RECORDS OF INSECT PESTS ON CHRISTMAS ISLAND AND THE COCOS (KEELING) ISLANDS, INDIAN OCEAN

G.A. BELLIS[1], J.F. DONALDSON[2], M. CARVER[3], D.L. HANCOCK[4] and M.J. FLETCHER[5]

[1]*Northern Australia Quarantine Strategy, GPO Box 3000, Darwin, NT 0801*

[2]*Queensland Department of Primary Industries, 80 Meiers Rd, Indooroopilly, Qld 4068*

[3]*CSIRO Entomology, GPO Box 1700, Canberra, ACT 2601*

[4]*PO Box 2464, Cairns, Qld 4870*

[5]*NSW Department of Agriculture, Orange Agricultural Research Institute, Orange, NSW 2800*

Abstract

A survey for pests of crops on Christmas Island and the Cocos (Keeling) Islands was conducted in May 2000. Fifteen new pest records were obtained from Christmas I., viz: *Aleurocanthus woglumi* Ashby and *Neomaskellia bergii* (Signoret) (Aleyrodidae), *Pentalonia nigronervosa* Coquerel (Aphididae), *Coccus* sp. and *Saissetia* sp. (Coccidae), *Lepidosaphes* sp. and *Lindingaspis* sp. (Diaspididae), *Dysmicoccus* sp. and *Nipaecoccus viridis* (Newstead) (Pseudococcidae), *Amrasca devastans* (Distant) (Cicadellidae), *Ophiomyia phaseoli* (Tryon) (Agromyzidae), *Bactrocera albistrigata* (de Meijere), *B. arecae* (Hardy & Adachi) and *B. umbrosa* (F.) (Tephritidae) and *Cosmopolites sordidus* (Germar) (Curculionidae). Six new records were obtained from the Cocos (Keeling) Is, viz: *Aphis gossypii* Glover, and *Rhopalosiphum maidis* (Fitch) (Aphididae), *Ceroplastes rubens* Maskell (Coccidae), ?*Icerya* sp. (Margarodidae), *Ferrisia virgata* (Cockerell) and *Saccharicoccus sacchari* (Cockerell) (Pseudococcidae) and *Cosmopolites sordidus* (Germar) (Curculionidae). *Aleurocanthus woglumi, Amrasca devastans, Bactrocera albistrigata* and *B. arecae* also represent new records for Australia although these species are known so far only from Christmas I. A list of insect pests so far recorded from these islands is also included.

Introduction

Australia's Indian Ocean Territories comprise Christmas Island and the Cocos (Keeling) Islands. They are remote from mainland Australia, with Christmas I. lying about 1700 km NW of the mainland and 300 km south of Java and the Cocos (Keeling) Is a further 900 km to the west. None were inhabited prior to settlement by the British in 1888. The Cocos (Keeling) Is were once owned by the Clunies Ross family, who attracted labour from Malaya and Singapore to maintain the extensive coconut plantations they established there. Prior to being transferred to Australian sovereignty in 1955, these islands were administered at various times by the governments of Sri Lanka and Singapore and the airstrip was used extensively by the Australian and British military during and after the Second World War. Christmas I. was administered by the British until transferred to Australian sovereignty in 1958. It was briefly occupied by the Japanese during the Second World War. Like the coconut plantations on Cocos (Keeling) Is, the phosphate mine at Christmas I. attracted large numbers of Chinese and Malay labourers.

The insect faunas of Christmas I. and the Cocos (Keeling) Is have been surveyed sporadically over the past 100 years (see Campbell 1966 and CSIRO 1990 for a full historical account). However, the relative lack of an

agricultural service on these islands, due in part to a lack of commercial agriculture, has resulted in an incomplete knowledge of the pest fauna present. In fact, only one survey for such pests has been undertaken on Christmas I. (Campbell 1968) and two on the Cocos (Keeling) Is (Campbell 1966), although the WA Quarantine and Inspection Service has periodically trapped fruit flies on Christmas I. The relative dearth of agriculture on these islands requires that nowadays most food, including fresh fruit and vegetables, must be imported from Perth, Western Australia or, in the case of Christmas I., also from Jakarta, Indonesia.

These surveys identified a number of pests that are not present on mainland Australia. The presence of these pests has resulted in these territories being regarded as having a different quarantine status from that of the mainland. Strict quarantine protocols are in place to prevent the spread of pests from these islands to the rest of Australia. Consequently, all records from these islands of pests that are not present elsewhere in Australia are regarded as technically present in Australian territory but exotic for quarantine purposes.

A survey of the insect pests of Christmas I. and the Cocos (Keeling) Is was conducted in May 2000. For the purposes of this paper, a pest insect is defined as an insect reported to feed on commercial plant species or products thereof or, in the case of ants, reported to cause environmental disruption or are pests of households. Those species collected in large numbers from commercial plant species or believed to be damaging the plant are also listed. Also for the purpose of this paper, mainland Australia includes all islands of the Commonwealth of Australia except those under consideration here.

Methods and materials

All inhabited areas and a representative number of uninhabited sites on the islands were visited. Plants, mostly food plants or their relatives, were inspected for presence of insect pests and these were collected by hand or sweep net. Mini light traps were set at Home and West Islands in the Cocos (Keeling) Is and in a rainforest site, locally known as the 'Pink House' and near the poultry farm on Christmas I. Steiner fruit fly traps baited with cuelure, trimedlure and methyl eugenol were also set on Home and West Islands and at the 'Pink House', Drumsite, Grant's Well, the Dales and at the market garden on Christmas I. Other material from Christmas I., lodged in the Australian National Insect Collection, CSIRO, Canberra (ANIC) and in the Agriculture WA collection in Perth (AgWA), was also examined.

Results

Tables 1 and 2 list all pest insect species thus far recorded from Christmas and Cocos (Keeling) Is. Fifteen species are newly recorded from Christmas I.; four are also new for Australia but so far are not known from the mainland. Six species are newly recorded from the Cocos (Keeling) Is but none are new for Australia.

Table 1. Pest insects recorded from Christmas Island. (N/I = no information).

Species	Family	Common name	Collected from	Source
ORTHOPTERA				
Gryllodes sigillatus (Walker)	Gryllidae	Indian house cricket / tropical house cricket	N/I	CSIRO 1990
Oxya orientalis Kirby	Acrididae	Grasshopper	N/I	Campbell 1968
Locusta migratoria (L.)	Acrididae	Migratory locust	N/I	Campbell 1968; CSIRO 1990
HEMIPTERA				
Aleurocanthus woglumi Ashby*	Aleyrodidae	Citrus blackfly	Lime	This study
Neomaskellia bergii (Signoret)	Aleyrodidae	Sugarcane whitefly	Sugarcane	This study
Aphis craccivora Koch	Aphididae	Cowpea aphid	N/I; Long bean	CSIRO 1990; this study
Aphis gossypii Glover	Aphididae	Cotton aphid / melon aphid	N/I	CSIRO 1990
Hysteroneura setariae (Thomas)	Aphididae	Rusty plum aphid	N/I	CSIRO 1990
Pentalonia nigronervosa Coquerel	Aphididae	Banana aphid	Banana	This study
Toxoptera citricida (Kirkaldy)	Aphididae	Black citrus aphid	N/I	CSIRO 1990
Toxoptera aurantii (Boyer de Fonscolombe)	Aphididae	Black citrus aphid	N/I	CSIRO 1990
Rhopalosiphum maidis (Fitch)	Aphididae	Corn aphid	N/I	CSIRO 1990
Icerya purchasi Maskell	Margarodidae	Cottony cushion scale	N/I	Campbell 1968
Dysmicoccus sp	Pseudococcidae	Mealybug	Guava	This study
Nipaecoccus viridis (Newstead)	Pseudococcidae	Spherical mealybug	Asparagus	This study
Nipaecoccus viridis (Newstead)	Pseudococcidae	Spherical mealybug	Lime	This study
Pseudococcus longispinus (Targioni Tozzetti)	Pseudococcidae	Longtailed mealybug	N/I	CSIRO 1990
Coccus sp.	Coccidae	Soft scale	Lime	This study
Saissetia sp.	Coccidae	Soft scale	Eggplant	This study
Saissetia sp.	Coccidae	Soft scale	Asparagus	This study
Tachardina ?aurantiaca (Cockerell)	Kerriidae	Lac scale	N/I	Campbell 1968

Aspidiotus destructor Signoret	Diaspididae	Transparent scale	N/I; Banana and coconut	Campbell 1968; this study
Lepidosaphes sp.	Diaspididae	Armoured scale	Lime	This study
Lindingaspis sp.	Diaspididae	Armoured scale	Lime	This study
Pseudaulacaspis pentagona (Targioni-Tozzetti)	Diaspididae	Peach white scale	N/I	Campbell 1968; this study
Kallitaxila granulata (Stål)	Tropiduchidae	Planthopper	Citrus, mango	CSIRO 1990; this study
Amrasca devastans (Distant) (?= *A. biguttula* (Ishida))*	Cicadellidae	Indian cotton leafhopper	Eggplant	This study
Cicadulina bipunctella (Matsumara).	Cicadellidae	Leafhopper	N/I	CSIRO1990
Typhlocybinae: Empoascini, ?genus	Cicadellidae	Leafhopper	Long bean	This study
Typhlocybinae: Erythroneurini, ?genus	Cicadellidae	Leafhopper	Winged bean	This study
Engytatus nicotianae (Koningsberger)	Miridae	Tomato mirid	N/I	CSIRO 1990
Hyalopeplus malayensis Carvalho & Gross	Miridae	Mirid	N/I	CSIRO 1990
Elasmolomus sordidus (F.)	Lygaeidae	Peanut trash bug	N/I	CSIRO 1990
Leptocoris subrufescens (Kirby)	Rhopalidae	Rhopalid bug	N/I	CSIRO 1990
Nezara viridula (L.)	Pentatomidae	Green vegetable bug	N/I	Campbell 1968; CSIRO 1990
COLEOPTERA				
Lasioderma serricorne (F.)	Anobiidae	Cigarette beetle / tobacco beetle	N/I	CSIRO 1990
Dinoderus minutus (F.)	Bostrichidae	Bamboo borer	N/I	CSIRO 1990
Heterobostrichus aequalis (Waterhouse)	Bostrichidae	Lesser auger beetle	N/I	Campbell 1968; CSIRO 1990
Minthea rugicollis (Walker)	Bostrichidae	Hairy powderpost beetle	N/I	CSIRO 1990
Rhyzopertha dominica (F.)	Bostrichidae	Lesser grain borer	N/I	CSIRO 1990
Sinoxylon anale (Lesne)	Bostrichidae	Auger beetle	N/I	Campbell 1968; CSIRO 1990

Xylothrips religiosus (Boisduval)	Bostrichidae	Northern auger beetle	N/I	Campbell 1968; CSIRO 1990
Dermestes ater De Geer	Dermestidae	Hide beetle	N/I	CSIRO 1990
Ahasverus advena (Waltl)	Silvanidae	Foreign grain beetle	N/I	CSIRO 1990
Cylas formicarius elegantulus (Summers)	Brentidae	Sweet potato weevil	N/I	Campbell 1968; CSIRO 1990
Cosmopolites sordidus (Germar)	Curculionidae	Banana root weevil / banana weevil borer	Banana	This study
Diocalandra frumenti (F.)	Curculionidae	Palm weevil borer / lesser coconut weevil	N/I	Campbell 1968; CSIRO 1990
Sitophilus oryzae (L.)	Curculionidae	Rice weevil	N/I	Campbell 1968; CSIRO 1990
Xyleborus perforans (Wollaston)	Curculionidae	Island pinhole borer	N/I	CSIRO 1990
DIPTERA				
Ophiomyia phaseoli (Tryon)	Agromyzidae	Bean fly	*Vigna unguiculata*	This study
Bactrocera albistrigata (de Meijere)*	Tephritidae	Fruit fly	CUE trap	This study
Bactrocera arecae (Hardy & Adachi)*	Tephritidae	Betel-nut fly	Sweeping lime tree	This study
Bactrocera cucurbitae (Coquillett)	Tephritidae	Melon fly	CUE trap	Campbell 1968; this study
Bactrocera papayae Drew & Hancock	Tephritidae	Papaya fruit fly / Asian papaya fruit fly	ME trap	Drew and Hancock 1994; this study
Bactrocera umbrosa (F.)	Tephritidae	Breadfruit fly	ME trap	This study
LEPIDOPTERA				
Plutella xylostella (L.)	Plutellidae	Cabbage moth / diamondback moth	N/I	Campbell 1968; CSIRO 1990
Diaphania indica (Saunders)	Pyralidae	Cucumber moth	N/I	Campbell 1968; CSIRO 1990
Hymenia recurvalis (F.)	Pyralidae	Beet webworm	N/I	CSIRO 1990
Nacoleia octasema (Meyrick)	Pyralidae	Banana scab moth	N/I	CSIRO 1990
Achaea janata (L.)	Noctuidae	Castor oil looper	N/I	CSIRO 1990

Chrysodeixis eriosoma (Doubelday)	Noctuidae	Looper	N/I	Campbell 1968; CSIRO 1990
Eudocima (= *Othreis*) *materna* (L.)	Noctuidae	Fruitpiercing moth	N/I	Campbell 1968; CSIRO 1990
Eudocima (= *Othreis*) *fullonia* (Clerck)	Noctuidae	Fruitpiercing moth	N/I	Campbell 1968; CSIRO 1990; this study
Helicoverpa armigera (Hübner)	Noctuidae	Cotton bollworm / corn earworm / tobacco budworm	N/I	CSIRO 1990
Helicoverpa assulta (Guenée)	Noctuidae	Cape gooseberry budworm	N/I	CSIRO 1990
Spodoptera litura (F.)	Noctuidae	Cluster caterpillar	N/I	Campbell 1968; CSIRO 1990
Spodoptera mauritia (Boisduval)	Noctuidae	Lawn armyworm	N/I	Campbell 1968; CSIRO 1990
Hyblaea puera Cramer	Hyblaeidae	Moth	N/I	Campbell 1968; CSIRO 1990
Papilio memnon L.	Papilionidae	Christmas swallowtail	N/I Lime	Braby 2000; Moulds and Humphrey 2000; this study
HYMENOPTERA				
Anoplolepis gracilipes (Fr. Smith)	Formicidae	Crazy ant	N/I	CSIRO 1990; this study
Monomorium floricola (Jerdon)	Formicidae	Ant	N/I	CSIRO 1990
Monomorium latinode Mayr	Formicidae	Ant	N/I	CSIRO 1990
Monomorium pharaonis (L.)	Formicidae	Pharaoh's ant	N/I	Donisthorpe 1935
Ochetellus glaber (Mayr)	Formicidae	Black house ant	N/I	CSIRO 1990
Paratrechina bourbonica (Forel)	Formicidae	Ant	N/I	CSIRO 1990
Paratrechina longicornis (Latreille)	Formicidae	Hairy ant	N/I	CSIRO 1990
Paratrechina minitula (Forel)	Formicidae	Ant	N/I	CSIRO 1990

Pheidole megacephala (F.)	Formicidae	Coastal brown ant / Madeira ant	N/I	CSIRO 1990
Solenopsis geminata (F.)	Formicidae	Ginger ant / tropical fire ant	N/I	CSIRO 1990
Tapinoma melanocephalum (F.)	Formicidae	Ghost ant	N/I	CSIRO 1990
Technomyrmex albipes (Fr. Smith)	Formicidae	Whitefooted house ant / black household ant	N/I	CSIRO 1990
Tetramorium bicarinatum (Nylander)	Formicidae	Ant	N/I	CSIRO 1990
Tetramorium insolens (Fr. Smith)	Formicidae	Ant	N/I	CSIRO 1990
Tetramorium lanuginosum Mayr	Formicidae	Ant	N/I	CSIRO 1990
Tetramorium pacificum Mayr	Formicidae	Ant	N/I	CSIRO 1990
Tetramorium simillimum (Fr. Smith)	Formicidae	Ant	N/I	CSIRO 1990

*New record for Australia but thus far restricted to Christmas Island.

Table 2. Pest insects recorded from the Cocos (Keeling) Is. (N/I = no information).

Species	Family	Common name	Collected from	Source
ORTHOPTERA				
Locusta migratoria (L.)	Acrididae	Migratory locust	N/I	Campbell 1966
Nomadacris guttulosa (Walker)	Acrididae	Spur-throated locust	N/I	Campbell 1966
HEMIPTERA				
Aphis gossypii Glover	Aphididae	Cotton aphid / melon aphid	*Chromolaena odorata*	This study
Pentalonia nigronervosa Coquerel	Aphididae	Banana aphid	N/I	Campbell 1966
Rhopalosiphum maidis (Fitch)	Aphididae	Corn aphid	*Thuarea involuta*	This study
Ceroplastes rubens Maskell	Coccidae	Pink wax scale	*Syzygium aqueum*	This study
?*Icerya* sp.	Margarodidae	Cushion scale	Lime	This study
Ferrisia virgata (Cockerell)	Pseudococcidae	Striped mealybug	Tomato	This study
Saccharicoccus sacchari (Cockerell)	Pseudococcidae	Pink sugarcane mealybug	Sugarcane	This study
Nezara viridula (F.)	Pentatomidae	Green vegetable bug	N/I	Campbell 1966

COLEOPTERA				
Oryctes rhinoceros (L.)	Scarabaeidae	Coconut rhinoceros beetle	Coconut	Campbell 1966; this study
Agrilus marmoreus Deyrolle	Buprestidae	Jewel beetle	Lime	Campbell 1966
Cosmopolites sordidus (Germar)	Curculionidae	Banana root weevil / banana weevil borer	Banana	This study
Diocalandra frumenti (F.)	Curculionidae	Palm weevil borer / lesser coconut weevil	Coconut	Campbell 1966
Dermestes ater De Geer	Dermestidae	Hide beetle	N/I	Campbell 1966
LEPIDOPTERA				
Achaea janata (L.)	Noctuidae	Castor oil looper	N/I	Campbell 1966
Chrysodeixis eriosoma (Doubelday)	Noctuidae	Looper	N/I	Campbell 1966
Helicoverpa armigera (Hübner)	Noctuidae	Cotton bollworm / corn earworm / tobacco budworm	N/I	Campbell 1966
Spodoptera litura (F.)	Noctuidae	Cluster caterpillar	N/I	Campbell 1966
Spodoptera mauritia (Biosduval)	Noctuidae	Lawn armyworm	N/I	Campbell 1966
HYMENOPTERA				
Anoplolepis gracilipes (Fr. Smith)	Formicidae	Crazy ant	N/I	Campbell 1966; this study
Paratrechina longicornis (Latreille)	Formicidae	Hairy ant	N/I	Campbell 1966
Solenopsis geminata (F.)	Formicidae	Ginger ant / tropical fire ant	N/I	Campbell 1966; this study

Discussion

Both Christmas I. and the Cocos (Keeling) Is contain a range of insect pests, many of which are tropicopolitan and are known to be spread by commerce. Some of these, for example crazy ant (O'Dowd *et al.* 1999), are causing considerable damage to the environment. The presence of a number of pest species that are not present on mainland Australia provides support for the current placement of quarantine restrictions between these islands and the mainland.

One can only speculate on how, when, whence and by whom or what the incursions were made. History and geographical location - early British

settlement, Asian labour, Asian and Australian administration and trade, Japanese wartime occupation of Christmas I., British military presence on Cocos (Keeling) Is and proximity to Indonesia, especially of Christmas I. - have undoubtedly been important factors in determining the exotic biotic composition of the islands. Significantly, all the pest species recorded are also known from southeast Asia, which suggests the likelihood that this region is the source of the majority of the pest species now present on Christmas I. at least. Insect adventives can reach an island environment by direct flight, aerial dispersal by wind, parasitism or phoresy and by drift, boat or airplane, with or without carriage on/in plant material or by human or animal agency.

Many of the adults of pest species listed are known to have excellent powers of flight. Small, lightweight insects, both apterous and alate, such as aphids and first instar crawlers of Coccoidea are commonly dispersed by wind (e.g. Loxdale *et al.* 1993, Willard 1974). The carriage over long distances as aerial plankton of leafhoppers (Cicadellidae) has been recorded (Ghauri 1983) and transport of Coccoidea by birds and bats (Lever 1969) is also possible.

However, arrival on or in plant material is likely to have been the most common method of entry of many of the species listed. Relatively immobile or apterous species, immatures and those species obligately or closely associated with their host plants, e.g. Coccoidea, are more likely to have arrived as contaminants of imported food or plant material. Fruit-infesting species such as tephritid fruit flies are commonly transported as larvae in fruit. All of the fruit fly species found on Christmas I. are known to breed in fruit likely to have been imported from southeast Asia (Allwood *et al.* 1999), although it is surprising that another major pest species of fruit fly present in southeast Asia, *B. carambolae* Drew & Hancock, was not also detected. Successful establishment of the adventives would be largely determined by environmental factors and host availability.

The Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), has not been detected on these islands despite intensive bait trapping. This fly is common in Perth from where host fruit is imported to both Christmas and the Cocos (Keeling) Is. Its absence on these islands suggests that fruit inspection protocols prior to or after importation are effective and/or these islands do not offer suitable habitat for this fly. The absence of fruit flies from the Cocos (Keeling) Is may be due to environmental or host availability factors but is more likely because these islands do not import host fruit material from southeast Asia.

Acknowledgements

This survey was funded by the Department of Territories and we thank them for their logistical assistance in organising the survey. We thank Andras Szito, AgWA and Kim Pullen, ANIC for the loan of material from their respective collections. Staff of Parks Australia are acknowledged for their logistical

assistance on the islands. Andrew Mitchell, Matthew Weinert and John Curran assisted with collection of insects and Angela Profke provided technical assistance with curation of specimens.

References

ALLWOOD, A.J., CHINAJARIYAWONG, A., DREW, R.A.I., HAMACEK, E.L., HANCOCK, D.L., HENGSAWAD, C., JIPANIN, J.C., JIRASURAT, M., KONG KRONG, C., KRITSANEEPAIBOON, S., LEONG, C.T.S. and VIJAYSEGARAN, S. 1999. Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *Raffles Bulletin of Zoology Supplement* **7**: 1-92.

BRABY, M.F. 2000. *Butterflies of Australia: their identification, biology and distribution.* 2 vols. CSIRO Publishing, Collingwood; xx + 976 pp.

CAMPBELL, T.G. 1966. *Entomological survey of Cocos (Keeling) Islands with special reference to the insects of medical, veterinary, agricultural and forestry significance.* Unpublished Report, CSIRO Division of Entomology; 32 pp.

CAMPBELL, T.G. 1968. *Entomological survey of Christmas Island (Indian Ocean) with special reference to the insects of medical, veterinary, agricultural and forestry significance.* Unpublished Report, CSIRO Division of Entomology; 48 pp.

CSIRO. 1990. *CSIRO Entomological survey of Christmas Island. Phase 2.* Unpublished Report, Australian National Parks and Wildlife Service Consultancy Agreement; 67 pp.

DONISTHORPE, H. 1935. The ants of Christmas Island. *Annals and Magazine of Natural History* **15**(10): 629-635.

DREW, R.A.I and HANCOCK, D.L. 1994. The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research Supplement Series* **2**: 1-68.

GHAURI, M.S.K. 1983. A case of long distance dispersal of a leafhopper. Pp 249-255, in: W.J. Knight, N.C. Pant, T.S. Robertson and M.R. Wilson (eds), *Proceedings of the first international workshop on biotaxonomy, classification and biology of leafhoppers and planthoppers (Auchenorrhyncha) of economic importance, London, 4-7 October 1982.* Commonwealth Institute of Entomology, London.

LEVER, R.J.A. 1969. *Pests of the coconut palm.* FAO Agriculture Studies No. 77. United Nations Food and Agriculture Organisation, Rome.

LOXDALE, H.D., HARDIE, J., HALBERT, S., FOOTTIT, R., KIDD, N.A.C. and CARTER, C.I. 1993. The relative importance of short and long range movement of flying aphids. *Biological Reviews* **68**: 291-311.

MOULDS, M.S. and HUMPHREY, M. 2000. First record of *Papilio memnon* L. (Lepidoptera: Papilionidae) from Christmas Island, Indian Ocean. *Australian Entomologist* **27**(2): 37-38.

O'DOWD, D., GREEN, P.T. and LAKE, P.S. 1999. Status, impact and recommendations for research and management of exotic invasive ants in Christmas Island National Park. Unpublished report to Parks Australia North.

WILLARD, J.R. 1974. Horizontal and vertical dispersal of California red scale (*Aonidiella aurantii* (Maskell) Homoptera: Diaspididae) in the field. *Australian Journal of Zoology* **22**: 531-548.