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Use of landsat TM satellite surveillance data to measure the impact of the 1998 flood on snail intermediate host dispersal in the lower Yangtze River Basin

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Abstract

To assess the impact of the 1998 flood on snail distribution in the lower Yangtze River Basin, two study areas were selected, one in the Poyang Lake region, and the other along the Yangtze River in Jiangsu province. Using image analysis software, geocoded Landsat TM data were used to create TNDVI maps based on the formula TNDVI = Sqrt[(band4 − band3/band4 + band3) + 0.5]. The images taken in the flood season were classified to produce a map depicting water and land. The images taken during springtime were processed and classified based on TNDVI. Composite images were created based on the time difference analysis, combining the flood season maps and spring vegetation maps to produce a map in which potential snail habitats were identified. When compared with ground survey data collected in the spring of 2000, the correspondence rate between potential snail habitats identified by image analysis of 1998–1999 Landsat TM data and ground survey data was over 90% in both regions. Results indicate that ecology based Landsat TM image analysis provides a new way to predict snail distribution under specific environmental conditions associated with the extent of the annual flood season.

Keywords: Remote sensing; *Oncomelania hupensis*; *Schistosoma japonicum*; Snail habitats; Flood

1. Introduction

The lower reaches of the Yangtze River Basin are characterized by marshlands with seasonal summer flooding and winter drought. Habitats of *Oncomelania hupensis*, the snail intermediate host of *Schistosoma japonicum*, have expanded during recent decades because the lower reaches of the river affected by more frequent major floods, resulting in snail migration and expansion into new niches (Chen et al., 1999; Zhang et al., 1999)

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and greater health risks for human populations along the river basin. Local landform changes created by summer flooding can either reduce or promote new snail habitats by respective scouring action or accretion of clay soils and silt that support suitable marsh vegetation (Lu et al., 1988). Predicting new snail habitats by remote sensing and GIS may provide a useful method for identifying schistosomiasis transmission areas. In previous studies, remote sensing and GIS methods were used to identify high risk areas based on water levels and environmental temperature (Zhou et al., 1999a,b).

The 1998 flood, the worst China has experienced in the last 100 years, was associated with a marked increase in snail intermediate host dispersal in 'lake marsh' and 'river marsh' transmission zone, with some reintroduction of the snail to canals in the 'river network' coastal plain area. Establishing effective control measures in high risk areas is important for the success of disease control programs. The aims of the current study were to: (1) evaluate use of Landsat TM data to map snail habitat area based on classification of ecological parameters related to the intermediate host's water and vegetation requirements, and (2) to assess and validate the impact of the 1998 floods on the extent of potential snail habitat in two areas, one in the Poyang Lake Region and one in the Lower Yangtze River Basin.

2. Materials and methods

2.1. Study site

Two study areas were selected to understand the impact of floods in 1998, one in the Poyang Lake region, and one along the Yangtze River in Jiangsu province. During 1998, 100-year record floods affected the entire valley along the Yangtze River. In Poyang Lake snails are distributed mainly in marshlands around the lake that flood in summer and dry out in winter and are characterized by the presence of vegetation that provides suitable conditions for the amphibious snail host to develop and reproduce. Agricultural communities around Poyang Lake have prevalence rates of 5–10% in human populations. Even higher prevalence rates are often found in water buffalo and cattle (McGarvey et al., 1999), the major reservoir hosts. The selection of the Nanjing part of the Yangtze River for this study allowed comparison to previous studies in the same area (Zhou et al., 1999a). Snail host habitats are found mainly in marshlands on river islands and along the banks of the river. In the lower basin of the Yangtze River, there is significant snails migration from upstream to the downstream during flood season. The Nanjing part of the Yangtze River were studied to compare with previous studies in the same areas (Zhou et al., 1999a).

2.1.1. Landsat TM data analysis

Landsat Thematic Mapper (TM) is an earth-observing scanning optical-mechanical sensor that records energy in the visible, reflective-infrared, middle-infrared, and thermal-infrared regions of the spectrum. It collects multispectral imagery that has higher spatial, spectral, temporal, and radiometric resolution than that obtained from the earlier Landsat MSS sensor. Landsat TM has an instantaneous field of view of 185 km^2, and a spatial resolution of 30×30 m at earth surface for six of the seven bands. Band 6 thermal-infrared data has a spatial resolution of 120×120 m (Beck et al., 2000). Four Landsat TM image scenes were purchased from the archives of the China Remote Sensing Satellite Ground Station in Beijing. Two satellite images were obtained of the Poyang Lake region, one on 25 August, 1998 and the second image on 4 April, 1999. The two images that covered the lower reaches of the Yangtze River from Nanjing to Zhengjiang were obtained on 8 August, 1998 and 5 May, 1999. The August 1998 images corresponded with the 1998 flood season and the April–May images corresponded to spring conditions of rapid marshland vegetation growth. Analysis was done using ARCVIEW 3.0a and ERDAS Imagine 8.3.1 software.

2.2. Image analysis

Image analysis was performed in ERDAS Imagine using methods described previously by Zhou et al. (Zhou et al., 1999a). Each image was geocoded based on the Digital Chart of the World. The geocoded Landsat TM data were used to create TNDVI maps based on the formula TNDVI = Sqrt[(band4 − band3/band4 + band3) + 0.5] and then 15 or 25 TNDVI classes for the Yangtze River and Poyang Lake regions, respectively. The August flood season images were used to create a mask of two classes, water and land. The spring vegetation images were then reclassified to identify the specific characteristics of healthy vegetation where snail habitats are most likely to occur. For the Nanjing study area, this was done by recoding the six highest TNDVI value classes into one combined class, resulting in a total of 10 classes. For the Poyong Lake site, 10 TNDVI classes were created by a total of 10 classes. For the Poyong Lake site, 10 TNDVI classes were created by combining classes 20–25 (the highest values), 15–9, 10–14 and 8–9.

The mask water class was assigned a value of 10 and the land class was assigned a value of 20 so that creation of a composite map from the mask and TNDVI maps resulted in unique class values for water, flooded non-vegetated area, flooded vegetated area and eight vegetated land classes outside the maximum extent of flood (Fig. 1 and Fig. 2). The final composite maps thus combined the time-difference images (flood season and spring growing season) to create maps that identified a specific zone where marshland was flooded during 1998 flood season and where vigorous growing vegetation occurred in spring. Based on the biological requirements of the *Oncomelania*, this zone represented the potential snail habitat area following 1998 flood season dispersal (shown as pink color in Figs. 1 and 2).

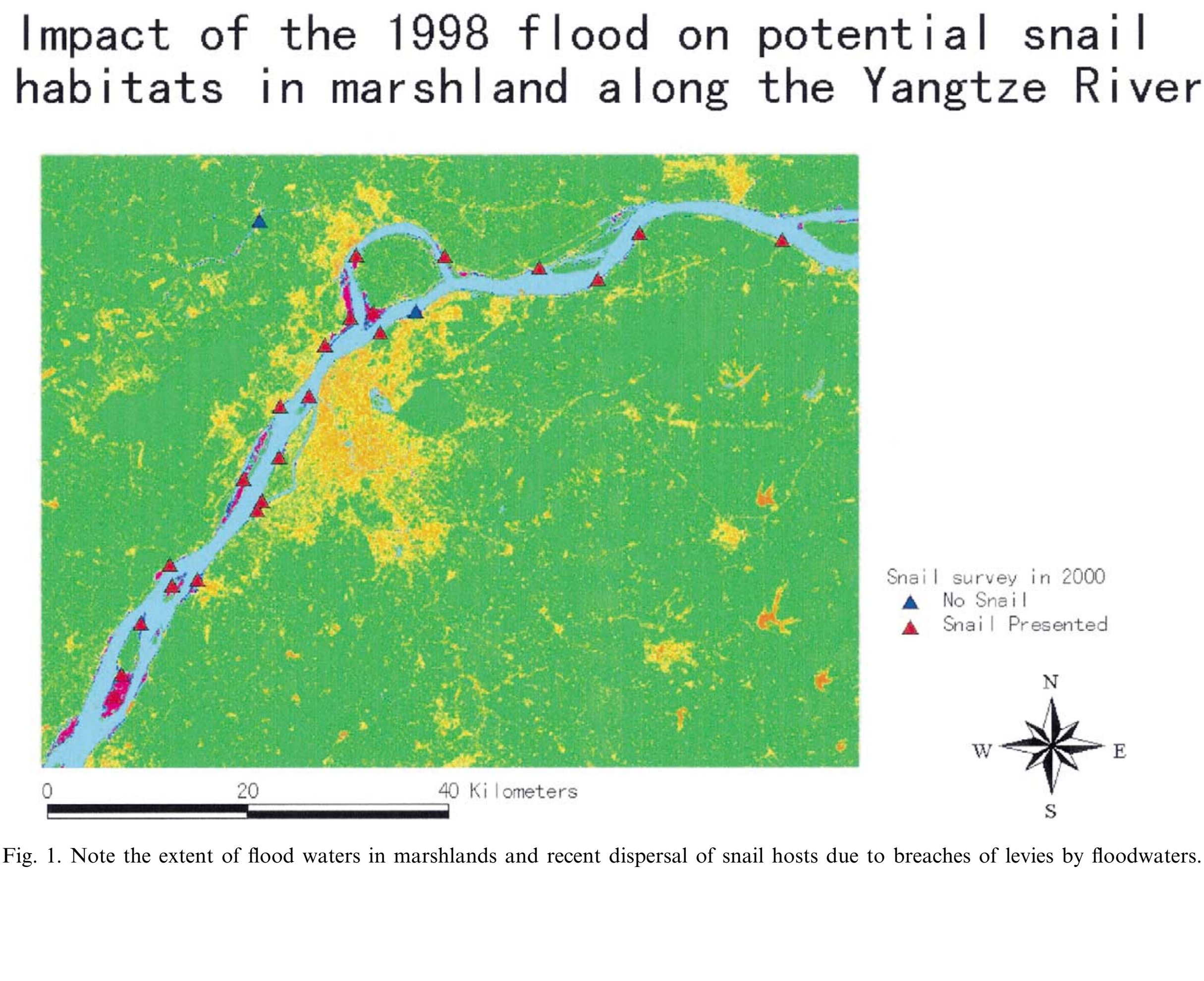

Fig. 1. Note the extent of flood waters in marshlands and recent dispersal of snail hosts due to breaches of levies by floodwaters.

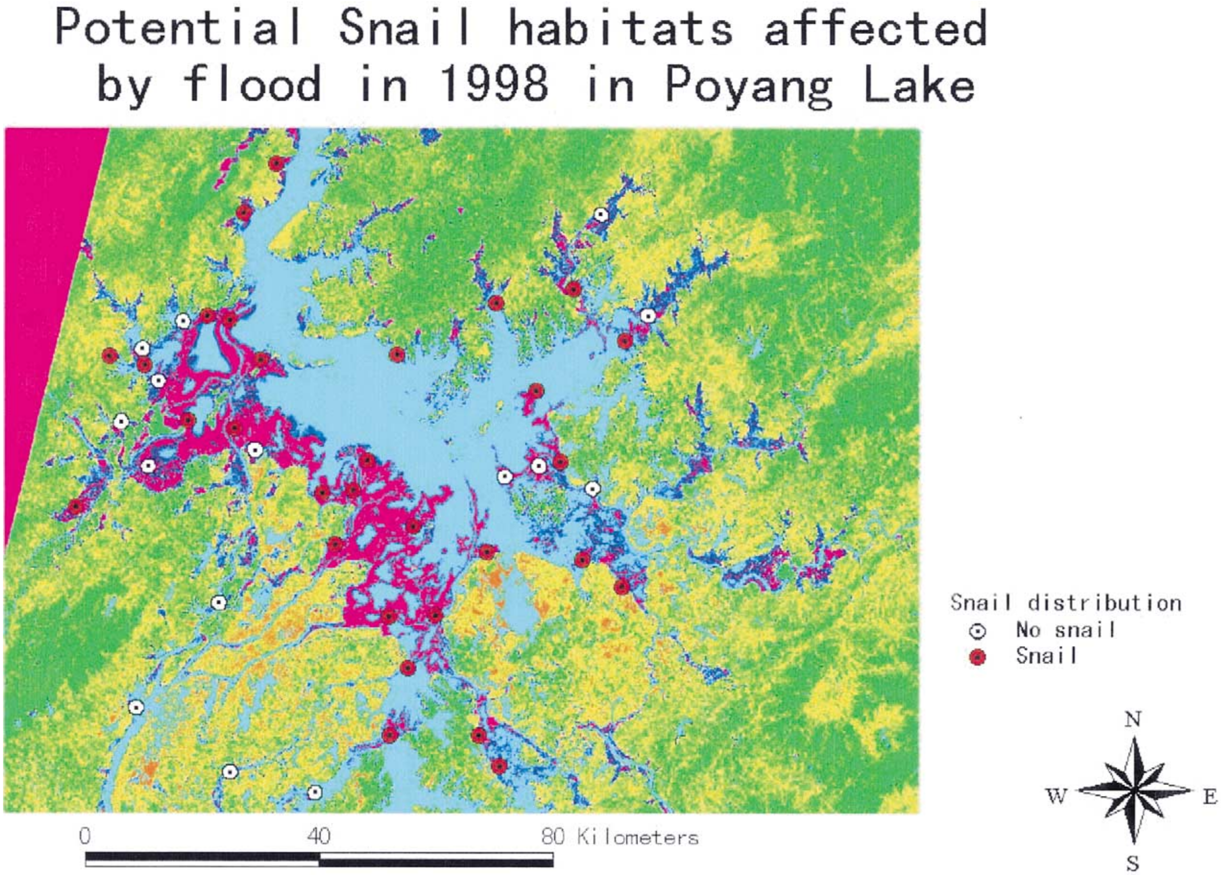

Fig. 2. The red zone represents the maximum (100-year record) extent of snail host dispersal and is bounded lakeside by the non-vegetated zone considered unsuitable for *Oncomelania*.

2.3. Field validation

Standard control program data from government schistosomiasis control stations in both the Poyang Lake and Nanjing marshland sites was used as field validation data on snail distribution. According to standard procedures recommended for government snail control programs in endemic areas, an annual field survey of snail infested area was done by sampling individually named marshland areas. In the Nanjing marshland, collectors walked transects spaced 10 m apart through each marsh, stopping each 10 m to collect all snails in a 10th meter square frame. In Poyang Lake, snail survey data was collected by less intense transect sampling methods for individual marshes because of the more extensive areas to be surveyed. Collectors stopped each 20 m along transects for sampling within a 10th meter square frame. If snails were found by survey teams within a given named marshland, it was considered to be infested. Collected snails were later counted and screened for infection by examining crushed snails for typical cercariae. Results are reported as to infection rate and density based on the area in square meters of each marshland searched. Data on snail distribution in marshlands were collected by local trained personnel in April–May, 2000 (2 years after the 1998 flood). Snail control personnel in both sites were presented with the map of GIS predicted snail habitat area and asked to return to the field to record data for any unsurveyed marshlands, lake sites or inland sites (via waterway connection to the river) that were predicted to be snail habitat by the model. Results were compiled and recorded in a GIS database file. For analysis, individual marshlands were categorized as large, medium or small based on whether they were over 2 000 000, 1 000 000 to 2 000 000 m^2 or less than 1 000 000 m^2, respectively, or as reclaimed marshlands if impounded within levees. The correlation rate of snail distribution data to that predicted by the composite map was calculated based on the relationship of surveyed snail distribution on the ground to potential snail habitats in the remote sensing composite map.

3. Results

The composite image map covering Poyang Lake showed the very large area of potential snail habitat (pink color in Fig. 1) where flood waters occurred in the summer of 1998 and where lush marsh vegetation occurred in the spring of 1999. The majority of potential snail habitats were distributed along the southwest shore of the Poyang Lake and in adjacent areas that were connected directly to the lake by small waterways. The composite image map of the Yangtze River from Nanjing to Zhengjiang revealed potential snail habitats to be mainly distributed in the marshlands along the river, especially around islands in the Yangtze River and along the river's banks (Fig. 2).

A total of 69 marshland sites, including 45 in the Poyang Lake region and 24 in the Nanjing part of the Yangtze River, were selected for validation by ground survey for presence of *Oncomelania*. GIS databases for each of the two regions were created that showed the correspondence between snail distribution in marshland areas from the ground survey and potential snail habitat area predicted by the GIS composite maps. In the Poyang Lake region, the correspondence rates were 92.31, 85.71, 50.00 and 0% in large, medium, small marshlands and inlands (with direct connection to the lake), respectively. For the Yangtze River site near Nanjing, the correspondence rates were 100, 100 and 83.33% in large, medium and small marshlands (Table 1).

4. Discussion

O. hupensis, the amphibious snails host of *S. japonicum* in China, is typically found in habitats with seasonally abundant water, clay soils, and dense marsh vegetation. Habitats in Poyang Lake and the lower reaches of the Yangtze River (from Nanjing to Zhengjiang) are described as marshland and lake regions, one of the three environmental strata in which *O. hupensis* flourished (Zhu, 1992). The other two strata are defined as plains-river network regions and mountainous regions, respectively. While, four subtypes of habitats are presented in the marshland and lake

Table 1
Comparison between potential snail habitats in composite images and snail distribution in ground survey in 2000

Region	Size of marshland*	Number of potential snail habitats selected	Number of marshlands with snails	Correspondence rate (%)
Poyang lake	Large	13	12	92.31
	Medium	14	12	85.71
	Small	12	6	50.00
	Reclaimed	6	0	0.00
Nanjing part of the Yangtze river	Large	6	6	100.00
	Medium	6	6	100.00
	Small	12	10	83.33

*, The size of large, medium and small marshlands are over 2 000 000, 1 000 000 M^2 and less than 1 000 000 M^2, respectively. The reclaimed marshlands (or inner embankment) are impounded within levees reclaimed.

regions, that are fork-beach, islet without embankment, islet with embankment, and inner embankment. The focus of the present study was to predict potential snail host habitat in the marshlands and lake regions, the major region where schistosomiasis is still of major importance in China. In marshlands, snails are abundant in areas flooded for 4 or 5 months, and they are usually absent in areas flooded for less than 1 month or areas flooded greater than 8 months a year. During the summer months, snails disperse through marshes by the effects of powerful currents. In winter, snail development is slowed, but their survival continues if protected from adverse conditions, such as within soil fissures.

Rainfall, temperature and seasonal flooding are among the most important factors affecting *Oncomelania* distribution and seasonal population density fluctuations (Zeng et al., 1998; Zhou et al., 1998). In order to characterize their habitats, features related to soil, vegetation, and food requirements need to be analyzed in conjunction with climatic factors and the extent of the annual flood. In nature, the food of *O. hupensis* consists of grasses, ferns, and mud rich in diatoms. Besides food, vegetation provides shade, an important factor for snail survival because it enhances feeding activities, egg laying capabilities and moisture retention (Zhong et al., 1995). In consideration of all these factors (i.e. temperature, water regime, shade and vegetation), Landsat TM images were analyzed at times suitable for evaluation of spring vegetation indices and summer floods season.

Two composite images were created and analyzed, one of high-risk snail ecological zones in the Poyang Lake Region and one of the lower Yangtze River Basin. Results revealed a correlation rate of predicted to field-validated habitat area of over 92% in large marshlands and over 85% in medium marshlands (Table 1), indicating that the spatial model used to identity snail habitats is a valid predictor of potential snail distribution area, one of the essential components needed for predicting high risk areas for human schistosomiasis. For small marshlands, a more accurate prediction rate of 83.3% was observed for potential snail habitat in marshlands along the Yangtze River than in Poyang Lake, where 50% of small marshlands were incorrectly predicted based on the ground truth data. In the ‘reclaimed marsh’ (or inner embankment) zones of Poyang lake, all six marshlands within this category were incorrectly predicted to be endemic, possibly because it is difficult for snails to disperse to within levees on land previously cleared of infestation.

In the 1998 flood year significant damage to levees occurred along the Yangtze River, indicating the need for implementation of prompt preventive control measures in areas where flooding causes re-introduction of snails. Snail dispersal into the downstream zone of the Yangtze River was demonstrated in water courses that directly connect to Poyang Lake and the Yangtze River after the 1998 flood. Schistosomiasis is one of the major emerging diseases in which control efforts can be based on water and topography alterations before and after flooding events. Hence, spatial analysis is important for obtaining a simple and precise way for predicting risk areas. Results indicated that a GIS spatial model based on time-difference change analysis may provide a rapid method to demonstrate *Oncomelania* habitats and high schistosomiasis risk areas in China. In conjunction with use of a GIS environmental change detection model, snail surveillance and monitoring will still be needed when snail dispersal is thought to have occurred in specific areas. It is recommended that potential snail habitats be monitored every 2 years, and that implementation of a GIS change detection model using Landsat TM or similar satellite sensor surveillance can be a practical means of identifying areas appropriate for intervention by public health authorities.

The change detection model developed in these studies demonstrated the full range of the maximum (100-year record in 1998) extent of potential snail habitat and the lowest extent of snail habitat in both Poyang Lake and the Nanjing site (bounded by the non-vegetated flood zone considered to be unsuitable for establishment of *Oncomelania*). Using this result as a maximum flood baseline, additional study of a Landsat data time-series covering a range of wet and dry years by similar methods may allow development of a model that will reveal long term patterns of snail dispersal and establishment in potential habitats, and relative *S. japonicum* infection risk, based on changes in the extent of the annual flood, including changes associated with the Three Gorges Dam project.

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