# About CABM

CABM expresses a fish stock as a collection of spatially referenced agents within a discrete spatial domain withcells. Agents in spatial cell are denoted by the set , where is the number of agents in cell . An individual agent denoted by is also a set where each element in is an agent attribute outlined in Table.

Table 1: Attributes recorded for all agents, where .

|  |  |
| --- | --- |
| Index | Description |
|  | Age (integer) |
|  | Length (continuous) |
|  | Length bin (integer) |
|  | Maturity (Boolean) |
|  | Sex (Boolean) |
|  | Weight (continuous) |
|  | Scalar = number of individuals |
|  | Natural mortality |
|  | Von Bertalanffy growth parameter |
|  | Natal cell (birth cell) |
|  | Current cell |
|  | Cartesian coordinate within the spatial domain |

Agent dynamics are functions responsible for modifying agents (growth), moving agents, creating agents (recruitment) and deleting agents (mortality). The inputs for these functions use both agent specific attributes (Table) and assumed parameter values. Agent dynamics are predominately stochastic, where agent actions are based on a randomly generated realisation from a random variable. For example, a dynamic that results in a binary outcome for an agent (i.e., an agent getting caught by a fishing interaction or an agent maturing) can be expressed by the Bernoulli random variable , where is the probability of an event occurring

Agent dynamics generally iterate over a collection of agents and for each agent, they apply an outcome based on a realisation from a random variable. The following example demonstrates the notation used when describing how an agent dynamic applies an event to all agents in cell

where denotes the ith agents () specific probability of the event occurring. This is the result of the function which uses agent attributes and parameters .

The agent dynamics described in the following sections define as a function of specific agent attributes (Table ). In all descriptions in is replaced with the specific agent attribute. For example, if was a function of an agent's length (), it would be defined as,

Agent Dynamics

## Ageing

Ageing is an implicit process in the model, each agent that is created or recruited gets assigned a birth year. The age of an agent is a calculation

Age = Current year – birth year

thus there is no explicit ageing dynamic occurs in CABM. Note that if age > max age the max age is returned. This is done for a coding convivence, often C++ objects are indexed by age and so age-specific containers will have a plus group.

This results in every agent automatically ageing by one at the end of the year, or you could think of ageing an agent at the very beginning of the year (tomayto, tomahto), just be aware that you don't have control over this process. Another consideration is that growth (link to section) is not directly tied with ageing, that is, an agent that ages one year does not also get a years’ worth of growth. This in unlike most partition-based models that will have an implicit assumption of growth with ageing. Although if one puts a growth process at the beginning or end of an annual cycle this can be achieved. This is just a side note to keep in mind when trying to align CABM to be consistent with other estimation models.

## Maturity

The process of converting an agent from immature to mature, only should be used if you have mature-biomass derived quantity (Section). This process changes the internal state of an agent i.e., no material change happens to the agent except . This could be useful down the track if we have dynamics that only occur to mature agents and so this internal flag can be checked against for use in a different algorithm. Maturity is applied using the ogive defined in the subcommand *maturity\_ogive\_label* in the @model block, and is applied for a single agent (assuming the agent is not already mature)

Maturity is applied to agents in cell at time-step following

where, is the probability of an immature agent at age becoming a mature agent, defined by the selectivity . Currently maturity can only be an age-based process, although this is not difficult to make a length based probability statement if someone in the future wanted this. A note about creating a logistic based maturity schedule. We recommend users use the selectivity *logistic\_producing* (Section) or a similar style of selectivity. The results will not be as expected if you use a normal logistic selectivity. This is because this is only applied to the non-mature agents and so the selectivity needs more thought than other situations.

An alternative way and perhaps more efficient method for capturing a snap shot of the mature biomass or abundance of all individuals in the population is by using the generic biomass or abundance derived quantities (Section ). Where we calculate mature agents at the time of the derived quantity, rather than having an explicit process that allows users to separate the maturation process from the summarising of abundance of biomass of the mature component.

## Recruitment

Recruitment is the process where new agents are created in the system. It is also the process that defines stock structure in the model. Stocks are not an explicit attribute of CABM so consideration on this process is important. How the stock is defined using the recruitment dynamic surrounds where we calculate Spawning Stock Biomass (SSB) and where the resulting recruits are first seeded. This means that for all recruitment types you will need to specify a or parameter and an associated derived quantity that defines the spatial resolution of the stock (SSB) for that event.

We have taken the parametrisation akin to that is a population-based formula (Mace & Doonan, 1988). There is scope to make this a “purer” agent-based model where we look at probability of finding a mate and etc, but for now this is all we have.

where is the compensation parameter known as the steepness parameter that represents the number of agents when the stock SSB is at 20% of , is the year class strength parameter also termed the stock recruitment residual that accounts for any deviation of the deterministic Beverton Holt relationship due to things like predation, environment etc. If there are multiple spatial cells that are associated with a recruitment event, then the allocation to a single cell is a simple multiplication with a proportion e.g.

where is the resulting agents in cell with proportion there is no stochastic behaviour in this process unlike other processes.

## Fishing

Fishing processes remove agents from the model. There are a range of different mortality processes, the most common are Baranov and exploitation

## References

Mace, P. M., & Doonan, I. J. (1988). *A generalised bioeconomic simulation model for fish population dynamics*.