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Description of the Agent-Based Model

The simulations for this work were performed by our agent-based simulation framework **QHG** ("Quantitative Humane Geophylogeny").

Environment

The agents in **QHG**, live and move on the nodes of a grid (for the simulations described here, we used a spherical grid based onthe subdivision of an icosahedron). Each node of the grid is assigned a set of environmental data pertainiing to its coordinates: geography (e.g. altitude, sealevels (REF:SEALEVEL), ice (REF:ICE), rivers), climate (temperature, precipitation), and vegetation (NPP (REF:NPP)). The carrying capacity of the cell is calulated from its NPP by means of a ramp function, given by the parameters $K_{min}, K_{max}, NPP_{min}, NPP_{max}$ as follows: If $NPP_{cur} < NPP_{min}$ then $K_{cur} = K_{min}$, if $NPP_{cur} > NPP_{max}$ then $K_{cur} = K_{max}$. Otherwise,

$$K_{cur} = K_{min} + (K_{max} - K_{min})(NPP_{cur} - NPP_{min})/(NPP_{max} - NPP_{min})$$

The environment data is updated every 1'000 steps (years) to reflect changes in climate, ice and sea-level

Seafaring, e.g. island-hopping to Australia, is realized by adding low-probability connections between two nodes separated by water

For a full description of the environmental variables cf. table 1.

Agents

At every time step an agent can perform different actions such as move, mate and bear offspring, and/or die. Movement is strongly influenced by the environment: the direction in which to move is a random choice weighted by altitude and carrying capacity of the neighboring nodes, and agents can not move to nodes under water or covered with ice.

Birth and death probabilities are calculated with linear functions leading to logistic growth:

$$p_{birth} = b_0 + (\theta - b_0)\frac{N}{K}, \qquad p_{death} = d_0 + (d_0 - \theta)\frac{N}{K},$$

where N is the number of agents, K is the local carrying capacity and θ is the turnover.

A description of the agents' configurable attributes can be found in table 2.

Table 1: Environmental Variables

Geography	
Latitude	latitude of node (radians)
Longitude	longitude of node (radians)
Altitude	altitude of node (meters)
Ice	ice (1) or no ice (0)
Water	presence of water (e.g. rivers)
Coastal	close to coast (1) or not (0)
Distances	distances to neighboring nodes
Area	area of region associated wit cell
Climate	
AnnualMeanTemp	current annual mean temperature in node
AnnualRainfall	current annual total rainfall in node
Vegetation	
NPP	Net Primary Production in node

Table 2: Agent Attributes

Birth and Death Probabilies	
Verhulst_b0	birth probability for $N = 0$
Verhulst_d0	death probability for $N = 0$
Verhulst_theta	turn-over rate
Fertility	
Fertility_interbirth	interbirth interval (years)
Fertility_max_age	maximum fertile age (years)
Fertility_min_age	minimum fertile age (years)
Old Age Cut-Off	
OAD_max_age	average age cut-off (years)
OAD_uncertainty	variance
NPP-Capacity Conversion	
NPPCap_K_max	K_{max} parameter for ramp function
NPPCap_K_min	K_{min} parameter for ramp function
NPPCap_NPP_max	NPP_{max} parameter for ramp function
NPPCap_NPP_min	NPP_{min} parameter for ramp function
NPPCap_water_factor	Capacity increase for presence of water
NPPCap_coastal_factor	Capacity increase for vicinity of coast
Move Probability	
WeightedMove_prob	move probability
Navigation	
Navigate_dist0	reference distance for crossing
Navigate_prob0	probability of crossing at reference distance
Navigate_decay	factor for exponential decay of probability with distance