Health and Irrigation

Incorporation of disease-control measures in irrigation, a multi-faceted task in design, construction, operation

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Preface

At the beginning of the 1980's, the International Institute for Land Reclamation and Improvement (ILRI) approached the Dutch Directorate of International Cooperation (*DGIS*) with a proposal that *DGIS* assist in financing an ILRI publication entitled *Health and Irrigation*. This publication would be concerned with health care in irrigation projects in areas where water-related diseases (e.g. malaria, schistosomiasis, filariasis, onchocerciasis) were endemic or could become endemic through the implementation of water-resources-development projects.

Before any irrigation project is planned, implemented, and operated, ILRI feels that a study should be made of the project's potential consequences for human health. This study should be holistic and multidisciplinary; it should identify any expected negative effects on human health, and should make a cost-benefit analysis of the measures that need to be taken to prevent, treat, and control any of the identified diseases. It should focus particular attention on environmental-management measures and on the institutional aspects of incorporating safeguards into the project. In this way, it would adhere to the principles of PEEM (Panel of Experts on Environmental Management for Vector Control), which was established jointly by the World Health Organization, the Food and Agriculture Organization, and the United Nations Environmental Programme.

DGIS's response to ILRI's proposal was positive, in principle, but before making a definite decision, it wished to discuss the matter with WHO and to hear the opinions of Dutch engineering bureaux working on projects in developing countries. The result of these consultations was that, in mid-1983, DGIS made funds available for the preparation of the manuscript of *Health and Irrigation*. In making this decision, *DGIS* added the provisos that the book give ample attention to practical examples and case studies, and that a Steering Committee be created to advise and guide the authors. The Steering Committee met eight times. Its members were:
- Dr D.C. Faber (Centre for World Food Studies, Wageningen);
- Ir W.C. Hulsbos (Euroconsult, Arnhem);
- Dr J. M. Lelyveld (Department of Environmental and Tropical Health, University of Agriculture, Wageningen);
- Drs F. Meyndert (*DGIS*), later succeeded by
- Drs M. de la Bey (*DGIS*);
- Dr A.M. Polderman (Institute for Tropical Medicine, University of Leiden);
- Ir K. Roscher (Department of Civil Engineering and Irrigation, University of Agriculture, Wageningen);
- Ir C. Storsbergen (DHV Consultants, Amersfoort);

The Group's Secretaries were:
- Ir W.T. Lincklaen Arriens (ILRI), later succeeded by
- Ir B.T. Ottow (ILRI).

In meeting the *DGIS* proviso of practical examples and case studies, Dr Jobin contributed greatly. The case study in Sri Lanka was taken from the field work of the students

J.J. Speelman and G. van den Top (Department of Irrigation and Civil Engineering at the Wageningen University of Agriculture). Another case study was derived from the literature study conducted by Ir W.B. Snellen of ILRI on 'Sanitation Works in Java, Indonesia'.

Information on the geographical distribution of vectors and vector-borne diseases was drawn from WHO publications. For schistosomiasis, a separate literature study was done by Jos L.M. Boeren, a student at the Department of Public Health, Wageningen University of Agriculture. The support given him by Dr S. Frandsen of the Danish Bilharziasis Laboratory in Charlottlund, and by Dr F.S. McCullough of WHO's Ecology and Vector-Control Unit in Geneva, is gratefully acknowledged.

Originally, *Health and Irrigation* was to be presented in one volume. Special circumstances, however, seemed to justify giving priority to the accelerated publication of parts of the book, namely the case studies and practical examples. Accordingly, these are presented in a separate volume, Volume 2, which is preceding the publication of Volume 1. Apart from providing some general information, therefore, this Preface is limited to matters that have a direct bearing on Volume 2. (The Preface to Volume 1 will contain more extensive acknowledgements.) Complying with the request of *DGIS*, however, we include the following passage:

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Responsibility for the contents and for the opinions expressed rests solely with the authors; publication does not constitute an endorsement by The Netherlands' Minister for Development Cooperation.

Introduction

Health and Irrigation is being published in two volumes. The first contains the main subject chapters and three technical notes. The second volume is a separate appendix with a series of practical examples and two case studies. A geographical overview of vector-borne diseases and the vectors themselves are included in the appendix.

– Title Health and Irrigation
Incorporation of disease control measures in irrigation; a multi-faceted task in design, construction, and operation

Annex 3:

- Tennessee Valley Authority, U.S.A.
- Lake Volta, Ghana.
- North-east coast reservoirs, Brazil.

Experience gained from working in these schemes suggests that the most rational way of avoiding serious health problems in reservoir areas is to use a variety of measures combined in a carefully planned and integrated program. These practical examples illustrate Chapter 5 in Health and Irrigation.

Annex 4 and 5

Annex 4

- The Gezira-Managil Irrigation Scheme, Central Sudan.
- Puerto Rico.
- Dez Pilot Irrigation, Iran.
- Sanitation Works, Java, Indonesia.

Annex 5

- Rice Cultivation, Niger River.
- Asian Bilharzia and Rice, the Philippines.
- Irrigation and vector-borne diseases, Sri Lanka.

Recent experience has emphasized the importance of environmental factors in the transmission of water associated diseases. Irrigation system design is at present inadequate to deal with the health aspects of water resources engineering. Examples in these two annexes show clearly that it is possible to exploit environmental factors in the development of stable, long term strategies for disease prevention and control.

Ecological methods were largely discarded when 'miracle' pesticides and drugs, symbolized by DDT and penicillin, were discovered in the 1940's. Gradually, ecological strategies towards disease control are being re-introduced. This is of particular importance to design engineers who can make provision for them in new irrigation schemes at a relatively low cost.

The examples of Annex 4 illustrate Chapter 6 in Health and Irrigation. The examples and case study of Annex 5 relate to Chapter 7.

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Annex 3

Annex 4

Annex 5

Annex 1
The geographical distribution of vector-borne diseases and vectors

1.1 Introduction

The diseases considered in this annex have been selected because their prevalence is probably related to the effect of irrigation. They include malaria, schistosomiasis, filariasis, onchocerciasis, a number of arbo-viral infections such as Japanese-B encephalitis, dengue fever, dengue haemorrhagic fever, and Chikungunia virus disease.
These diseases are discussed using the following regional classification (WHO 1982)

Region 1 Central America and the West Indies
Region 2 South America
Region 3 The Mediterranean region
Region 4 North Africa and the Arabian Peninsula Desert
Region 5 Africa (excluding the countries covered in Region 4)
Region 6 Northern European and Asiatic regions
Region 7 The Middle East and South Asia
Region 8 South East Asia (coastal)
Region 9 South East Asia (hill)
Region 10 The Chinese region
Region 11 Oceania and Australia

A different regional classification has been used for schistosomiasis.

The habitat requirements of the mosquito vectors have been referred to using fairly broad categories. A classification of breeding habitats and the geographical distribution of mosquitoes can be found in Chapter 3, Section 3.2.5. For more detailed information about mosquito breeding habitats see WHO Manual *Environmental Management for Mosquito Control* (1982) and Manson *Tropical Diseases* 1982.

1.2 Malaria

With the exception of some countries in Regions 3, 6, and 11 malaria is prevalent world-wide. Malaria vectors are listed in Table 1.1 (WHO 1982).

1.3 Filariasis

The disease is prevalent in the following countries in Region 1: Panama, the Bahamas, Haiti, the Dominican Republic, Puerto Rico, and the Lesser Antilles. Region 2: Trinidad, Guyana, Surinam, French Guyana, and Brazil. Region 4: East Turkey, Egypt, and Oman. It exists in nearly all the countries of Region 5 and in many of the countries of Regions 8 and 9. Some countries of Region 11, including Fiji, Tonga, the Pacific

Ocean Islands, Irian Jaya, and Papua New Guinea also host filariasis. The vectors of filariasis are listed in Table 1.2 (WHO 1982, 1984).

1.4 Onchocerciasis

Onchocerciasis occurs in Mexico and Guatemala in Region 1. In Region 2 it is found in Venezuela, Colombia, and Brazil, and in Region 5 it is found in almost all countries. The largest endemic area occurs in Region 5 and in the Volta basin area. It incorporates parts of Benin, Ghana, Ivory Coast, Mali, Niger, Togo, and the whole of Burkina Faso. WHO has its Onchocerciasis Control Programme (OCP) in this area. The vectors of onchocerciasis are listed in Table 1.3 (WHO 1976).

1.5 Japanese B-encephalitis

The disease is prevalent in the countries of Regions 8, 9, 10 and in some countries of Region 11, for example Irian Jaya and Papua New Guinea. The vectors of Japanese B-encephalitis are *Culex tritaeniorhynchus*, *Culex vishnui*, *Culex gelides* (which maintains the virus in pig-to-pig transmission), and *Culex annulus* (WHO 1982, 1985).

1.6 Dengue fever

The disease is found in nearly all the countries of Region 1, in many of the countries of Region 2 with the exception of Brazil, Peru, Paraguay, Uruguay, Chile and Argentine, and almost all the countries of Region 5. It also occurs in the countries of Regions 8 and 9, Bangladesh, Sri Lanka and Nepal, and in Australia in Region 11.
The vectors of dengue fever are *Aedes aegypti*, *Aedes albopictus*, *Aedes scutellaris* and *Aedes polynesiensis* (WHO 1982, 1985).

1.7 Dengue haemorrhagic fever

The disease is prevalent in Cuba and Jamaica in Region 1, in India in Region 7, and in a number of countries in Regions 8 and 9. It is found in Taiwan in Region 10, and in New Zealand, Fiji, Tonga, Pacific Ocean Islands, Irian Jaya, and Papua New Guinea in Region 11.
For the vectors of dengue haemorrhagie fever see Section 1.6 (WHO 1982, 1985).

1.8 Chikungunia virus disease (O'Nyong Nyong)

The disease is prevalent in all countries of Region 5 with the exception of Ethiopia, Somalia, Sudan, Uganda, Kenya, and Tanzania. The disease also occurs in India in Region 7.

The vectors of Chikungunia virus disease are *Aedes aegypti, Aedes albopictus, Aedes africanus, Aedes taylori,* and *Aedes furcifer* (WHO 1982, 1985).

Table 1.1 Mosquito Vectors (Anopheles species) of Malaria

Region 1	*quadrimaculatus; freeborni; albimanus(*); pseudopunctipennis; aztecus; aquasalis; bellator; punctimacula.*
Region 2	*darlingi(*); balbimanus(*); aquasalis; pseudopunctipennis; nuneztovari(*); balbitarsis; punctimacula; bellator; cruzii.*
Region 3	*sacharovi(*); labranchiae labranchiae; labranchiae atroparvus; superpictus(*); claviger; macullipennis messeae; sergentii; hispaniola.*
Region 4	*sergentii(*); pharoensis(*); multicolor; hispanolia; culicifacies; arabiensis(*).*
Region 5	*dthali; pharoensis; gambiae(*); arabiensis(*); melas(*); merus; funestus(*); nili; moucheti.*
Region 6	*labranchiae atroparvus; sacharovi(*); pattoni; macullipennis messeae; sinensis.*
Region 7	*culicifacies(*); dirus; stephensi(*); minimus; fluviatilis(*); varuna; annularis; philippinensis; hyrcanus(*); pulcherrimus(*); superpictus(*); sundaicus; dthali.*
Region 8	*sundaicus; letifer; umbrosus; balabacensis(*); dirus; maculatus; minimus; minimus flavirostris; subpictus; sinensis; aconitus; campestris; donaldi; philippinensis; leucosphyrus.*
Region 9	*minimus(*); annularis; maculatus.*
Region 10	*sinensis; pattoni; lesteri; martinius.*
Region 11	*farauti(*); koliensis(*); punctulatus(*); bancrofti; subpictus; karwari.*

Source: WHO 1982
* Species responsible for continuing transmission

Table 1.2 Mosquito Vectors of Filariasis

Region 1 and 2	*Wucheria bancrofti-periodic: Culex quinquefasciatus and Anopheles darlingi.*
Region 4	*Wucheria bancrofti-periodic: Culex molestus and Culex quinquefasciatus.*
Region 5	*Wucheria bancrofti-periodic: Culex quinquefasciatus; Anophetes arabiensis; Anopheles funestus; Anopheles gambiae; Anopheles melas; Anopheles merus.*
Region 8 and 9	*Wucheria bancrofti-periodic: Culex quinquefasciatus, Aedes poicilius, Anopheles balabacensis, Anopheles dirus, Anopheles donaldi, Anopheles flavirostris, Anopheles candidiensis, Anopheles anthropophagus, Anopheles letifer, Anopheles leucosphyrus, Anopheles maculatus, Anopheles minimus, Anopheles sinensis, Anopheles subpictus, Anopheles vagus, Anopheles whartoni.* *Wucheria bancrofti-subperiodic: Aedes harinasutai, Aedes niveus.* *Brugia malayi-periodic*: (South-east China, Vietnam, Thailand, Malaysia, Indonesia, Philippines); *Anopheles anthropophagus, Anopheles barbirostris, Anopheles campestris, Anopheles donaldi, Anopheles kweiyangensis, Anopheles sinensis, Mansonia annulata, Mansonia annulifera, Mansonia uniformis.* *Brugia malayi-subperiodic*: (South-east China, Vietnam, Thailand, Malaysia, Indonesia, Philippines); *Mansonia annulata, Mansonia bonneae, Mansonia dives, Mansonia uniformis.* *Brugia timori-periodic*: Indonesian islands of Flores and Timor; *Anopheles barbirostris.*
Region 11	*Wucheria bancrofti-periodic: Culex pipiens pallens, Culex quinquefasciatus, Anopheles farauti, Anopheles koliensis, Anopheles punctulatus, Culex quinquefasciatus.* *Wucheria bancrofti-subperiodic: Aedes cooki, Aedes fijiensis, Aedes kesseii, Aedes oceanicus, Aedes polynesiensis, Aedes pseudoscutellaris, Aedes samoanus, Aedes tutuilae, Aedes upolensis; Aedes vigilax.*

Source: WHO 1982, 1984

Table 1.3 The Fly Vectors of Onchocerciasis

	The vectors are Simulium flies (black flies)
Mexico	: *S. ochraceum, S. metallicum, S. callidum*
Guatamala	: *S. ochraceum, S. metallicum, S. callidum*
Colombia	: *S. exiguum*
Venezuela	: *S. metallicum, S. exiguum*
Brazil	: *S. ochraceum*
All African oncho-countries	: *S. damnosum complex*, i.e. *S. samboni* and in Zaire and Uganda also *S. neavei*
Egypt, Tanzania, Malawi	: *S. woodi* (occurs very locally)

Source: WHO 1976

1.9 Schistosomiasis

Table 1.4 gives an overview of the geographical distribution of snail species which can act as intermediate hosts for six types of schistosomiasis species: *Schistosoma haematobium* (H), *Schistosoma intercalatum* (I), *Schistosoma japonica* (J), *Schistosoma mansoni* (M), *Schistosoma mekongi* (Mek) and *Schistosoma rhodani* (R). These letters H, I, J, M, Mek, and R are also used in Table 1.4 to indicate the schistosome. *Biomphalaria, Bulinus, Ferrissia, Oncomelania, Robertsiella,* and *Tricula* are intermediate hosts and the table indicates their relationship to the schistosomes. It gives their habitat characteristics and geographical distribution by country and region.

Snail nomenclature is a problematic area. Information about snails and snail classification found in the literature is often inconsistent. In Table 1.4 the old names are listed under the most recent ones as 'subspecies' or 'synonyms' in situations where there might be confusion. Whether they really represent subspecies is sometimes doubtful.

The following symbols are used in Table 1.4 to indicate the relationship of the intermediate hosts to the schistosomes:

'!' very important intermediate host

'?' assumed to be acting as intermediate host although this has not yet been proved either experimentally or in nature

'exp.' proved to be a possible intermediate host under laboratory conditions

Table 1.4 Geographical Distribution of Schistosomes, its Vectors and Vector Habitats

Snail Species and Schistosome	Country	Habitat
Snail Species Biomphalaria		
B.albicans and M exp.	Puerto Rico	

B.alexandrina and M	Egypt: Saudi Arabia Yemen	Nile Delta Menia Province	Slowly flowing irrigation channels, brackish lakes near outflows from freshwater drains and terminal canals
B.alexandrina and M?	Libya: Sudan:	Taurorga, the Mediterranian coast west of Misurata between Khartoum and Kosti	Stable conditions with fairly dense aquatic vegetation
B.amazonica and M	Brazil:	Manour, Careiro island, along Salimoes Madeira and Jurua Rivers in the State of State of Amazonas	Slowly flowing water with abundant *Eichhornia.* Ph 6.0-7.0
B.angulosa and M	Malawi: Zambia:	Swamps 70 km north of Nkota Kota Chambezi Wantipa near Mbesuma Chozi River	
B.angulosa and M exp. full	Tanzania:	Kalenga swamp and irrigation scheme, Little Ruaha swamp, Iringa district	The Kalenga swamp dries out in the dry season but is up to two meters deep when
B.arabica and M	Arabian peninsula: southern region		see: *B.pfeifferi*
B.camerunensis and M *B.camerunensis* and M?	Benin Cameroon Central African Republic Nigeria Togo Southern Zaire Ghana Nigeria Togo Zaire		Shallow water on thick mud bottom, heavily shaded by palm trees. Slowly flowing or stagnant waters with abundant vegetation including papyrus where *B.pfeifferi* is not found
B.chilensis and M exp.	Chile		
B.choanomphala (= *B.elegans*) and M	Kenya: Tanzania: Uganda:	Lake Victoria, Kisumu Lake Victoria, Bukoba, Mwanza Albert Nile Victoria Nile Lake Victoria, Entebbe Lake Albert Lake Kyoga	Kisumu: on stones at the water's edge, found at depths of ten meters. Mwanza: on mixed substrata of sand and mud. Entebbe: on gravel and soft sedimentary rocks at depths of two-three meters off-shore

			from sandy beaches where higher plants were present.
B.glabrata and M	Antigua Brazil Curacao Dominica Dominican Republic French Guyana French St. Martin Guadeloupe Haiti	Hispaniola Martinique Montserrat Puerto Rico St.Christopher St. Kitts St. Lucia Surinam Venezuela	Standing or moderately flowing fresh waters. Adapts to wide ranges of water temperature, to salinity, and to pH (5.8-9.0) Found at depths of ten meters below water surface
B.havanensis and M	The Antilles region Central America Mexico South America (northern part)		Standing waters, and the bottom of shallow streams
B.helophila and M exp.	Belice Cuba Guadeloupe Puerto Rico Peru		Shallow standing and slowly flowing waters, and environments subject to seasonal drought
B.peregrina and M (exp.)	Argentine: west of Andes from the equator to Lat 41 °S Bolivia: Barbosa (eastern areas) Brazil: eastern part between 43 °W and 15 °S Chile Colombia: east of the Andes between Lat. 11 ° and 15 °S Ecuador Uruguay		
B.pfeifferi (= *B.adowensis*) (= *B.bridouxiana*) (= *B.gaudi*) (= *B.germaini*) (= *B.hermanni*) (= *B.nairobiensis*) and M!	All African countries between Lat. 15 °N and 15 °S, including Madagascar, but excluding the eastern coasts at the Indian Ocean from Somalia southwards to Northern Mozambique. Algeria: isolated stations in Sahara Chad: isolated stations in Sahara Libya: South West Sahara Saudi Arabia South Yemen and Yemen		Streams, seepages and a variety of man-made water-bodies, including irrigation channels, dams and swimming pools but not found in small seasonal pools or large swamps such as those inhibited by *B.sudanica*. Depth does not seem to be a limiting factor.
B.pfeifferi (subsp. *adowensis*) and M	Ethiopia: Adowa		see: *B.pfeifferi*
B.pfeifferi (subsp. *bridouxiana*) and M	Zaïre: Lake Tanganyika western shore		see: *B.pfeifferi*

B.pfeifferi (subsp. *gaudi*) and M	Senegal:	Dakar area	see: *B.pfeifferi*
B.pfeifferi (subsp. *germaini*) and M	Algeria:	Southern Algeria	see: *B.pfeifferi*
B.pfeifferi (subsp. *hermanni*) and M	Namibia		see: *B.pfeifferi*
B.pfeifferi (subsp. *nairobiensis*) and M	Kenya:	Nairobi area	see: *B.pfeifferi*
B.pfeifferi (subsp. *ruppelli*) and M	Ethiopia: Kenya Sudan Tanzania Uganda Zaire	Eritrea	
B.philippiana and M exp.	Ecuador		
B.riisei and M exp.	Puerto Rico and other islands in the Antilles		Standing waters
B.salinarum and M exp.	Angola: Namibia	six localities between Cangandala and Vila Artur de Paiva	
B.sericea and M	Ecuador:	Los Rios, Guayar	
B.smithi and M exp.	Uganda:	Lake Edward Lake Mirambi	Vegetation growing on sand; depths up to four meters
B.stanleyi and M exp.	Chad: Ruanda: Uganda:	Lake Chad Lake Tsohoha Lake Edward	Vegetation on sand in one meter of water
B.straminea and M	Argentina: reaching to 35°S Brazil, Costa Rica, French Guyana, Grenada, Martinique, Panama, Paraguay, Peru, eastern regions Trinidad, Venezuela		Standing and slowly flowing fresh waters – well adapted to seasonal drought
B.sudanica and M!	Cameroon, Central African Republic, Chad Ethiopia: Lakes Awasa, Margherita, and Zwai Ghana Kenya: Liberia Sudan: Tanzania:	 Lakes Jipe, Naivasha, and Victoria northwards towards Shambat Arusha, Lake Victoria	Swamps which are sufficiently permanent to support a rich aquatic vegetation. The intermediate host of Schistosomiasis is common to the papyrus swamp near

	Zaire: Zambia:	South-eastern Zaire, Lake Edward, Lake Kisale, Lake Tanganyika Northern Zambia	Lake Victoria. This distribution might be associated with the spread of *Eichhornia sp.*
B.sud.rugosa and M?	Chad: Zambia:	Lake Chad Northern Zambia	
B.sud.tanganyicensis and M?	Tanzania: Zaïre:	Lake Tanganyika Lake Tanganyika	
B.tenagophila and M	Argentine Bolivia: Brazil: Peru:	 Santa Cruz, Chiquitos from Lat. 15° southwards Paraguay, Uruguay, Cajamarca	Standing and slowly flowing fresh waters
Snail Species Bulinus			
B.abyssinicus and H	Ethiopia: Somalia:	Marshes near the Awash River at Assaita, Gewani and further upstream towards Lake Lyadu Shebeli River Basin, Giuba River Basin, Lakes near the border with Kenya	Ethiopia: apparently restricted to marshes associated with the Awash River and not found in irrigation systems. Somalia: canals and drains of sugar estates (with *B.forskalii*).
B.africanus and H	Ethiopia: Kenya: Lesotho, Mozambique South Africa: Tanzania: Uganda: Zaïre: Zambia: Zimbabwe:	Jimma, Lake Tana, North-East of Gondar Nairobi District, Thika District, Machakos District, and around Lake Victoria northern provinces of Natal and westwards to the foot of the Drakensberg Escarpment in the Tugela Basin. Southwards along the coast to the Numansdorp area and through the Vaal Basin to the Warrenton District Mwanza district and near Iringa westwards to Arua Katanga Lake Bangweulu area around Harare	A variety of water bodies with or without higher plants; some regularly become dry but *B.africanus* does not inhabit such briefly filled pools as *B.nasutus*. Usually not successful in irrigation systems. Kenya: in some seasonal streams with *B.nasutus*. South Africa: higher toleration to cool condition than *B.globosus*
B.bavayi and H exp.	Aldabra Atoll: Madagascar:	South Island widespread	Aldabra: shallow and highly alkaline ponds. Madagascar: in a variety of water bodies including rice fields and

			irrigation drains. It is often present in many sites which lack other B.species. Some sites have considerable salinity.
B.beccarii and H	Yemen:	Khouzaiga Valley between Taiz and Hodeida	Perennial streams with a high calcium content
B.camerunensis and H and I exp.	Cameroon:	Western Cameroon, Lake Barombi, Lake Kotto, and Lake Debundsha	
B.cernicus and H and I exp.	Mauritius		Waters of widely different chemical composition. Present in the slowly flowing parts of streams from 600 meters down to sea-level
B.crystallinus and H and I exp.	Angola:	The northern escarpment of Angola and the Salazar District	Slowly flowing streams with rotting vegetation and irrigation channels
B.forskalii and I and H exp.	Range comprises much of African continent including Cape Verde Islands and Madagascar. Cameroon, Gabon North Africa: Sahara; Tejerhi, Air Mali: Nigeria: Chad: North-East Africa: Nile Delta southwards to Luxor Southern Africa: Namibia and the lower Orange River. Natal and Eastern Cape Province Ethiopia: Somalia: Sudan:	 Northern Mali Northern Nigeria Lake Chad, Jebel Marra Common at low altitudes and not found in highlands with the exception of the Lake Tana Basin from Webbi Shebeli area southwards Nile/Atbara confluence southwards	A wide variety of natural and artificial water-bodies, including the margins of lakes and permanent swamps. Most abundant in small water-bodies.
B.globosus and H!	Present in most of Africa south of the Sahara. The limits apparently lie in Senegal and Southern Sudan. Southern limits lie in Angola or on the lower Cunene and Okavango Rivers. South Africa: Northern Transvaal and the Natal coastal plain		Common in stagnant or slowly flowing waters with rich aquatic vegetation. Found also in rivers with bottoms of gravel or sand and seasonal pools.
B.globosus and I!	Zaïre		Ghana: the establishment of dense populations in

			streams within the forest seems to be the result of human activities.
B.hightoni and H exp. and I exp.	Kenya:	north-eastern Kenya (near Hola on the lower Tana River)	Shallow depressions filled seasonally by rain though with aquatic vegetation including waterlilies. The only other snail found was *B.forskali*
B.jousseaumei and H	Chad Gambia: Gambia River Guinea Bissau Mali Mauretania: Monguel Region Niger Senegal Sudan		Gambia: abundant on waterlily leaves in the slower flowing parts of permanent streams (*bolons*) in the upper Gambia. No great ability to aestivate being absent from temporary pools unlike *B.senegalensis*
B.nasutus and H	Kenya: Tanzania:	south-eastern Kenya Kitui and coastal area coastal region, south to Tunduru and westwards to Mbarali in the Southern Highlands	Associated with seasonal water bodies which must(!) dry out for periods of about five months. Particularly isolated pools formed by see-page, residual pools in stream-beds and road-side ditches. Uncommon in irriga-tion schemes except in Tanzania and Kenya.
B.natalensis and H (exp.)	Ethiopia Kenya Mozambique Somalia South Africa: particularly in Natal Tanzania Zimbabwe		A wide variety of water bodies, including small pools and slowly flowing rivers, also in lakes.
B.obtusispira and H	Madagascar:	western Madagascar including the lower Mangoky district, Majunga, and Tananarive	Common in rice fields and capable of aestivation for at least seven months
B.productus (= *B.nasutus*	Kenya: Tanzania:	western Kenya Lango district	See: *B.nasutus*

productus) and H		eastwards to the shores of Lake Victoria and extending further eastwards along the shore to Shinyanga	
B.reticulatus and H exp.	Ethiopia: Kenya: Mozambique: South Africa: Tanzania: Zambia: Zimbabwe:	north of Gondar Rift Valley at Marigat and north of Nakuru; the plains near Lake Victoria, Masai Mara Game Reserve. Masingere in Sul do Save Numerous localities centering on an area which includes Upington and Aberdeen, and extending up the Orange River Valley towards the Lesotho border Moshi, Misungwi district near Mwanza, Mbarali Mazabuka Nyabira near Harare, Fort Victoria	Small pools which contain water for brief seasonal periods. Kenya: on the Kano Plain in the west. It is only found during the main rainy period from March to May. It has the capacity to aestivate for prolonged periods, longer than *B.senegalensis* and *B.scalaris.*
B.scalaris and I (exp.)	Angola: Ethiopia: Kenya: Namibia: Uganda: Zaïre: Zambia: Zimbabwe:	coastal plain, northern plateau Gondar, Jimma Kano Plain near Lake Victoria Ovamboland, Kaokoveld Lira; between Mbarara and Masaka South-eastern Zaire Mbale, Monze, Mazabuka Newlands bridge near Harare	Ethiopia and Kenya: only in seasonal pools which lack higher aquatic plants. Angola and Namibia: a wider range of habitats is reported including concrete lined irrigation channels, nearly permanent ponds and a ditch flowing from a warm spring.
B.senegalensis and H and I (exp.)	Gambia Mauritania Senegal		Abundant in seasonally filled rain pools on the laterite plateau along the Gambia River. Between rainy seasons, survives in the mud.
B.truncatus (= *B.guerni*) (= *B.contortus*) (= *B.coulboisi*) (= *B.rohlfsi*) and H!	Algeria: Cameroon Chad: Egypt: Ethiopia:	Inkermann-Saint Aimé, Foundouk, Biskra A number of isolated localities in the Algerian Sahara Lake Chad Delta region Roseires, irrigation systems in the Awash Valley, lakes in the southern Rift Valley and streams in the highlands	A wide variety of water bodies, including seasonal pools, irrigation systems and concrete cisterns. Also successful in lakes, including the man-made Lake Nasser Tunisia: in drainage areas around artesian wells and in irrigation canals.

	Ghana Iran: Iraq Israel Italy: Kenya: Lebanon Libya: Malawi:	 Khuzistan region Sardinia, Sicily Kano Plain Isolated localities in the southern part of the country Karonga	Egypt: in channels and drains, to a lesser extent in the main channels but occurs even in the Nile itself and in some of its tributaries e.g. the Rosetta and Damietta branches.
B.truncatus (= *B.guerni*) (= *B.contortus*) (= *B.coulboisi*) (= *B.rohlfsi*) and H!	Mauritania: Morocco: Nigeria Portugal Saudi Arabia: South Yemen Spain Sudan: Syria Tanzania: Tunisia: Turkey Uganda: Yemen Zaïre	Atar District in the vicinity of the coast and southern Morocco south-western high-lands Jebel Marra Region, Faya District certain oases Mwanza Chott Djerid region some localities	Especially in back-water baylets, with vegetation or in residual pools. Occurs also in some oases although they had been removed from them in 1952. Distribution in the rest of Africa can only be established by further studies of snails identified as *B.t.rohlfsi* or *B.guernei*. The finding of what appears to be typical *B.truncatus* in the Atar district of Mauritania provides a tenuous link between the populations living in a tropical region and those inhabiting North-West Africa
B.truncatus (subsp. *contortus*) and H	Egypt		
B.truncatus (subsp. *coulboisi*) and H	Burundi: Kenya: Rwanda Tanzania: Uganda Zaïre:	Lake Tanganyika lakes in the western Rift Valley Central Tanzania and Lake Tanganyika Lake Kivu	Lagoons and streams on the shore of Lake Tanganyika, not found within the lake itself.
B.truncatus (subsp. *guerni*) and H	The Gambia: Mauritania:	northern Gambia south-western Mauritania, particularly in Rosso	Small shallow streams, flowing rapidly among clumps of grass. Small pools fed by springs and containing water

			lilies. After several years of drought abundant in rice-paddies
B.truncatus (subsp. *guerni*) and H exp.	Cameroon Gambia Ghana Mauritania Senegal		
B.truncatus (subsp. rohlfsi) and H	Angola: Cameroon: Congo Republic: Dolisie, Loudima Gare Ghana: Ghana: Chad Niger Republic Burkina Faso and Mali: from Lake Chad westwards Zaïre:	northern coastal plain Lake Barombi Mbo Lake Barombi Kotto northern and south-eastern regions and Lake Volta common between Tshela and Kinshasa	Small permanent pools, small lakes, rivers flowing over sand. Weed-beds of *Ceratophyllum sp.* provide favourable conditions.
B.wrighti and H and I exp.	Oman: Saudi Arabia: Central Province, Riyadh Province, Arfaa South Yemen: Hadhramaut and Upper Aulaqui regions	north-west of Saiq in Jabal Akhdar	Pools filled temporarily by rain water.
Snail Species Ferrissia			
F.tenuis and H	India:	surroundings of Bombay and small area north of Bombay	Slow running streams and standing waters.
Snail Species Oncomelania hupensis			
O.hup.hupensis and J!	China:	Yangtze River drainage system	Amphibious snails
O.hup.lindoensis and J!	Indonesia:	Sulawesi near Lake Lindu, Napu Valleys	Amphibious snails
O.hup.nosophora and J!	China: Japan:	southern region including Anhwei, Chekiang, Hunan, Hupeh, Kiangsi, and Kiangsu Jamanashi Prefecture, Kofu Basin, Middle Basin Chikugo River, Katayama and Hiroshima Prefecture, and Tone River	Amphibious snails. In irrigation ditches from sea-level up to 40 meters. Low temperature and rather dry periods acceptable.
O.hup.quadrasi and J!	Philippines:	Mindanao, Samar Islands, Leyte (eastern part), Luzon (extreme south-eastern part), Mindoro (eastern part), Bani, and Siargao	Amphibious snails. Flood plain forests, swamps, rice fields (not in Mindanao), streams, near dams and wallowing sites. Irrigation ditches.

Snail Species Robertsiella		
R.kaporensis and M!	Malaysia	

Snail species Tricula		
T.aperta and Mek!	Kampuchea: Kratie	
	Laos:	Mekong River (Kong Island)
		Thailand: Mum River

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