS systematically, including: Tobacco Whitefly (biotype B) (Liu et al. 2007; Luan et al. 2008; Lü and Wan 2008; Jiu et al. 2007; Li et al. 2010; Wang et al. 2010; Xu et al. 2010; De Barro et al. 2011), Rice Water Weevil (Jiang et al. 2004; Shi et al. 2007), Oriental Fruit Fly (Shen et al. 2010, 2011), Coconut Leaf Beetle (Lu et al. 2006, 2008), Red Turpentine Beetle (Sun et al. 2004; Yan et al. 2005; Liu et al. 2008), Codling Moth (Yan et al. 1999; Wang et al. 2004), Pine Wood Nematode (Cheng et al. 2008, 2010; Robinet et al. 2009), and Crofton Weed (Wang and Wang 2006; Niu et al. 2007; Feng et al. 2007, 2009; Feng 2008a, b; Li et al. 2008; Gong et al. 2009; Li and Feng 2009; Wang et al. 2011).

Applied Research. Recently, China's government has increased attention to applied research of IAS and initiated a series of programmes focusing on the sustainable management of IAS in China. Examples include the National Key Technologies R & D Programme (China's 11th Five-Year Plan), the National High-Tech Research and Development Programme ("863" Programme), and the Special Fund for Agro-scientific Research in the Public Interest. These programmes mainly investigated or supported new technology of prevention and early warning, detection and monitoring,

emergency control, ecological regulation and sustainable management of important IAS in agriculture or forest (Wan et al. 2011c).

Applied research topics can be divided into four areas:

1. **Early warning and risk assessment technology** targeting IAS: Not introduced but with higher potential, introduced but only occurring sporadically, and alien species with higher invisibility and outbreak potential. Until now, we have completed the forecasting of the potential geographical distributions of the 64 worst invasive species.
2. **Rapid detection and network monitoring technology** This topic focuses on invasive species that are difficult to identify from morphological characteristics, or are labour and cost intensive for monitoring. Developing and improving rapid detection methods for inspecting and detecting potentially important IAS would directly prompt the interception techniques of IAS of Custom and Entry-Exit Inspection and Quarantine Bureaus in China's provinces, autonomous regions and municipalities. In addition to introduction of rapid detection methods and field surveillance tools, Wan et al. (2011b) also systematically reviewed the techniques and methods for detection and surveillance of 39 invasive crop pathogens, agricultural and forest IAS.
3. **Effective containment and rapid eradication technology** aims at IAS newly introduced and requiring emergency treatment. To effectively control or manage the IAS, Wan et al. (2008b) introduced theories of classical biological control, the latest technical findings, and summarized the biocontrol achievements for 19 important invasive weeds and insects in agricultural, forest and natural conservation ecosystems.
4. **Area-wide control and sustainable management technology** targets widely distributed IAS that cause serious damage to the environment, agriculture or forest production (Wan et al. 1993). Biological invasion is a novel topic in China and control/ management experience has been limited. Wan et al. (2008a) introduced international IAS management strategies, national regulations and legislation, national prevention and management guidelines in the selected developed and developing countries. Subsequently, Wan et al. (2011a) describe invader characteristics, the relationships between invaders and natives, and how an ecosystem responds to invasion and deals with the invasive potentiality, the population establishment and expansion, eco-adaptation and evolution of invasive species, and resistance and invasive ability of an ecosystem.

Summary. Invasive alien species pose a severe threat throughout China, affecting the ecological environment, national economy, and human welfare. Greater expenditures from governmental public and private funds would be cost-effective to protect the country from on-going and future damages. Increasing losses from IAS brings more pressure upon government to more effectively manage this threat. Therefore, research and management strategies of IAS in China should focus on six elements: (1) Research and management guidelines; (2) Essential work and infrastructure platforms; (3) Basic research and applied innovative technologies; (4) Promotion of invasion biology research and recruitment of talented research

teams; (5) Scientific knowledge dissemination, public awareness (outreach) and education; and (6) International and regional cooperation. Under the coordinated guidance of government departments, the research and management of IAS should be gradually implemented.

3.5 Conclusion

With the development of international trades and the requirements of IPPC and SPS Agreement, China places more attention to plant quarantine and IAS management. It has achieved more transparency and harmonization in China, basing on the domestic regulatory framework and technical support. The three levels of China's legal system, the international collaboration between China and other members of WTO and FAO, and the domestic collaboration among AQSIQ, MOA, SFA, MEP, related Academies and Universities, are presenting important contributions in plant quarantine and IAS management. Risk Assessment, IAS detection, monitoring, emergency alert and quarantine treatment of exotic pests constitute the framework of plant quarantine and invasive species management. It is acquiring significant biological and ecological information and progress toward exclusion, management and eradication of IAS with continuing support from government.

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