This document is a description of the Shellfish Discard model, which is a modified version of the PaleoscapeABM. Following Grimm and colleagues' 2020 recommendations, this protocol includes the old ODD (M1) as well as the additions made to it (M2 and M3). The Shellfish Discard model is identified as M3.

Model Description

M1. This supplement is a description of our model following the Overview Design Details + Decision (ODD+D) Protocol initially described by Grimm et al. (2006; 2010) and later updated by Müller et al (2012) to incorporate human decision making.

This version of the model is used in Wren, C.D., Botha, S., De Vynck, J.C., Janssen, M.A., Hill, K., Shook, E., Harris, J., Wood, B.M., Venter, J., Franklin, J., Cowling, R.M., Fisher, E.C., Marean, C.W., 2020. The foraging potential of the Holocene Cape South Coast of South Africa without the Palaeo-Agulhas Plain. Quaternary Science Reviews. An earlier version of the model and this ODD was published in Wren, C.D., Atwater, C., Hill, K., Janssen, M.A., De Vynck, J.C., Marean, C.W., In Press. An agent-based approach to weighted decision making in the spatially and temporally variable South African Palaeoscape, in: Proceedings of the 44th Computer Applications and Quantitative Methods in Archaeology Conference (CAA 2016). Oslo, Norway.

The model is an adapted version of Janssen and Hill's (2014; 2016) model of the hunting system among Ache hunter-gatherers. Like Janssen and Hill, the current model is explicitly based on principles of Optimal Foraging Theory (for an alternative approach to blending OFT and ABM in a foraging model see Lake, 2000; 2001). The principal difference is that part of the present model is designed for plant and shellfish harvesting as well as hunting. This leads to a cascade of differences in how mobility decisions are made.

M2. This model is very similar to M1, but it adds projectile weapons that hunters can use when hunting preys. Those weapons are discarded on the landscape based on multiple probabilities, which produces a proxy archaeological record.

This version of the model is used in Gravel-Miguel et al. 2021.

M3. This model builds on M2 and adds a log of where and how food is processed over time, as well as provides more details on the camps' occupation of cells. The hunting and gathering dynamics are the same as M1 and M2.

This version of the model is used in Gravel-Miguel et al., in review.

Overview

Purpose and patterns

M1. The purpose of this model is to explore the dynamics of a human foraging system including the exploration of decision-making rules for camps and foragers. The landscape and food resources relate to the Middle Stone Age of coastal South Africa during an inter-glacial phase such as MIS 5e. Several specific research questions will be addressed with the model including maximum sustainable population size, proportion of diet from different resource types, and the spatial pattern of resource exploitation.

M2. This model aims to explore reasons behind the low frequency of projectile armatures recovered in Middle Stone Age archaeological sites. It is run within the PaleoscapeABM, to test how a realistic landscape affects the rate of points' discard and their geographical distribution.

M3. This model aims to explore where and how much shellfish is discarded at coastal and non-coastal locations by daily coastal foraging. We use this model's output to test the idea that we can confidently use the archaeological record to evaluate the importance of shellfish in prehistoric people's diets.

The recognition that aquatic adaptations likely had significant impacts on human evolution triggered an explosion of research on that topic. Recognizing coastal foraging in the past relies on the archaeological signature of that behavior. We use this model to explore why some coastal sites are very intensely occupied and see if it is due to the shellfish productivity of the coast.

Entities, state variables, and scales

M1. There are three types of entities in the model: habitat cells and two types of agents. Cells each represent one hectare of a foraging landscape. A georeferenced raster map of a section of South Africa is imported with values representing one of 14 terrestrial and coastal habitat types. Each cell is assigned associated variables relating to the caloric return rates of resources, time required for resource exploitation, current state of resource depletion, and time until replenishment based on its type. The total landscape is 421,200 hectares, with a portion of that representing inaccessible ocean. Two coastal sub-regions of 60,000 hectares each are used for testing purposes.

The return rates of coastal cells cycle between two values, one for regular and Neap tides which last for 10 days, and one for Spring tides which last 5 days. The return rates from plant foraging on terrestrial cells cycle seasonally. The spatial and temporal distribution of resource abundance over the landscape influences the pattern of mobility and the proportions of resources collected.

There are two types of agents, namely foragers and camps. Camps may move at the beginning of each day but have a limited mobility range. Camps make mobility decisions designed to maximize caloric returns for the group over a given number of days. Foragers are individual people, each a member of specific camp, who have a time budget in hours that are available each day. Foragers are divided into two types, hunters and gatherers, which follow different daily behaviours. Foragers make their own mobility and resource exploitations decisions designed to maximize their caloric returns during the time they have left in their day. Foragers' time budgets are reduced by fractions of hours while exploiting resources and while walking between cells. Camp and forager variables are used to keep track of time left and kilocalories collected.

M2-3. These models add the ***table*** and ***array*** extensions.

Tables 1 detail the global, agent, camp and patch variables used by those models, and mentions the model version they come from.

Table S1. List of variables used by the M2 and M3 versions.

Global variables	Description	Original to version
success-rate	Success rate of catching species	M1
prey_cal	Calories associated with hunted species	M1
file	Outputs the values of the discarded artifacts	M2
outputs?	Yes/No variable to output the discarded artifacts' values	M2
max-tick	Input variable to stop the model at a specific point	M2
point-recycling	Determines the ratio of embedded points that get reused	M2
point-hunting	Determines the ratio of hunts using a projectile	M2

archeo-patches	For outputs. Set of patches with discarded armatures	M2
site-patches	For outputs. Set of patches where a camp settled at some point	M2
habitat-hit-table	Table of the damage probabilities for each vegetation type	M2
point-table	Table recording which index is associated with which key (armature traits)	M2
onsiteProcessThreshold	If the gatherer's camp is further than this threshold, they process the shellfish where they collected it	M3
Hunter variables		
projectile	Records the edge damage on a projectile point	M2
campsite	Hunters remember where they come from to discard some of their point in camp	M1
body-part	Identifies the animal's body part hit by the projectile point	M2
onsiteProcessing?	Identifies if the shellfish collected is processed on site or at the camp	M3
Camp variables		
this-vt	Records the vegetation where the camp is	M3
Patches variables		
vt	Vegetation type	M1
site?	Records if a camp settled on it at some point	M2
assemblage	Records the values of the projectile points and knives when they are discarded	M2
total-kcal-shell	Records the kcal amount of shellfish brought back to the cell when it is occupied by a camp	M3
total-kcal-shell-process	Records the kcal amount of shellfish processed on cell when the camp is too far away	M3
total-kcal-shell-temp	Records kcal at each move (gets aggregated after each day). For easier output analysis	M3
total-kcal-plant	Records the kcal amount of plants brought back to the cell when it is occupied by a camp	M3
total-kcal-meat	Records the kcal amount of meat brought back to the cell when it is occupied by a camp	M3
previous-vt	Records the vegetation the camp was at before moving here	M3
dist-coast	Records the distance from the nearest coast	M3

Process overview and scheduling

M1-M3. Each time step represents one day (Figure S1). At the beginning of the day, cells and camps are updated. A 15-day tidal cycle advances by one day and if in the last 5 days of this, return rates are updated to reflect Spring tide resource availability even if it had been harvested during the previous 10 days. A seasonal plant cycle also adjusts plant harvesting return rates on days zero, 92, 183, and 273 of each 365-day year. Any cell that is completely depleted remains depleted until the start of the next season.

The camps assess their previous seven days of returns to see if they are still meeting the needed caloric threshold, and then if not they use a decision making algorithm to decide on their new location for the end of the day. If the selected cell is within range they will move to it, if it is beyond their range, they will move 75% of a day's walk in the direction of that cell.

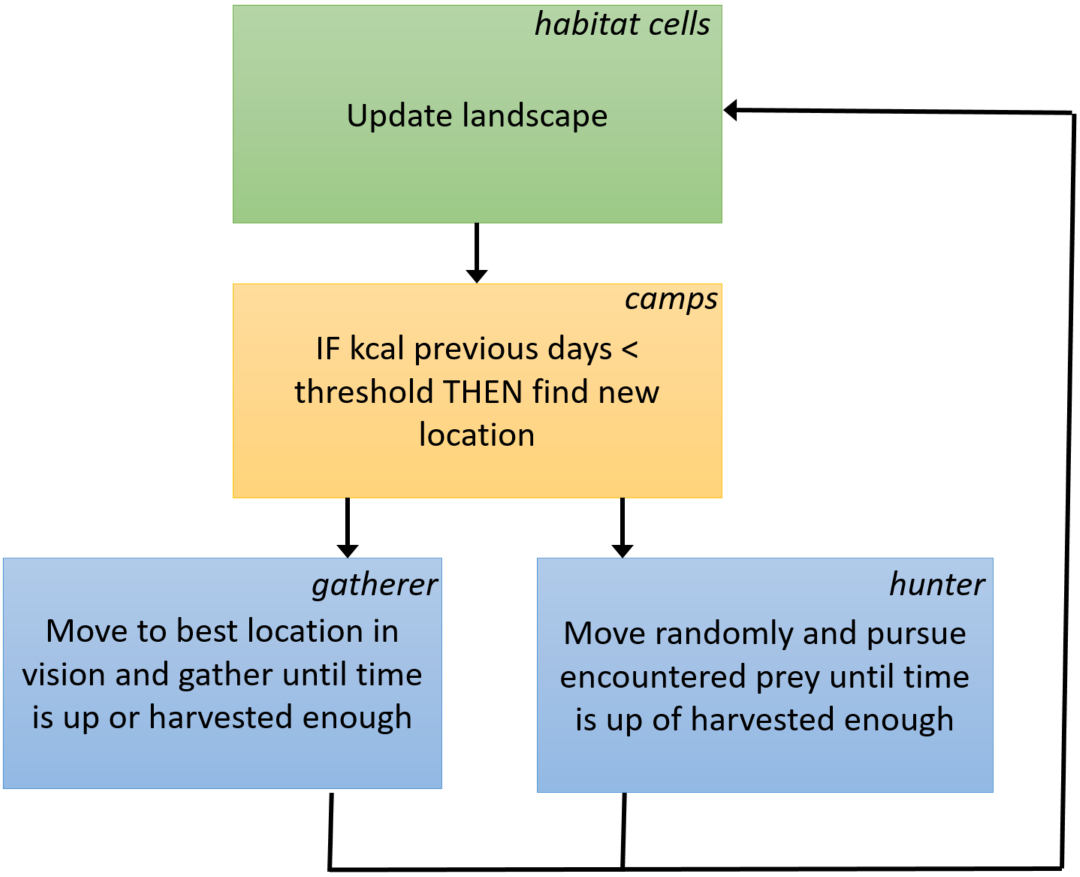

Fig. S1: Flow diagram of the basic components of the model.

Gatherers then begin a loop where they make mobility and gathering decisions with the time they have left in their day. During each iteration of the loop, foragers in random order estimate the time required to walk directly to their assigned camp. If their time left is greater, they make a mobility decision designed to maximize their daily caloric return after time lost to travel. After moving to a cell, they subtract their travel time. If the cell is an inland terrestrial cell, they harvest 20% of the resources of that cell, reflecting a linear 100m transect with 10 m visible on either side, and subtract the time expended in harvesting that resource. If the cell is coastal, they harvest 33% of the resources reflecting our experimental results demonstrating that three people can completely harvest a 100m strip of coastline in one pass (i.e., they each harvest 1/3). If a gatherer collects shellfish far away from their camp, they process their bounty on the spot, whereas if they are close enough from the camp, they accumulate what they collect for later processing. We assume that gatherers are able to observe a previous gatherer's transect and thus, the return rate of each cell remains constant until it is completely depleted (Fig. S2). If their travel time to camp is less than or equal to their time left, they move one cell towards their camp and do not harvest resources. Gatherers repeat this loop until they run out of foraging time. As harvest times are different per habitat, gatherers are asynchronous during each day. When all gatherers have used up their time and returned to camp average caloric returns are calculated by each camp.

Upon being fully harvested, terrestrial cells remain depleted until the start of a new season means new plants are available for harvest.

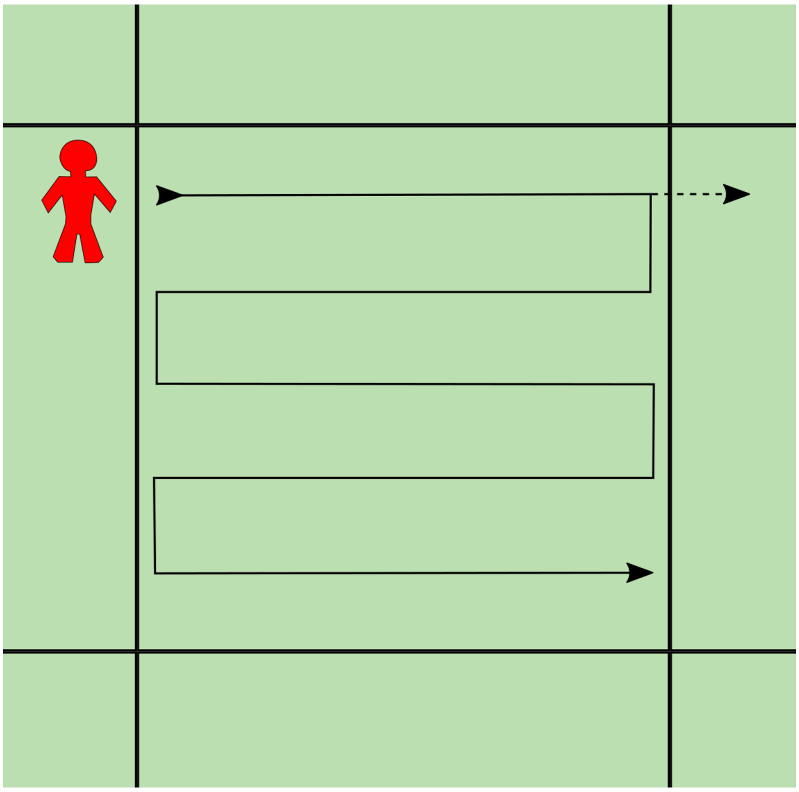

Fig. S2: Schematic of a gatherer agent systematically searching a single cell (solid arrow). By not overlapping the swaths (we assume they are able to recognize previous gatherers' harvesting activities) they maintain a constant return rate over five passes across the cell. Alternatively, the gatherer could decide after the first pass that the neighbouring cell has a higher return rate and move there (dashed arrow). That would leave the cell with the same return rate but 20% less harvestable time available to future gatherers until the start of the next season replenishes it completely.

Hunters begin their day by first picking one random hunter to select a good direction to begin walking. This decision ranks habitat types and tries to find the closest cell of that type within their radius of perception before moving on the check for the next best habitat type. Once a cell has been selected all hunters face that direction. The hunters then begin a loop where they, in randomized order, go through a series of tasks. First, they check the time left in their day against the travel time to their camp to see if they can continue hunting. If so, they adjust their direction by small left or right turns up to 15 degrees and move ahead to the next cell. In the new cell they check for game, pursue if available, and try to kill their prey. Each encounter can break or embed their weapon in the prey, in which case, the weapon is either discarded at the hunting site, reused, or brought back to be discarded at the camp at the end of the day. To finish the loop, their time left is adjusted for movements and pursuits and their daily calorie tally is updated. If their travel time to camp is less than or equal to their time left, they move one cell towards their camp and continue to check for game. Hunters each repeat this loop until they have run out of foraging time.

At the end of each day, the foraged and hunted resources get transported back to camp, where they are consumed by the whole group. The cell on which the camp stands record the amount of each food type collected by the camp's people as a proxy archaeological record of discarded refuses. Here, we assume that all the food gathered is consumed on the same day. This should be improved in future versions to allow transport of some leftover food when the camp moves the following day.

Design concepts

Theoretical and empirical background

The model design is based on Optimal Foraging Theory (OFT) and implemented according to OFT's definitions of habitats, patches, and prey (Stephens and Krebs, 1986; Janssen and Hill, 2014; 2016). Habitats are geographical regions with consistent characteristics such that a statistically constant pattern of food resources will be encountered. This leads to an average expected return rate for individuals searching that habitat. Patches are smaller units of habitat with a finite number of resources. On the time scale relevant to daily foraging, patches may be depleted as their return rate relative to other patches drops. In our model we assume a systematic search per patch, which means that the return rate per patch remains constant until that cell's resources have been completely exhausted at which point no other resources are available. While our field research has shown that certain plant resources do appear in concentrated clumps only a few meters across, at the scale of a hectare an individual forager has a reasonably consistent return rate given a habitat specific amount of searching and processing time.

For hunting, we use a prey-based model where individual species vary by probability of encounter calculated from estimates of density per habitat, probability of a successful kill if encountered, pursuit time needed, and the calories per animal retrieved if killed. The probabilities of breaking or embedding the weapon during the hunt are based on experimental data (Fischer et al. 1984; Schoville et al. 2010; Schoville and Otárola-Castillo 2014) and an estimate of different plants' coverage per biome based on botanical surveys of the region (Cowling et al., 1988; Rebelo et al., 1991; Mucina and Rutherford, 2006; Vlok et al., 2007; De Vynck et al., 2016c)

While the broad framework of the model is based on OFT and ethnographic observations, some model details have been incorporated that are specific to South Africa. We have worked closely with a variety of researchers with knowledge of South African archaeology, ethnography, ecology, botany, and marine biology to ensure the relevant factors are being considered in the decision-making framework of camps and foragers.

Individual Decision Making

Camps and gatherers make similar decisions designed to maximize their caloric return given their available time. In each case, the agent assesses individual patches with the assumption that its neighboring patches will be similar. That is, the return rate of a cell is multiplied by up to several days of foraging time even though that patch may be fully exploited in a fraction of that time. This is a reasonable, though not strictly accurate, heuristic that we use for computational efficiency. This heuristic introduces some uncertainty into the estimated return for camps and gatherers since the neighboring cells may not have the same return rate or may be depleted. We assume that camps and gatherers have prior experience in this landscape and thus know the condition of cells in the landscape. No partial memory aspect is included. See below for details.

Hunters have no expectation of a constant return rate and so are less able to precisely target cells. Instead, they maximize their time in the habitat types that are most likely to yield game while endeavoring to cover as much ground as possible within their time allowed.

As hunting returns are so much lower than plant and shellfish returns, camp movement does not factor in expected returns from hunting at all.

Gatherers who collect shellfish have to decide where they will process what they collect. This decision is based on how far they are from their camp, as complete shellfish can be heavy, and the shell itself has no caloric value. The distance threshold they use to make that decision can be changed by the user.

Learning

Camps and foragers do not learn or adapt their decision-making strategies in this version of the model.

Individual sensing

In their decision-making algorithm, camps use the daily foraging budget, distances to assessed cells, return rate of all cells, and whether a cell is depleted or not. In assessing the return rate, camps also understand the impact of the tidal cycles on return rates, and may forecast the high return Spring tides several days in advance. Although not explicitly modeled, camps are assumed to have global knowledge of current return rates through information exchange and experience. This assumption will be revisited in the future when larger spatial extents are modelled.

Gatherers keep track of how much time they have left in their day, the distance to their camp and how much time it will take to travel there, how many kilocalories they have collected so far that day, and the current return rate of patches within a specified radius and coastal patches even if they are outside of the radius.

Hunters keep track of their time, the distance and travel time to their camp, and how many kilocalories they have acquired. They do not sense whether or not a cell has been visited by a hunter recently. We simulate sensing of prey using probabilities of encountering specific species per habitat type.

Cells record if and how many times they are occupied by a camp, as well as how long each occupation lasts. They also take on different values of artefacts and ecofacts discarded by hunters and gatherers (sum of calories from plants, meat, and shellfish processed/eaten there). If shellfish processing occurred on the beach, the cell where it took place records the sum of calories associated with that process.

Individual prediction

Although not explicitly modeled, camps and foragers are assumed to have knowledge of the tidally affected coastal return rates through the observation of lunar phases. This also allows camps to anticipate the arrival of the Spring tide.

Interaction

Camp and gatherer interaction is largely indirect as their mobility decisions are affected by other gatherers' depletion of resources. Camps will not move to another camp's cell, but no additional buffer zone is considered. The location of other foragers are not factored into the mobility decisions of foragers. Hunters indirectly affect each other by game being scared away from cells (ie. encounter rates go to zero) that have been recently visited by another hunter.

Collectives

Camps consist of a number of hunters and gatherers who begin their day at the previous day's camp location, and end their day at the new camp site. Average caloric returns are calculated both for individual foragers as well as for camps under an assumption of food sharing. Foragers are assigned a camp on initialization of the model and do not change camps.

Heterogeneity (agents)

There is no heterogeneity in state variables or processes between agents of the same type (ie. camps, gatherers, and hunters).

Stochasticity

The order in which camps move, and foragers move and forage, is randomized. Since each forager is indirectly affected by the distribution of available resources, there is a minimal impact of this randomization. In certain rare circumstances, a forager is not able to move to or towards the cell they determine to have the highest net return due to an uninhabitable cell being in the way (such as an ocean). In these cases, foragers move to a randomly selected cell in their immediate 8-cell neighborhood to help them continue moving. Similarly, in very rare cases where camps have tried to move towards a target cell and are blocked by ocean, they will choose the highest current return rate cell at their mobility distance (even if that cell's return rate is zero) in order to keep moving.

Two specific values during hunting, pursuit time and probability of success, are pulled from a random normal distribution when needed based on parameter values for mean and standard deviation. For example, this means that the time it takes to pursue a specific prey will vary according to that distribution each time one is encountered. Hunters also turn a random left or right by a random number less than 15 degrees with each step to simulate fanning out through the local environment during hunting. If the cell selected during this fanning process is an invalid cell (i.e., ocean or off the map), they choose a random neighboring cell instead.

When hunting, a probability defines where the weapon will hit the prey or if it will hit a plant as it misses the prey. In turn, those locations are linked to their own probabilities that the weapon will break or get embedded in the flesh of the prey. Embedded but not broken weapons can be reused, based on a probability set by the user. Embedded points that are not reused can be transported back to be discarded at the camp based on a probability of transport linked to the body part that was hit. These probabilities are all based on experimental data.

Observation

Output variables will vary based on the specific research question being evaluated. The model accounts for time spent and calories collected per forager, per camp, and per cell. These may then be aggregated into average caloric returns, days without food, and proportion of different foods (e.g. plant vs shellfish vs mammal, or per habitat type). Mobility characteristics such as frequency of camp movement, distance traveled per camp or forager, and time spent in proximity to the coast may also be measured.

M2. The model outputs the geographical distribution of discarded projectile weapons, as well as all cells that were occupied by a camp at least once during the run.

M3. The model outputs the food discard information of all cells where something was discarded, the identity of all cells that were occupied by a camp at least once during the run as well as the length of each of their occupation, and the identity of all cells where a weapon was discarded as well as the number of weapons it holds.

Details

Implementation details

The model is implemented in Netlogo 6.2.0 and may be downloaded from the author's comses.net account.

Initialization

During the setup procedure, variable settings are read from the user interface to determine which landscape will be used, and how many camps, gatherers, and hunters there will be. If there are no hunters, the model will initiate, but will not run. Setup assigns gathering return rates and times, prey encounter rates to all cells based on their habitat type. Global hunting values including kilocalories, pursuit time, and success rates per species are established as means and standard deviations. Several other accounting variables are set to zero such as calories collected, and distance traveled. Additionally, if a number of days of foresight are being used, a temporal multiplier is calculated using the hyperbolic time-discounting formula for use in camp mobility decisions. All terrestrial cells are set to be full of resources which usually results in the first year of the simulation being a bit more productive than subsequent years. Tables of probabilities are created, including one for breakage per vegetation and plant hit, as well as one that identifies the item number related to each weapon's data. Each hunter is given one projectile weapon, which is a list of 6 values.

Input data

Habitat data

The habitat map consists of two data sources. Vector GIS layers of terrestrial habitats were taken from a digital appendix to Mucina and Rutherford (2006) and converted into raster format at one hectare resolution. This pre-agricultural Holocene distribution is used as a proxy for the interglacial high sea-level phases. Climate and vegetation simulations are underway to model habitats for glacial climate phases.

De Vynck et al. (2016a) walked the coastline of the study region in order to sample underlying geology. They found that shellfish return rates varied consistently with underlying geology and used this as the basis for differentiating returns rates among other variables. We used GPS data from this coastline survey and combined it with the terrestrial data to create a raster model of all habitats, terrestrial and coastal, at 1 hectare resolution divided into 14 distinct habitat types.

Details of field experiments in coastal shellfish foraging are documented in De Vynck et al. (2016a), and in plant foraging in De Vynck et al. (2016b;c) with some additional caloric data from Singels et al. (2016a;b) and Botha et al. (in prep). For currently used parameter values for all habitats across seasons and tidal cycles, see the main text of the article.

Fig S3: Example screenshot of the NetLogo raster landscape where habitats are colour scaled according to their caloric return rates (lighter shades = higher returns). This view is during a neap tide when coastal returns rates are low (black). In the current paper, a smaller spatial extent map is used which is centered around Pinnacle Point (inset square).

Parameter values

Other parameter values are either estimated from ethnographic sources or are actively being derived from fieldwork in South Africa. For example, walking speeds through different habitats are being recorded during the process of plant surveying. The amount of harvesting time available to foragers is estimated from ethnographic sources including Hill's work with Ache foragers of Paraguay (Janssen and Hill, 2014; 2016) and this is consistent with Hadza foragers in nearby Tanzania (Hawkes et al., 1997). One exception to these two sources is the camp mobility distance which is calculated as a percentage of a day's walk (Eq. S3).

Table S2: Default values and ranges for other parameters used in the model.

Parameter	**Description**	**Default value**	**Value range**
nrforagers	Number of foragers overall	200	10-400
nrcamps	Number of camps	10	5-20
Hunter-percent	% of foragers that are hunters	0.5	0-1
Walk-speed (km/hr)	Speed foragers will walk when not harvesting resources	2	1-5
Camp-mobility	Maximum distance a camp may travel per day	Eq. S3	n/a
Vision-forager (cells)	Distance in hectare cells that a forager sees when making a mobility choice	20	5-75
Global-knowledge?	Switch to determine if camps have knowledge of all cells, or only ones within the vision-camp radius	True	True/False
Spatial-foresight	Switch to determine if camps move randomly	True	True/False

	or make decisions		
Forager-movement?	Switch to determine if foragers move randomly or make decisions	True	True/False
Map-zone	Selects the full region or different sub-zones of the study area	z2 (Pinnacle Point)	z1 (Vleesbaai), z2 (Pinnacle Point), or full
Max-kcal-collect (kcal)	Maximum kcal a gatherer will collect in a day	10000	2000-10000
Camp-move-threshold (kcal/forager)	Minimum number of kcal/forager required before moving to new camp location	2000	0-5000
Days-of-foresight	Number of days camps will forecast return rates over	5	1-5
Discount-rate	*k* in Eq. S2. Controls the steepness of the fall-off in value with days of foresight	0.1	0.01, 0.1, 0.25
Max-tick	The time step at which the model stops	365	Unlimited
Outputs?	Determines if a CSV is produced	OFF	ON/OFF
Point-recycling	The percentage of embedded non-broken points that are reused	25%	0-100%
Point-hunting-rate	The percentage of hunts that use a projectile weapon	30%	0-100%
onSiteProcessThreshold	The distance threshold (km) that determines if shellfish are processed on the beach or in camps	5	0-50

For specific density and mammal hunting parameter values, please see Wren et al. 2020.

Submodels

Here we discuss the details of the forager and camp mobility decisions, the tidal cycle, and include our implementation of forecasting return rates over several days.

Camp decision algorithm

Camps assess all cells for gathering return rates then select the cell which has the maximum net caloric return determined by Eq. S1. If the cell is a coastal cell, an adjustment is made as the return rate is different for the two hours of lowest tide at the beginning of the day versus the remaining hours. In this case, the first two hours (minus travel time) are multiplied by the low tide return rate, followed by the remaining hours multiplied by a randomly selected adjacent terrestrial cell. We distinguish options to calculate the expected net caloric return, namely for the hunter and for the gatherer.

Available time may also be multiplied over a specified number of days of foresight to reflect future planning. In these cases, the caloric returns of future days are discounted according to a hyperbolic time discounting formula (Eq. S2). The discount rate parameter (*k*) determines the fall-off rate of value with number of days in the future.

*Net caloric return = ((discounted_return) * hours_per_day – (distance / camp_mobility * hours_per_day * current_return_rate)* (S1)

where *camp_mobility* is defined by Eq. S3 and *discounted_return* represents the summed returns over a defined number of days of foresight (d_f)

(S2)

$$\text{discounted\_return} = \sum_{D=0}^{d_f} \frac{A}{(1+kD)}$$

where *A* is the caloric return after a delay of *D* (in days), and *k* is the discount rate parameter and

*camp_moblility = daily_time_budget * walk_speed * 0.75 * 10* (S3)

which assumes that the maximum distance the camp can move in one day is 75% of a day's constant walking. We also multiply by 10 to convert from km to the hectare scale of the map.

Gatherer decision algorithm

Like camps, gatherers assess cells (within a visual range) and select the cell with the maximum net caloric return (Eq. S4). The algorithm similarly subtracts travel time and adjusts for the low and high tides. The only difference is that gatherers' available time is based on how much time they have left in their day and no future days are accounted for.

*Net_caloric_return = current_return_rate * (time_left – (time_walk_cell * distance))* (S4)

where *time_walk_cell* is the time in hours needed to walk 100 m as calculated from the *walk_speed*.

When collecting shellfish, gatherers will process them where they stand if the distance from their camp is above the *onsiteProcessThreshold*. The cells where the processing occurs (on gathering site or at camp) records the quantity of shellfish processed there.

Lunar tidal cycle and forecasting

The ~15-day lunar cycle has a dramatic effect on the return rates of inter-tidal shellfish availability such that only around the Spring tides, are foragers able to get a sufficiently high caloric return to justify the risk of acquiring the resource. De Vynck et al. (2016a) demonstrated that under the best combination of conditions return rates could exceed 3000 kcal/hr. However, waves along this coastline can be powerful and could sweep foragers off slippery rocks into the ocean making the lower return rates during non-Spring tides much less attractive. These intertidal foraging experiments during different parts of the lunar cycle and under a variety of weather and forager characteristics have led us to determine that only 5 days out of each 15-day cycle have high return rates, with the other 10 being much lower.

A tidal-cycle procedure updates the return rates of coastal cells at the beginning of each model day. If a coastal cell is fully depleted during a non-Spring day, it will be replenished to the full return rate on the first Spring tide day to reflect foraging lower in the inter-tidal zone. If a cell is fully depleted during a Spring tide day, that cell will not be replenished until the beginning of the next Spring tide (i.e. will remain at zero return rate during the 10 days of non-Spring tides).

To allow for forecasting return rates over a number of days of foresight, a list of return rates over the 15-day cycle is first established based on whether or not the cell is currently depleted. The position in the list is determined by where on the tidal cycle the current day rests, and then a sublist of based on the number of days of foresight under consideration is extracted. The discounted return formula (eq. S1) is then applied but using the different return rates for Spring tides and non-Spring tides instead of a fixed return rate.

Hunting decisions

One agent selects from the best available hunting grounds the cell that is nearest as the target. All agents face that target, then fan out with small randomized left or right turns by a randomized number of degrees below 15. They continue to move as long there is time for hunting. Each cell the agent passes, the agent will check whether it has encountered a species.

If a species is encountered, the agent spends an amount of time to pursuit the species and is successful with capturing the animal with a certain success rate. The hunter chooses to hunt with a projectile weapon with *projectile-point-rate* probability. Pursuit time and probability of success are drawn randomly from a normal distribution determined by a mean and standard deviation. If the animal is captured, encounter rates for that species drop to zero for a seven-day period.

When the hunter uses a projectile, several probabilities are used to determine if the weapon will break, get embedded into the prey, as well as where it will be discarded. The probabilities of breakage in each environment depends on the vegetation where the hunt took place. Table S3 shows the plants' rate for each biome. 60% of weapons break when hitting a tree, 14% break when hitting grass, and 33% break when hitting a shrub (Fischer et al. 1984). In rocky environments (TMS), we assume that a missed throw will hit a rock, which breaks weapons 70% of the time.

Table S3. Vegetation cover of each biome with plants.

Biome	**Tree**	**Bush**	**Grass**	**Reeds**
Freshwater wetland	0.00	0.30	0.30	0.40
Alluvial vegetation	0.50	0.15	0.25	0.10
Strandveld	0.10	0.80	0.10	0.00
Saline vegetation	0.00	1.00	0.00	0.00
Renosterveld	0.00	0.80	0.20	0.00
Sand Fynbos	0.00	0.95	0.05	0.00
Albany Thicket	0.50	0.45	0.05	0.00
Limestone Fynbos	0.00	0.95	0.05	0.00

When the hit is successful, the weapon will hit one part of the prey body. Assuming that the hunter aims for the kill zone (heart), here are the probabilities of hitting all body parts, based on Schoville and Otárola-Castillo (2010)'s experiments. Each body part is associated with a probability of breaking or embedding the projectile armature.

Table S4. Probabilities of hitting each body part when aiming for the kill zone, and each part's breakage and embedding probabilities

Body part	**P hit (%)**	**P breakage (%)**	**P Embedding**
Body cavity	45	13.7	12.7
Femur	3	19.5	19.6

Humerus	3	17.2	4.5
Pelvis	3	38.6	15.8
Radius/ulna	4	65.6	2.8
Rib cage	15	11.1	12.7
Scapula	7	18.8	6.1
Vertebrae	14	18.6	13.2
Kill zone	6	17.6	10

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