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Habitat suitability modelling for predicting potential habitats of freshwater snail intermediate hosts in Omo-Gibe river basin, Southwest Ethiopia

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ABSTRACT

In spite of considerable progress made in the prevention and control of schistosomiasis and other snail-borne diseases, transmission has intensified in some endemic areas as a result of land-use and climate changes. We used decision tree models and multivariate analysis to identify factors affecting the occurrence and abundance of medically important freshwater snail intermediate hosts in the Omo-Gibe river basin, Ethiopia. The models were based on a dataset of 140 samples collected from lakes, wetlands, rivers, dam reservoir shores and irrigation canals. A total of 1866 freshwater snails belonging to four genera and seven species were collected. *Biomphalaria pfeifferi*, *Lymnaea natalensis and Bulinus globosus* had fair to moderate predictive performance based on Kappa statistics ($\kappa > 0.2$), indicating that these species have clear environmental requirements within the habitat gradient studied. The most important variables influencing the abundance and occurrence of snail species were the presence of predator and competitor, canopy cover, type of water body, waste dumping and water pH. In conclusion, snail species occurred less frequently and in smaller numbers in water bodies with minimal human disturbances. Therefore, preventing human disturbance in water bodies may enhance aquatic biodiversity, thereby increasing the abundance of snail predators and competitors. Preventing the pollution of these ecosystems is essential to maintain their ecological integrity and sustain the ecosystem services they provide to local communities.

1. Introduction

Freshwater gastropods are intermediate hosts of various trematode species causing intestinal and urinary schistosomiasis, fascioliasis and other snail borne diseases of humans and animals (Table 1). In spite of considerable progress made in the prevention and control of snail borne diseases in several African countries, their transmission has intensified in some endemic areas (Bergquist et al., 2017). The incidence and prevalence of snail borne diseases have been increasing particularly in areas where there is water resources development which have led to the formation of suitable habitats for snail intermediate hosts (Zein-Eddine et al., 2017). In Ethiopia, new snail foci and infectious areas have been discovered in different parts of the country, mainly due to climate and land-use changes (Amsalu et al., 2015). Climate simulation models predict an increase in the mean global temperature from 1990 to 2100 of 2.4 °C to 5.4 °C (Johns et al., 2003), resulting in temporal and spatial changes in temperatures, precipitation and humidity that are expected to occur under different climate change scenarios. The global temperature increase will affect the biology and ecology of snail intermediate hosts and consequently the risk of snail borne diseases (Githeko et al., 2000). Higher temperatures increase the snail metabolic rate, fecundity, and feeding frequency, reducing the duration of the development periods and increasing the number of generations per year and the size of snail populations (De La Rocque et al., 2008; Kristensen et al., 2001). Changes in precipitation and evapotranspiration rates may cause the disappearance of intermediate hosts in some hot and low altitude regions (Mutuku et al., 2011). But other areas in highlands now too cold to support the snail hosts may become favourable sites for intermediate snail hosts and schistosomiasis transmission (Manyangadze et al., 2016).

The distribution of snail-borne diseases largely depends on the spatial distribution of intermediate snail hosts (Ali et al., 2006; Sangwan et al., 2016). The principal factors which affect the occurrence and relative abundance of snail populations include physical factors

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Table 1
The freshwater gastropod species found in the study area which are intermediate hosts of various parasites infection to human or animals.

Freshwater gastropod	Parasites	Reference
Biomphalaria pfeifferi	*S. mansoni*	Erko et al., 2006; Kloos et al., 1988
Biomphalaria sudanica	*S. mansoni*	Alebie et al., 2014
Lymnaea natalensis	*Fasciola gigantica*	Walker et al., 2008
Lymnaea truncatula	*Fasciola hepatica*	De Kock et al., 2003
Bulinus globosus	*S. haematobium*	Woolhouse and Chandiwana, 1990; Pedersen et al., 2014
Bulinus forskalii	*S. haematobium*	Labbo et al., 2007
Physa acuta	No role in transmission of any parasite	De Kock and Wolmarans, 2007

such as canopy cover, water flow velocity, substrate type, water temperature and turbidity (Dida et al., 2014; Monde et al., 2016; Zein-Eddine et al., 2017); chemical factors such as dissolved oxygen concertation, five day biochemical oxygen demand (BOD_5), pH, electric conductivity and hardness (Camara et al., 2012) as well as biological factors such as availability of food, competition and predator-prey interactions (Stensgaard et al., 2006; Turner and Chislock, 2007; El Bardicy et al., 2009;Younes et al., 2017). However, the relative importance of various environmental factors varies significantly among ecological settings region to the other (Camara et al., 2012), suggesting that local investigations are needed to identify the preferred habits of snail intermediate hosts.

Although several epidemiological studies were carried out in different parts of East Africa, few studies are available on habitat suitability modelling of snail intermediate host in that region. Habitat suitability modelling is a tool for forecasting the suitability of habitats for a given species based on known affinities with environmental parameters (Anderson et al., 2003; Mereta et al., 2012). Habitat suitability modelling is used for identifying the most important biotic and abiotic factors affecting the occurrence and relative abundance of organisms (Anderson et al., 2003; Stensgaard et al., 2006; Store and Kangas, 2001). Thus, a better understanding of the environmental factors that affect snail intermediate hosts is important to facilitate disease prevention and control programs. We developed habitat suitability models using decision tree models and multivariate data analysis to investigate the freshwater snail community structure in the water bodies of the Omo-Gibe river basin. The information obtained from this study may be used to identify freshwater snail hot spots and design effective snail borne disease prevention and control programs.

2. Methods and materials

2.1. Study area

This study was conducted in the water bodies of Omo-Gibe river basin situated between latitudes 4°25′51.6″ N and 9°22′28.05″ N and longitudes 33°0′24.4″ E and 38°24′42.24″ E (Fig. 1). The Omo-Gibe river basin has an area of approximately 79,561 km^2. It is Ethiopia's second largest river basin, accounting for 14% of Ethiopia's annual runoff, and being second only to the Blue Nile in runoff volume (Awulachew et al., 2007). Elevation data derived from ASTER DEM imagery shows that the basin has an altitude between 500 m.a.s.l around Lake Turkana and 3000 m.a.s.l. around Bako Town in the north. The regional climate varies from is tropical hot and semi-arid in the lowlands to temperate and wet in the highlands, with an average annual rainfall around 1550 mm. Based on the rainfall distribution patterns, the basin is characterized by three distinct rainfall regimes. The central eastern part has a bimodal rainfall pattern, the north-eastern region has an asymmetric bimodal pattern, and the western mountain slopes have a strongly flattened unimodal profile. Rainfall strongly decreases from north to south of the watershed, with < 300 mm/year near Lake Turkana (National Meteorological Agency, 2016). During recent decades, the Omo-Gibe watershed has been subjected to considerable human pressure, which mainly originates from rapid human population growth on-going urbanization and hydro-electric development. Three dams (Gilgel Gibe I, II and III) have been completed, and two more are being planned on the main river and tributaries in the Omo Gibe river basin.

The investigated water bodies consist of several rivers, wetlands (Awetu, Haro, Boye), shallow lakes (Keribela and Bulo), a hydroelectric dam (Gilgel Gibe I) and irrigation canals (near Chebera Churchura National Park). Multiple sites were selected within each habitat type along a gradient of visible human disturbance (from pristine to heavily disturbed sites). We selected a total of 140 observation sites distributed over five water body types: (rivers/streams = 100 sites; wetlands = 20 sites; lakes = 10 sites; dams = 5 sites and irrigation canals = 5 sites).

2.2. Malacological survey

Snail sampling was conducted in each observation site for 30 min using a scoop net (Madsen et al., 1987; Opisa et al., 2011). Time was allotted proportionally to cover different meso-habitats such as open water and emergent vegetation. Within each site, all stones and vegetation were overturned, surfaces scraped, and the substrate was agitated by hand and snails were removed. The collected snails were transported to the Laboratory of the Department of Environmental Health Sciences and Technology, Jimma University for identification using taxonomic keys (Itagaki et al., 1975; Brown, 1994; Harrold and Guralnick, 2010).

2.3. Invertebrate predators and competitors sampling and identification

Macroinvertebrates were collected at each sampling station using a rectangular frame net (20 × 30 cm) with a mesh size of 300 μm. Each collection entailed a 10-min kick sampling over a distance of 10 m (DNRE, 1999; Gabriels et al., 2007). Time was allotted proportionally to cover different meso-habitats, including open water and emergent vegetation. The bottom sediment was disturbed by foot during sampling in order to dislodge and collect the benthic macroinvertebrates (Gabriels et al., 2007). Macroinvertebrates were sorted in the field and kept in vials containing 80% ethanol and labelled. Afterwards, macroinvertebrates were identified at the family level using a stereomicroscope (10 x magnifications) and the identification key of Bouchard (2004).

The identified macroinvertebrate taxa were categorized into one of the five functional feeding groups (FFG): gatherer-collectors (GC), filterer-collectors (FC), predator (P), scrapers (Sc), and shredders (Sh) (Tomanova et al., 2006). Scrapers were considered as competitors of freshwater snails. Macroinvertebrates belonging to Physidae (*Physa acuta*) were considered as competitors (De Kock and Wolmarans, 2007). The invertebrates, such as Dytiscidae beetles (Inoda et al., 2015), Belostomatidae bugs (Lodge et al., 1987; Younes et al., 2017), Odonates (Turner and Chislock, 2007), Psychodidae or drain fly larvae (El Bardicy et al., 2009) and Glossiphoniidae leeches (Brönmark and Malmqvist, 1986) were considered as snail predators.

2.4. Environmental variables

Multiple environmental variables were quantified at each surveyed site in each habitat type. Water depth and thickness of the sludge layer were measured at multiple locations ($n = 5$) at each observation site using a graduated stick. Water flow velocity was determined using a flow meter (Valeport BFM001channel). In addition, transparency was measured by a 30 cm diameter secchi disc. Conductivity, pH, daytime dissolved oxygen concentration, and water temperature were measured in the field using a multi-probe meter (HQ30d Single-Input Multi-Parameter Digital Meter, Hach). Turbidity was measured using Aqua-