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A global network for the control of snail-borne disease using satellite surveillance and geographic information systems

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Abstract

At a team residency sponsored by the Rockefeller Foundation in Bellagio, Italy, 10-14 April 2000 an organizational plan was conceived to create a global network of collaborating health workers and earth scientists dedicated to the development of computer-based models that can be used for improved control programs for schistosomiasis and other snail-borne diseases of medical and veterinary importance. The models will be assembled using GIS methods, global climate model data, sensor data from earth observing satellites, disease prevalence data, the distribution and abundance of snail hosts, and digital maps of key environmental factors that affect development and propagation of snail-borne disease agents. A work plan was developed for research collaboration and data sharing, recruitment of new contributing researchers, and means of access of other medical scientists and national control program managers to GIS models that may be used for more effective control of snail-borne disease. Agreement was reached on the use of compatible GIS formats, software, methods and data resources, including the definition of a 'minimum medical database' to enable seamless incorporation of results from each regional GIS project into a global model. The collaboration plan calls for linking a 'central resource group' at the World Health Organization, the Food and Agriculture Organization, Louisiana State University and the Danish Bilharziasis Laboratory with regional GIS networks to be initiated in Eastern Africa, Southern Africa, West Africa, Latin America and Southern Asia. An

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Internet site, www.gnosisGIS.org, (GIS Network On Snail-borne Infections with special reference to Schistosomiasis), has been initiated to allow interaction of team members as a 'virtual research group'. When completed, the site will point users to a toolbox of common resources resident on computers at member organizations, provide assistance on routine use of GIS health maps in selected national disease control programs and provide a forum for development of GIS models to predict the health impacts of water development projects and climate variation.

Keywords: Schistosomiasis; Snail-borne disease; Geographic information systems; Remote sensing; Rockefeller Foundation

1. Introduction

An Incantation for the Worm

.a-nu ir-hi-a-am ša-me-e ša-mu-ú' er-şe-tam ul-⌜du-nim⌝
er-şe-tum ú-li-id bu- ša-am bu-šum ú-li-id lu-hu-ma-a-am
lu-hu-mu-um ú-li-id zu-ba zu-u[b]-bu ú-li-id tu-ul-tam

Anu engendered heaven, heaven bore earth,
earth bore stench, stench bore mud,
Mud bore the fly, the fly bore the worm

From Cunningham, G., (1997). 'Deliver me from evil' Mesopotamian incantations 2500-1500 B.C.

The worm is the subject of five incantations from ancient Mesopotamia — two in Akkadian and three in other languages — that identified the worm as the cause of ailments ranging from toothache to eye disease[1]. Medicine was placed on the offended part and the verses were delivered. The worm in this incantation was borne from 'stench', a telling portrayal of its mode of survival. In a testimony to the search for causes amidst the human ignorance of the time, the association of 'stench' and worms had seemingly been made. Environmental contamination and ignorance remain the keys to transmission of *Schistosoma* spp., the soil borne helminthes, and a long list of other diseases of public health importance.

In the excitement of modern medical discoveries and stunning technologies, it is easy to forget one of the hard-won success stories of an earlier time in the United States — hookworm eradication from the old South. In the early part of the last century, hookworms impacted life in the Southern USA in a negative and entirely preventable way. Barefoot children contracted blood-sucking parasites that weakened, with sometimes devastating effects, the people who lived in this warm, moist climate. With continued addition of new parasite eggs by fecal contamination, the environment favored survival of the hookworm. The vision that relatively simple, informed interventions could be successful was given the opportunity to succeed in a campaign spearheaded by the Rockefeller Foundation. Armed with a strategy of stool examination, drug treatment, sanitation and community education, elimination of hookworms as a public health problem occurred wherever it was implemented. The hookworm inevitably joined the ranks of beaten 'diseases of development'.

The Rockefeller Foundation tradition of support for public health began with intervention against hookworms and went on to other diseases, including efforts to control schistosomiasis in Egypt, the Caribbean island of St Lucia, and elsewhere (Anon, 2000; Shaplan, 1964). In the St Lucia Project, careful epidemiological studies sponsored by the Foundation from 1965 to 1981 were done to compare the success of control strategies in separate island valleys based on use of new, safer drugs to kill worms, molluscicides and/or safe water supplies and sanitation to interrupt transmission (Jordan, 1985). Results led to a general recommendation for control of morbidity by integration of surveillance, chemotherapy, fo-

[1] The above verses were offered by Piotr Steinkeller, a Bellagio Center resident scholar and Professor of Assyriology, in response to a dinner discussion on recognition of worms as causes of disease in ancient times.

cal molluscicide and public education that is still followed in many endemic countries. At the end of the 16-year project, the prevalence of *S. mansoni* had been reduced from 40 to 5%. The outcome of the campaign was sealed by the introduction of the competitor snail, *Thiara granifera* (Prentice, 1983), and the beginning of a period of sustained socio-economic development. *Thiara* ultimately displaced *Biomphalaria glabrata* vectors of schistosomes in most areas of St Lucia, as it already had on other Caribbean Islands. A project team member who re-visited St Lucia in 1996, sponsored by the Castries Rotary Club, reminisced on the success of the original project aims after encountering an 'almost unrecognizable' island with abandoned control program structures, a few isolated mountain pockets of remaining *B. glabrata*, an absence of new cases of *S. mansoni*, and an economy transformed by new roads, prosperous tourist hotels and petrochemical businesses (Sturrock and Sturrock, 1998). In St Lucia, as with hookworms in the Southern USA, was the demise of *S. mansoni* a by-product of development — or part of the process?

Progress of intervention against hookworms and schistosomes has been mixed elsewhere. In some places, success has been as dramatic as the situation of hookworms in the Old South, and post-transmission schistosomiasis is already emerging as a new concern in newly eradicated areas (Giboda and Bergquist, 2000). In others these diseases continue to take their toll and remain as age-old scourges. The geohelminthes and the snail-borne schistosomes are all too successful, but the underlying causes and vulnerability to sound public health measures are similar. Inevitably they will fall to development, political will in support of public health campaigns, and strategic allocation of health resources based on better information.

GIS and remote sensing arose from cold war defense technologies — picture the stereotypical 'war room' electronic array on a large wall of threatening events and the readiness status of security forces to deal with mutually assured destruction. The dream, the end game of medical GIS may be similar. Can we construct a near 'real time' array of data on the global status of schistosomiasis and other tropical diseases on a virtual world constructed from earth observing satellite sensors — the schistosomiasis or malaria report — as of yesterday?

This may not be far off. Global climate models, geographic information systems (GIS), global positioning systems (GPS) and the increasing public availability of electronic databases provide new information that can be linked to satellite data maps. GIS models can be used to match the response of parasites to the environment by their intrinsic environmental preferences and limits of tolerance. One wonders how much the hookworm campaign in the Old South or schistosomiasis control in St Lucia could have been speeded by use of GIS, GPS and remote sensing to aid the process of informed intervention, and to better allocate scarce health care resources via delivery of better information — such as the spatial and temporal determinants of parasite survival and transmission — to guide control programs. Might GIS models have been used to predict the environmental suitability of St Lucia for introduction of *Thiara* spp, as can now be done for crops? Or, more relevant to the future elsewhere, could the recent epidemiological disasters of explosive schistosomiasis in water development projects in Africa (Southgate, 1997) have been predicted, and perhaps averted, by space age epidemiological tools that allow evaluation of the environmental determinants of snail vectors and disease?

In keeping with the Rockefeller Foundation tradition of broad support for public health, the Foundation responded positively to a proposal to address these questions at a team residency entitled 'Health Maps: A Global Network for Control of Snail-Borne Disease Using Satellite Surveillance and Geographic Information Systems' that met on 10-14 April 2000 at the Bellagio Study and Conference Center in Italy. The objective of the team residency was to create a global network of collaborating health workers and earth scientists dedicated to the development of computer-based models that can be used for improved control programs for schistosomiasis and other snail-borne diseases of medical and veterinary importance (Bergquist et al., 2000).

2. Organization of the working group

A collaboration plan was developed that calls for linking a 'central resource group' at the World Health Organization (WHO), the Food and Agriculture Organization (FAO), Louisiana State University (LSU) and the Danish Bilharziasis Laboratory (DBL) with regional GIS networks to be initiated in East Africa, Southern Africa, West Africa, Latin America and Southern Asia (Fig. 1). A workplan was developed for research collaboration and data sharing, recruitment of new contributing researchers, and means of access of other medical scientists and national control program managers to GIS models that may be used for more effective control of snail-borne disease. An Internet site, www.GnosisGIS.org (GIS Network On Snail-borne Infections with special reference to Schistosomiasis using GIS), has been initiated to allow interaction of team members as a 'virtual research group'. When completed, the site will point users to a toolbox of common resources resident on computers at member organizations, provide assistance on routine use of GIS health maps in selected national disease control programs, and provide a forum for development of GIS models to predict the health impacts of water development projects and climate variation.

Members of the central resource group and the chairs of each regional working group will meet formally at least once each year to evaluate progress, develop annual work plans and approve new regional project members. The tasks of the regional networks are to: (1) facilitate collaboration between described individual research projects to create compatible regional GIS databases, (2) collaborate on construction and operation of the regional component of the internet site, in English and the dominant local language, and (3) to work with a regional advisory committee of key leaders from the medical, academic and government sectors to facilitate regional implementation of project results and GIS models for control of schistosomiasis and other snail-borne diseases. Individual contributing research projects in each regional working group may be funded from a variety of sources, typically via a local-international research team represented by a local scientist in collaboration with a member from an advanced country research center. The regional GIS will be located and administered from a designated research unit in respective regions in cooperation with a coordinator from the central resource group. 'Correspondent' membership is possible for scientists interested in GIS applications on other vector-borne diseases who are able to both contribute GIS resource results and utilize working group resources on topics of mutual interest.

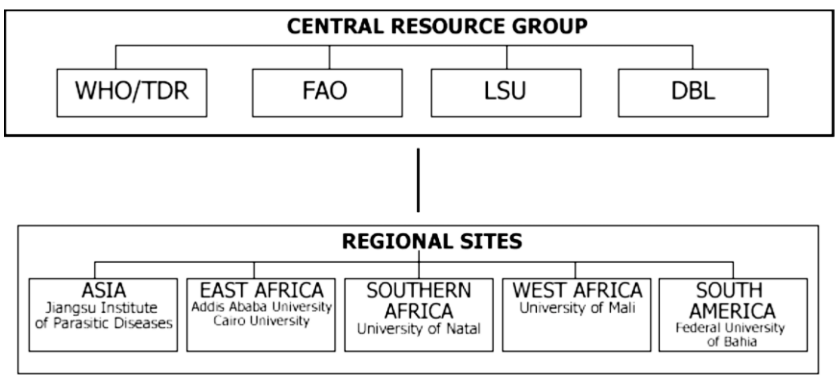

Fig. 1. Organizational structure. The central resource group will provide collaborative support to each of the five regional GIS sites via designated research unit(s) in the region, in partnership with the resource group through a member with extensive experience in the region. Regional sites are currently centered at the Jiangsu Institute of Parasitic Diseases, P.R. China, for Asia, Addis Ababa University, Ethiopia and Cairo University, Egypt for the IGAD/Nile region, the University of Natal, South Africa for the SADC region, the University of Mali for West Africa, and the Federal University of Bahia, Brazil for South America.

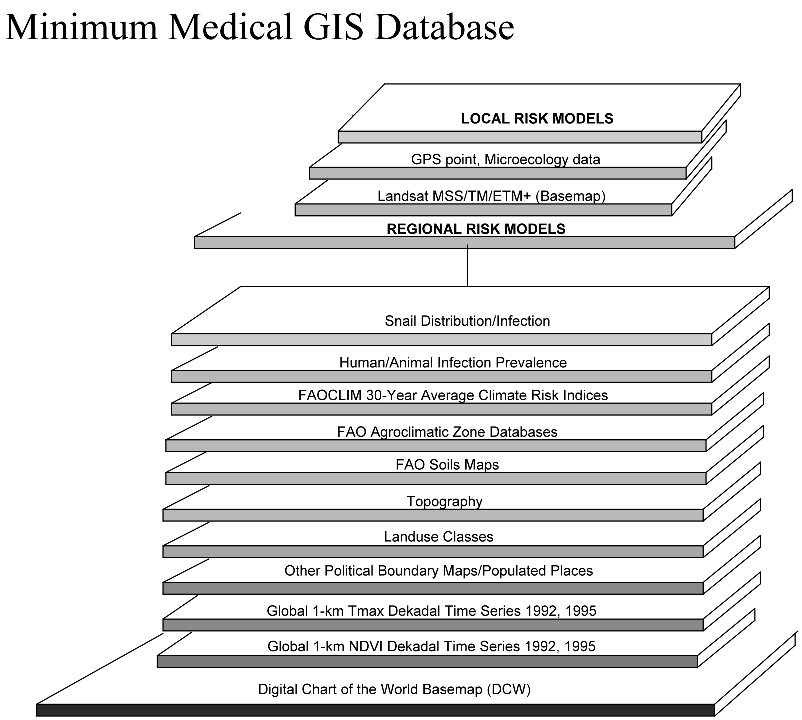

Fig. 2. The initial minimum medical GIS database (MMDb). Datalayers will be georeferenced to latitude–longitude, decimal degree projection format and will include the most complete public access environmental databases available, with relevant medical data on the ecology and epidemiology of parasites and snail hosts.

3. A minimum medical GIS database

The initial team goal is to construct digital geospatial models using (1) GIS methods, (2) global climate data, (3) sensor data from earth observing satellites, (4) disease prevalence data, (5) the distribution and abundance of snail hosts, (6) soils, landuse and topographic maps, and (7) other data on environmental factors that may affect development and propagation of snail-borne disease agents. Agreement was reached on the use of compatible GIS formats, software, methods and data resources, including the definition of a 'minimum medical database' (MMDb) to enable seamless incorporation of results from each regional GIS project into a global model (Fig. 2).

GIS databases will be in geographic latitude–longitude, decimal degree format. This global format is most commonly used for public access map database resources and can be readily re-projected as needed for compatibility with various national mapping systems. There is no 'required' software, but the common commercial GIS and/or image analysis software packages that have mutual import–export functions are recommended, including the ArcView, ARC/INFO (ESRI, Redlands, CA) and MapInfo (Seattle, WA) GIS packages, the ERDAS Imagine (Atlanta, GA) and IDRISI (Lowell, MA) image analysis packages, and public access software available from FAO (WinDisp) and EpiInfo/EpiMap from the Centers for Disease Control and Prevention (CDC, Atlanta, GA).

The initial MMDb will be prepared for each regional site in cooperation with LSU, and will consist of relevant medical data and global public-access databases deemed needed for all projects. The MMDb is meant to be a dynamic, common resource and will be modified and improved by mutual agreement as rapidly proliferating new data sources and GIS map products emerge and are proved to be useful by working group members. It is proposed that much of the 'inertia' preventing wider use of GIS in health applications relates to the difficulty of choosing and learning specialized GIS software/hardware, the great duplication of effort in developing fundamental medically-useful databases from among databases used for other purposes, and adjusting to GIS models and methods that are non-uniform and sometimes incompatible. The working group aims to diminish these issues as concerns.

4. Implementation of GIS models in disease control programs

The ultimate goal of the working group is to improve control of schistosomiasis and other snail-borne diseases by routine use of GIS health maps in national disease control programs. While much can be gained by the availability to control program managers of a comprehensive 'database with maps' that can be readily updated and easily queried, GIS and satellite surveillance have the potential to provide far more powerful tools as prediction models. A major task of the working group will be to establish links of researchers, via the regional advisory committees, to control program personnel to provide a forum for development of models that will have practical usefulness in comprehensive national health program planning and operations. In particular, key measures of the success of the working group will be the effectiveness of efforts directed at: (1) use of GIS models to predict the health impacts of water development projects, (2) the consequences of both inter-annual climate variation and long-term global climate change, and (3) the cost–effectiveness of hypothetical or proposed modifications of control strategies.

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