Marine Mammal Movement and Behavior (3MB)

v10.14

A Component of the Effects of Sound on the Marine Environment (ESME) Distributed Model

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Marine Mammal Movement and Behavior (3MB)

This document describes the operation of the **Marine Mammal Movement and Behavior (3MB)** computer program, which provides a means for simulating the movement and behavior of marine mammals in the ocean. This program is currently implemented in the Effects of Sound on the Marine Environment (ESME) simulation package and is used to couple simulations of marine mammal movement and behavior with simulated acoustic exposures. The 3MB program provides a flexible framework within which the user may specify the behavior of a particular marine mammal species based upon current available knowledge of that speciesô oceanic behavior. The specified behavior may then be used to simulate animals (**animats**) within a synthetic environment.

Two mechanisms are provided to the user in creating a simulation of marine mammal movement and behavior: vector models and alternative distribution models. Vector models allow for more detailed control over simulations and are appropriate when detailed knowledge of a speciesô movement and behavior exists. The alternative distribution models allow a more ñapproximateò simulation framework, requiring less detailed information and less time for construction. Alternative distribution models are provided to allow the simulation of species for which summary information is available in the literature or when detailed knowledge of oceanic behavior does not exist. Under some circumstances, even detailed behavioral information may be suitably approximated with the alternative models, thus simplifying the creation of a simulated species. Mixtures of vector and alternative distribution models are permitted within 3MB.

Overview

The **3MB** simulator works on the principle of clustering components of movement and behavior into a species definition and then applying that definition as a control mechanism for animats within a simulated oceanic environment. The species definition is created in the **Species Builder**; the definition of the species is the sole responsibility of the user and a species definition need not encompass that species movement and behavior across all possible spatial and temporal scales. Multiple definitions may be developed for a species specific to a particular region and time, e.g. a species definition may be developed for grey whales (*Eschrichtius robustus*) foraging in the Bering Sea during the summer and another may be developed for grey whales in the Bay of La Paz during the winter. The level of encapsulated detail is at the discretion of the user and dependent upon the temporal and spatial framework of the simulation. The **3MB** module should ***not*** be used in simulations spanning long time periods (e.g., many weeks, months or years) as it does not currently incorporate relationships between behavior, energetics, and the environment that would be necessary for such simulations.

Definitions of species behavior include descriptions of movement in the horizontal plane (e.g., direction of movement and rate of horizontal travel), vertical plane (e.g., diving depth, rates of ascent/descent), surface intervals, and behavioral states, which can affect the parameter values for movement (Houser, 2006). Behavioral states can be ignored if deemed unnecessary to the simulation but all other components are necessary for proper simulation (i.e. at least one behavior state must be completely defined). If detailed information exists, demonstrating differences in movement that correspond to changing behavioral states, it may be incorporated into a vector model thus providing a more realistic forecast of species activity. Additionally, criteria for an aversive response to an acoustic exposure can be included in the species definition.

Once created, species definitions are used to control a user-defined number of individuals. Movement and behavior is stochastic but bounded by probabilities and relationships between variables as described in the species definition. The location at the start of a simulation can be randomized, pseudo-randomized, or user-defined thus allowing expert knowledge of species distribution to be incorporated. Behavioral parameters and acoustic exposure parameters can be logged for each individual providing a record of movement, behavior and acoustic exposure throughout the simulation period. This latter function is essential for estimating animal activity during exposure simulations and compiling information across multiple simulations for use in later statistical analyses.

The following sections will describe in detail the steps necessary to create and implement a species definition.

Creating Species Definitions with the Species Builder

The **Species Builder** provides a graphical user interface (GUI) for the creation of species definitions. The front panel of the **Species Builder** (Fig. 1) allows the user to establish the number of behavioral states that define the species, test the diving and horizontal travel behavior associated with each state, and test the transition between behavioral states. In addition, the definition can be assigned to a ñspeciesò under the *Species Membership* menu. This menu contains all currently known species of marine mammal. Assignment of a species name to the definition permits criteria and thresholds for acoustic harassment to be included in the species definition. This information is called upon in **3MB** during scenarios involving acoustic sources and is used to create the ñtakeò file for the scenario. ***This feature is a hold-over from a prior version of 3MB. Criteria and thresholds are regularly reviewed and new thresholds may be periodically implemented by regulatory agencies. For this reason, it is not recommended that this function be used for estimating harassment under regulatory guidelines. Users should confer with their respective regulatory agency prior to implementing thresholds for estimating takes using 3MB. Such analyses can be performed in post-processing.***

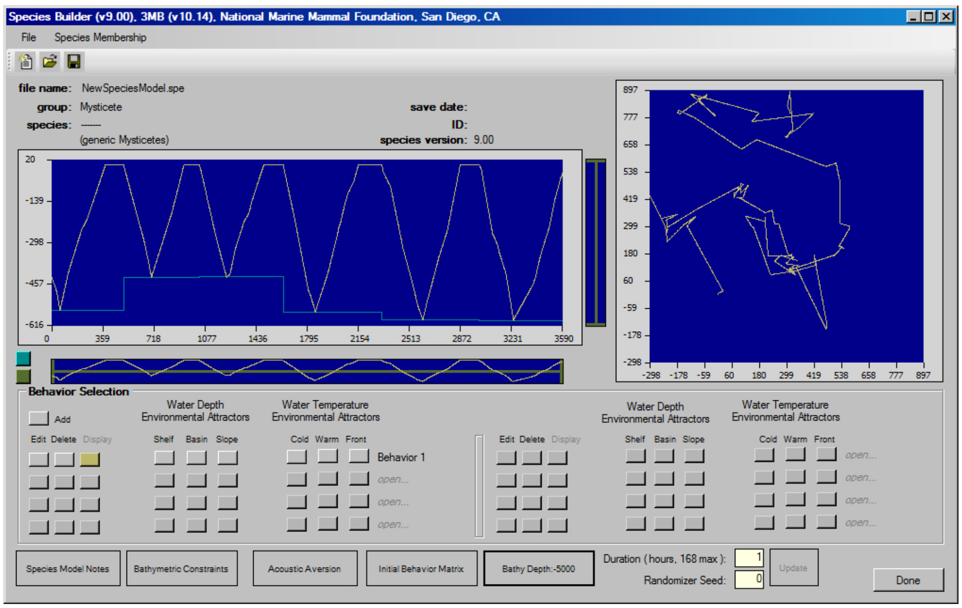


Figure 1. Front panel of the Species Builder.

Behavior Selection Sub-Panel

The Behavior Selection sub-panel allows the number of behavior states for the species definition to be defined. Behavioral states can be added by clicking the ñAddò button. Each behavior is initialized with the same default value and the behavior must be edited to provide a different behavioral state. If a behavioral state is no longer desired, it can be deleted. (Note* - The ñWater Temperature Environmental Attractorsò is a placeholder for future enhancements. It is not functional at this time.)

Once the number of behavioral states required for defining a species has been determined, each behavioral state must then be defined and the sub-models associated with each behavioral state parameterized. To begin, single click the ñEditò button next to the behavioral state to be edited. This will launch the Behavior Model panel.

Behavior Model Panel

The Behavior Model panel (Fig. 2) provides the interface for defining all of the behaviors that compose a behavioral state. The default values for all of the behavior sub-models defining a behavioral state are shown in the panel below. The name of the behavioral state can be changed by left-clicking on the top box of the sub-panel.

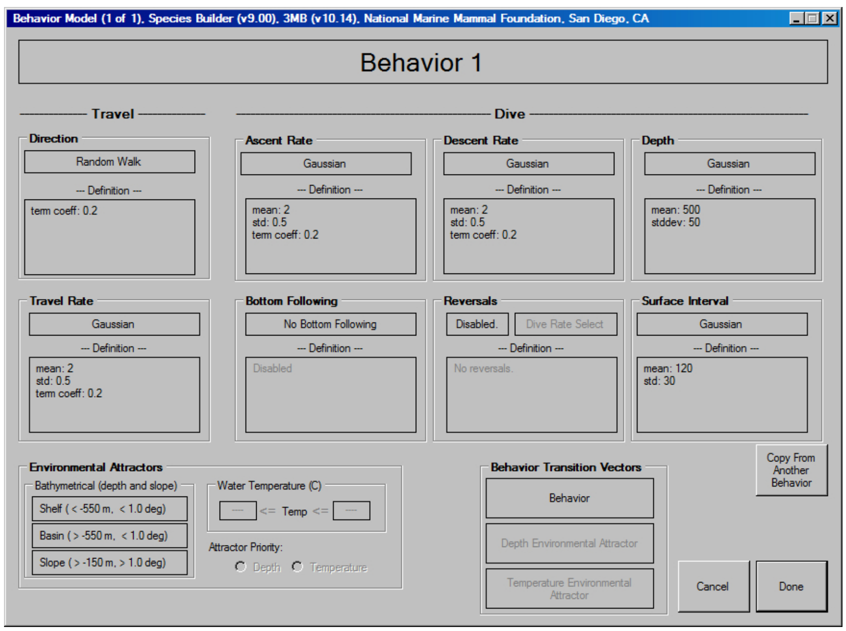


Figure 2. The Behavior Model Panel.

Behavior sub-models are grouped as either ñTravelò or ñDive;ò the former encompasses sub-models that define movement in the horizontal plane and the latter for movement in the vertical plane. These sub-models are briefly described below.

<u>*Travel sub-models:*</u>
Direction ï determines the animatõs choice of direction in the horizontal plane. Movement may range from strongly biased, as in a migrating marine mammal, to undirected, as may occur in some instances of feeding or play.

Travel Rate ï defines the rate of travel of an animat in the horizontal plane. When combined with vertical speed and dive depth, the dive profile of the animat is produced.

Dive sub-models:

Ascent Rate ï defines the rate of travel of an animat in the vertical plane during the ascent portion of a dive.

Descent Rate ï defines the rate of travel of an animat in the vertical plane during the descent portion of a dive.

Depth ï defines the maximum depth to which an animat will dive.

Bottom Following ï determines whether an animat returns to the surface once reaching the ocean floor, or whether it follows the contours of the bathymetry.

Reversals ï determines whether multiple vertical excursions occur once reaching the maximum dive depth. This behavior is used to emulate the foraging behavior of some marine mammal species at depth.

Surface Interval ï determines the amount of time spent at the surface prior to performing another dive.

Building Sub-Models

Each sub-model is defined by a probability distribution from which random values are sampled. The probability distribution defining each sub-model can be selected by left clicking on the box immediately beneath the sub-model name. Successive clicks will cycle through the distributions available. Typical distribution options are *Vector, Gaussian* and *Uniform*. Some sub-models will have additional options available to the user.

Associated with each parameter is a termination function that determines when the value of the parameter changes. When the amount of time a parameter value has been used for control of an animat exceeds the time allotted by the termination function, a new value is assigned to the parameter by randomly sampling from the appropriate probability distribution. A new random number between 0 and 1 is then obtained and is compared to the termination function on each update of the animat to determine if the parameter value should be changed. The termination function is

$$P_{term} = c * \log(t_e)$$

Where P_{term} is the probability of termination, c is the termination coefficient, and t_e is the time elapsed since the last transition in seconds. The termination function is very sensitive to the selection of the termination coefficientôs value and appropriate values should be explored by the user prior to assignment of the value within the sub-model.

Distribution options:

Gaussian ï the user must set the mean and standard deviation of the Gaussian distribution from which random values are drawn, as well as the termination coefficient.

Uniform ï the user must set the maximum and minimum of the Uniform distribution from which random values are drawn, as well as the termination coefficient**.**

Vector ï the user has the greatest flexibility in defining the shape of the probability distribution with this option (Fig. 3). The user creates an array of probabilities and sets a ñstep size.ò The probability distribution must be structured as a series of <u>cumulative transition probabilities</u> separated by a space and beginning with 0. For real valued movement parameters, each successive element of the array corresponds to an increase, or step size, in the parameter value (e.g., below, the step size for ascent rate is set to 0.5 m/s).

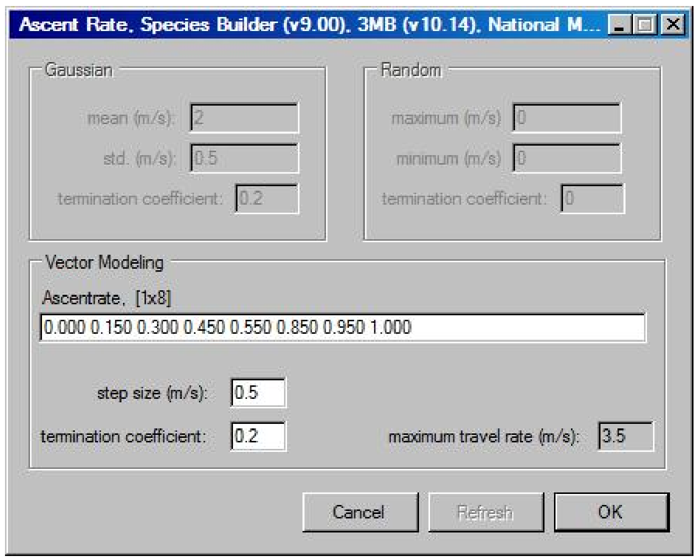


Figure 3. The Vector Sub-Panel.

Upon updating, the value that is assigned to the parameter is determined as a random sample between the upper and lower bounds of the occupied column. For example, for a step size of 0.5 m/s, the value for the ascent rate when the random number drawn at update is between 0.0 and 0.15 would be randomly selected from a uniform distribution with minimum and maximum bounds of 0.0 and 0.5 m/s, respectively. If the random number drawn was between 0.3 and 0.45, the bounds of the uniform distribution from which the new parameter value is determined would be 1.0ï 1.5 m/s. As with the previously described distributions, the user must also set a termination coefficient.

<u>*Travel sub-model – a special case:*</u>
Special alternative distribution models are provided for determining the bearing of an animat. These include algorithms for the random walk (RW), correlated random walk (CRW), and correlated random walk with directional bias (CRW_{db}). Also included in the ñTravelò sub-model are various vector options.

RW and CRW - The RW model is familiar to most readers and no further explanation is provided here. The CRW is similar to the RW model except that a user-defined dependence upon the previous direction of travel, termed the *perturbation value*, is instituted. The CRW model assumes that the bearing of an animat at the time the current direction of travel is terminated is the mean value of a Gaussian distribution describing the probability of choosing the next bearing of travel. The perturbation value is equivalent to the standard deviation describing the spread of the probability function around this mean. Greater perturbation values result in a broader spread around the mean and provide a greater probability of making larger turns off of the current path. Conversely, smaller perturbation values result in a greater probability of smaller turns and directional travel that has a greater probability of being closer to that of the previous bearing. The CRW model is useful for animals that engage in movement that does not demonstrate irregular or radical variations.

CRW_{db} - The $\mathrm{CRW_{db}}$ is similar to the CRW in that a perturbation value is defined. In addition, a direction of bias (D), bias factor (β), and arc-value (A_v) must also be defined. The direction of bias is an absolute direction, relative to true North, to which the animat shows an affinity for travel. Values for D fall within the range of 0ï 360°. The bias factor is used in conjunction with A_v to determine the increased probability of turning in the direction (left or right) closest to D. Values for β may range from 0.01ï 0.5, whereas values of A_v may vary from 1ï 180°. The bias factor is a value added to the probability of turning either right or left, whichever is closer to bringing the animat toward D. It is an additive bias that increases the probability of turning toward D. Bias accumulation is a function of the number of A_v steps away from D.

For example, an animat can have a user-defined direction of bias to true North (D=0). In this case, the bias term for the animat is β=0.01 and the arc-value is set to A_v=40. The current bearing of the animat is 45° (Fig. 4). An A_v is centered on D such that there is an arc of equal angular value to either side of D (the animat is used as the origin of the circle). In this case, an arc of 40° is centered on true north, or D=0, such that there is a 20° arc to both the right and left of D. This is the first increment of the arc value, or A_{v1}. The arc is incremented by another arc value, A_{v2}, such that the arc is now 40 to each side of D. Another addition of the arc value produces an arc of 60° to the left and right of D. It is within this increment of the A_v that the bearing of the animat exists.

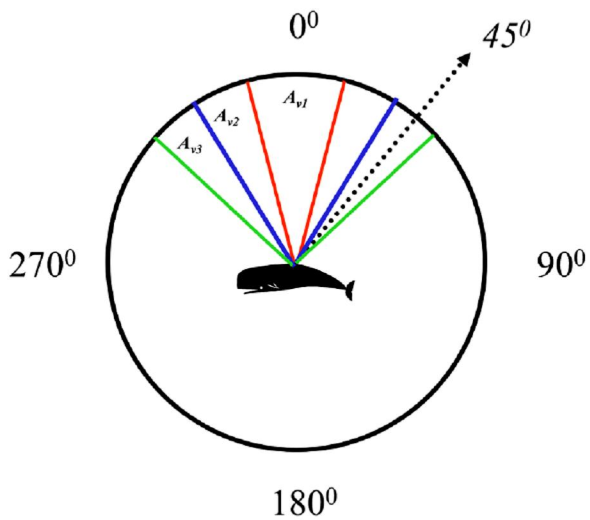


Figure 4. Demonstration of how the correlated random walk with directional bias is implemented.

Now the probability of turning toward can be determined as

$$P_D=0.5 + (N*\beta)$$

where P_D is the probability of turning toward D and N is the i-th increment in A_v. In the example case, the animat is traveling at a bearing of 45°, which is within the third increment of A_v.
Since β =0.01, then

$$P_D=0.5+(3*0.01)$$

$$P_D=0.53$$

there is a 0.53 probability that the animat will turn in the closest direction to D.

Vector - The vector option allows the user to define the probability that a particular direction will be traveled when the Travel sub-model is updated. The step-size of the array is in degrees and is determined by dividing 360° by the length of the array, e.g. an array length of 18 corresponds to a step-size of 20°. *The creation of the array for the Travel sub-model differs from that of the other vector options. The array values are simple probabilities of turning, not a cumulative probability. This particular option was designed this way to permit biases in direction change as a function of the current direction of travel.* The vector is entered in the ñProbability of Turningò box. Values should be separated by spaces (Fig. 5). The **Species Builder** will automatically update to the appropriate vector length based on the inputs of the user.

The base vector option, *vector without bias,* assumes that the probability of turning a particular direction is independent of the current direction of travel. If considerable information is known about the behavior of a population and that it demonstrates particular biases in directional movement, this data be incorporated using the vector with directional bias option. This approach involves the creation of a square matrix, i.e. equal numbers of rows and columns, which should be created based on the size of the ñProbability of Turningò array. Note that it is important to enter both the ñProbability of Turningò array and the ñProbability of Turning Bias Matrixò prior to clicking the ñRefreshò button. If the dimensions of the bias matrix and length of the ñProbability of Turningò array are not equal, **Species Builder** will adjust the array size and pad the additional elements with a value of 1.0.

Within the bias matrix, each row corresponds to its respective column and the related direction of travel. For each direction of travel, the corresponding row consists of weights that are applied to the base vector when a change in direction occurs (i.e., the weight and base vector value in the same column are multiplied together). The resulting vector is then scaled from 0 to 1 in order to obtain a new vector of turning probabilities. This option is the most difficult to implement and requires considerable information about the movement patterns of the animals in question.

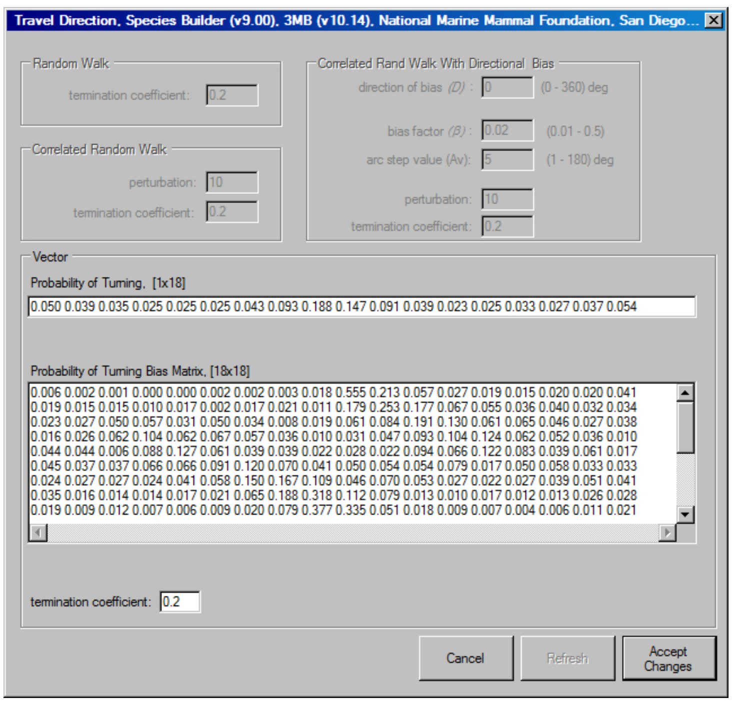


Figure 5. Horizontal Travel Vector Model with Directional Bias Panel.

Behavior Transitions

Once multiple behavioral states have been created, the transition probability from one behavioral state to another behavioral state must be determined. A button marked *Behavior* is located on the Behavior Model panel, below ñBehavior Transition Vectors.ò Left-clicking this button will launch the Transition Matrix panel (Fig. 6). Within the Transition Matrix panel the user sets the probability of transitioning from one behavioral state to the next when the time for terminating the current behavioral state has occurred.

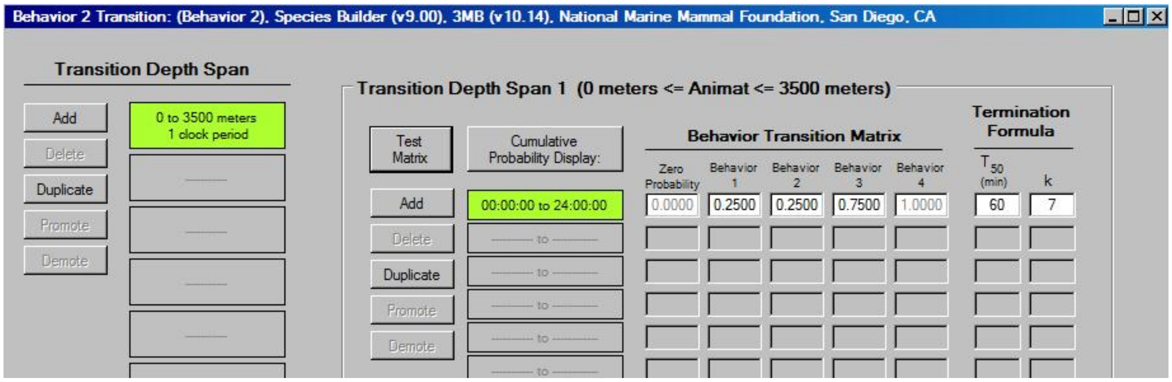


Figure 6. The Behavior Transition Panel.

Transition probabilities may be entered as either simple probabilities or as cumulative probabilities, whichever is most intuitive to the user. Users may select which option they prefer by clicking on the white box labeled either ñCumulative Probability Displayò or ñSimple Probability Display.ò The button label displays the active probability display. When entering cumulative probabilities, the user should take care to ensure that the behavioral state for which the probabilities are being set does not allow for the probability of transitioning into itself. To avoid this, set the probability for the behavior being edited equal to the probability of transitioning to the behavior state just prior to it (see Fig. 6 ï setting the transition probabilities to behavior states when the current state is behavioral state #2). If the behavior is the first behavioral state, set the value to 0.00. The **Species Builder** will turn the entry cells red if cumulative probabilities do not increase in value or stay the same. This serves to warn the user that the entries are invalid.

The amount of time spent in a particular behavioral state is determined by one of two functions. The user has the option to choose either a sigmoidal or a Gaussian function by left clicking on the words ñTermination Functionò located above the two columns located to the far right. The sigmoidal functions is of the form

$$P_{term} = 1/(1+10^{((\log_{10}(T_{50})-\log_{10}(t))*k)})$$

where t is the time until termination of the current behavior, T_{50} is the midpoint of the function, and k determines the steepness of the slope factor. The Gaussian function is of the form

$$P_{term} = \frac{1}{\sqrt{2\pi\delta^2}} e^{-(t-\mu)^2/(2\delta^2)}$$

where t is the time until termination of the current behavior, μ is the mean of the Gaussian distribution, and ŭ is the standard deviation of the distribution.

The Transition Matrix panel also allows the user to make the transition probabilities and termination function dependent on the time of day, as may be observed when there are diel variations in dive behavior, and/or as a function of ocean floor depth (Fig. 7). The default is to have the probabilities remain the same for the full 24-hour clock cycle or across all ocean depths. However, additional combinations of transition probabilities can be added by left-clicking the box labeled ñAdd.ò There are two such boxes, one for adding rows to the Transition Depth Span, and another for adding rows for the time of day. Transition probabilities based on the time of day are nested within Transition Depth Span.

Each click of the ñAddò button under the Transition Depth Span adds another button with a range of depth values. These buttons can be clicked to change the depth span over which a transition matrix is defined. Note that if multiple depth span buttons are added, the lower depth span buttons will automatically adjust so that the combination of depth spans completely accounts for the entire depth span (0-3500 m). Whenever a depth span button is clicked it becomes active, which is designated by the green color (inactive cells are colored light blue).

Whenever a depth span button is active, rows may be added to the behavior transition matrix by clicking the ñAddò button. Each added row allows the timeframe for the new transition probabilities, the transition probabilities for each of the behaviors, and the termination function of the behavior to be defined. The addition of time span rows allows diel variations in behavior transition probabilities to be implemented. As with the Transition Depth Spans, time span buttons associated with the Behavior Transition Matrix can have the time spans changed by left clicking on them. A time span button is active when it is green. Note that time spans will automatically adjust to ensure that a 24-hour cycle is preserved for a given depth span assignment.

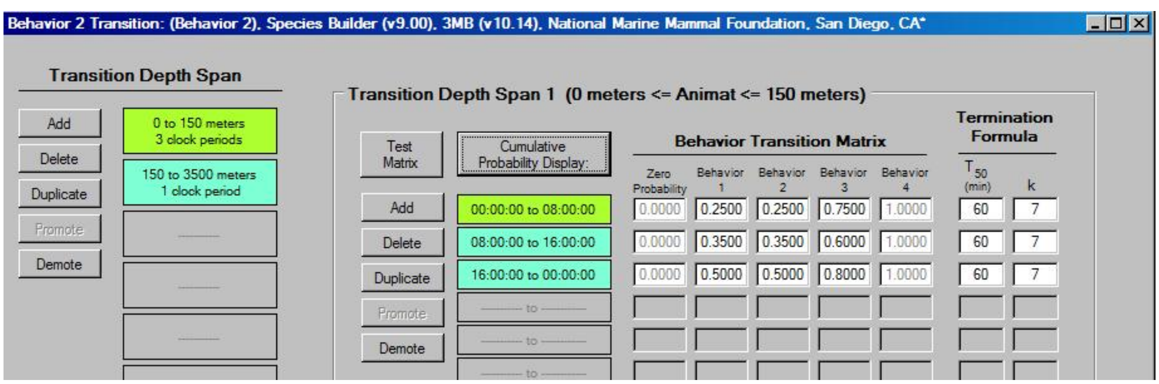


Figure 7. Behavior Transition Probability Matrix ï accounting for diel and depth variations in behavioral transitions.

Other Front Panel Controls

Other front panel controls include the ñSpecies Description,ò ñBathymetric Constraints,ò ñAcoustic Aversion,ò ñInitial Behavior Matrix,ò and inputs for the dive display window, which will be described in a later section. Some of these controls must be set while others are optional. The purpose of each is described below.

Species Description (optional)

The ñSpecies Descriptionò is an optional control that allows a short description of the species, its design, user comments, documentation of the model design, etc., to be entered. The number of characters that can be added is limited to 4095.

Bathymetric Constraints (required)

The ñBathymetric Constraintsò control (Fig. 8) permits 1) the user to place limits on the depths at which an animat may be seeded during the initialization of a simulation (*Seeding Depth – Minimum*), and 2) to define depths that the animat will not travel into and which prevents the animat from running ashore (*Bathymetry Shore Following Value*). Each of these values is in units of meters. The user must enter these values or the default value (10 m depth for both values) will be implemented when the simulation begins. Note that the values are entered as negative numbers. An additional control, *Seeding Depth – Maximum*, can be used to place a maximum depth limit on the initial seeding of the animat. This control is not automatically available to the user, but can be activated by clicking on the bold box surrounding the phrase *Seeding Depth – Maximum*.

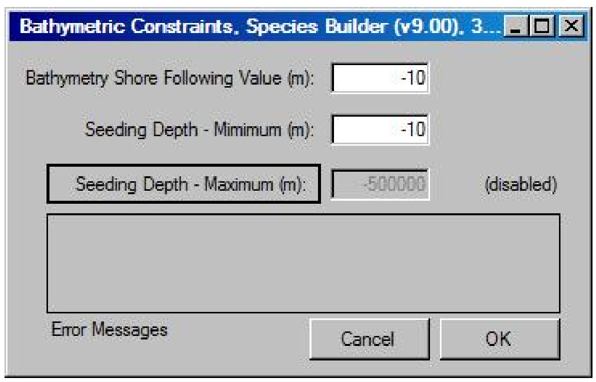


Figure 8. Bathymetric Constraints Input Panel.

Acoustic Aversion (optional)

The ñAcoustic Aversionò panel allows the user to define a behavior that an animat exhibits once its acoustic exposure exceeds a threshold value (Fig. 9). Thresholds for reaction are dictated by the species group membership and equate to the exposure resulting in Level A or Level B harassment. (More information on the implementation of the harassment thresholds and their relation to the triggering of acoustic aversion is provided in the section entitled ***Acoustic Aversion***, which appears on p.30 of this User Manual.)

All of the behavior sub-models that are available on the Behavior Model panel are also available here, thus permitting the user to redefine some or all of the behavior sub-models that were entrained just prior to the aversion. Each of these models can be redefined by clicking on the sub-model box labeled ñDisabled.ò This will enable the sub-model and allow the parameters to be changed. In addition, the user can define several other control modifications.

Exposure breaks pod up ï Within **3MB** the user may assign animats to pods (*see section on operating 3MB).* If an animat within the pod receives an exposure that exceeds the threshold for aversion, the user has the option to allow the pod to break apart. A group of animats assigned to a pod at the beginning of a simulation maintains cohesion (within some user-defined limits) throughout the simulation. If, however, the option to break up the pod is set to ñyes,ò then upon exceeding the threshold for aversion, the members of the pod will act as individuals without the constraints on movement required for pod cohesion. Each animat will thereafter act independently of other pod members.

Animat Beaching ï Users may turn off the depth limitations for shore following and thus permit animats to beach themselves. If turned on, the user must define the water depth at which the animat is considered beached. The default is 2 m of water.

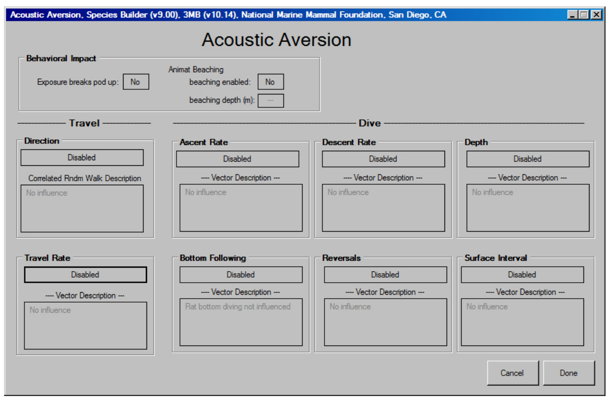


Figure 9. The Acoustic Aversion Control Panel.

Initial Behavior Matrix (required)

The ñInitial Behavior Matrixò determines the probability of a particular behavior state being assigned to an animat at the start of a simulation. The matrix is operated identically to that presented under ***Behavior Tranisitions*** (above). If no matrix is entered, the default assignment of all animats being placed in the first behavior state will be implemented at the start of the simulation.

Front Panel Displays

Two displays are provided on the front panel to help in the creation of the species behavior. The largest window shows the species dive behavior as it occurs over a 1 hour period of time (Fig. 10). The lines defining the dive are colored according to the behavioral state of the animat. Additional simulation hours can be added by changing the integer value of the box on the lower right labeled ñDuration.ò Below the dive display is a thin window that shows the same dive information vertically compressed (Fig. 11). At either end of this window is an expansion bar that may be clicked and dragged in order to focus in on a segment of the dive profile. Similarly, a vertical expansion bar exists to the right of the dive display that permits the depth range to be limited/expanded.

The smaller of the display windows (right side of the Front Panel) is the travel display. This display gives a top-down view of animat movement. As with the dive display, lines are color coded to indicate the behavioral state to which a particular line corresponds.

Figure 10. Front panel of the Species Builder program. The displays permit the user to view the result of their programmed behaviors.

Saving Species Definitions

Once all of the behaviors have been defined and a species group has been selected, the file can be saved. The saved file is known as the ñspecies definitionò and can be called within **3MB** to emulate members of the species type. Clicking the ñSaveò or ñSave Asò button saves the file and assigns it a unique identifier. Both the date the definition was saved and the unique identifier will then be displayed on the Front Panel. Each subsequent save will change the date and unique identifier for the species definition.

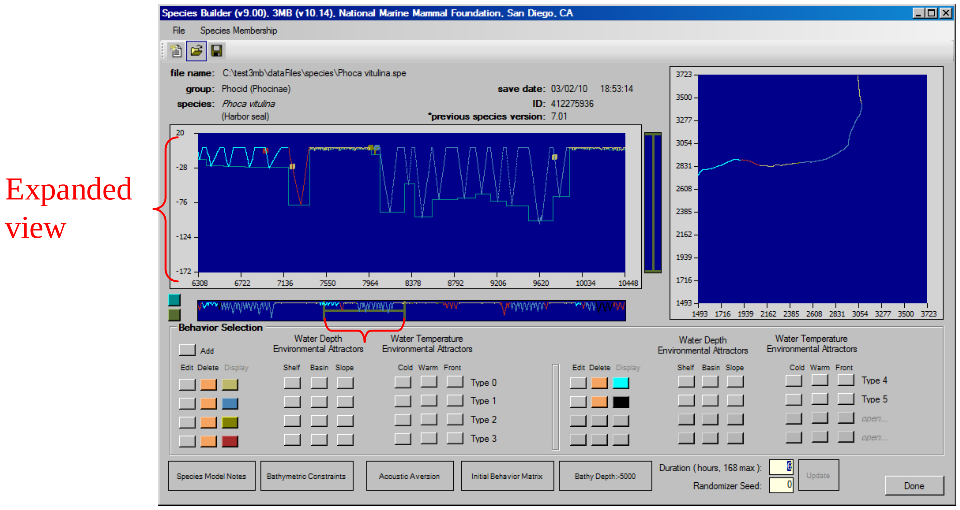


Figure 11. Front panel with the expansion bar controlling time compressed to show a narrow range of the dive profile. The travel display window updates accordingly.

Using 3MB

3MB is the program used to run animat simulations, or scenarios, and can be used to perform simple evaluations of acoustic aversion (Main Panel shown in Fig. 12). Within 3MB, one can define a region of the ocean where a simulation is to be run, load multiple species definitions, utilize a number of tools to seed the environment with individuals or pods of animats, introduce a mobile or static sound source, and generate a ñtakeò estimate based on MMPA definitions of take. (Note ï the values used for generating a take estimate may not be equivalent to that used by the NMFS. Users interested in using **3MB** for estimating takes of marine mammals should consult with NMFS for the appropriate take thresholds.)

Using **3MB** is easy and straightforward. To run a scenario, the following steps must be completed:

1) Set a start time and duration for the scenario
2) Load a bathymetry file
3) Seed the environment with animats (and a sound source, if desired)
4) Set the options for output
5) Run the simulation

At the conclusion of this manual is a Quick Start Guide if there is a preference to begin **3MB** operation with the species definitions and bathymetries provided with the software package. In-depth directions on the operation of **3MB** and descriptions of program functionality are found in the following sections.

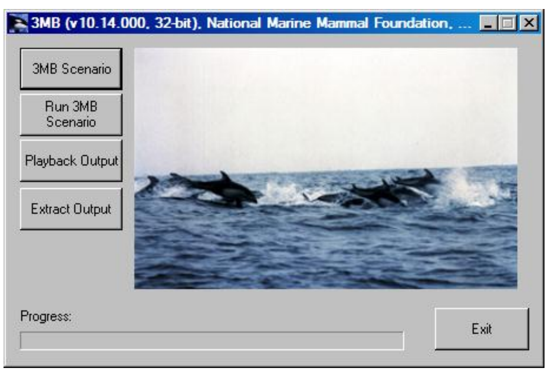


Figure 12. The Main Panel of **3MB**.

Front Panel Operations

Front Panel Buttons

3MB Scenario ï Brings up the Seed Sub-panel that allows the user to place animats into an environment.

Run 3MB scenario ï Prompts the user to load and execute a previously saved 3MB scenario file (.sce).

Playback Output ï Clicking this button brings up a panel in which the travel behavior (i.e. horizontal movement) of the animats in a previously run scenario can be viewed. A .3mb file must be loaded with the *Load File* button. Once loaded, the movement of the animats can be viewed by using the play controls at the bottom of the panel. An individual track can be highlighted in the ñIndividuals List.ò Once selected, the track of the individual will be highlighted in yellow.

Extract Output ï This option prompts the user to load binary output files (.3mb) from previous simulations and extract them into a space delimited text file. Text files are typically larger in size and the binary format is used as a more efficient means of outputting and storing data. (Note - This tool is useful prior to importation into spreadsheet programs, but the user should be aware that the parsing process when importing into spreadsheet programs based on space delimiters can cause mis-alignment of the column headers and associated columns of data.)

The Seed Sub-Panel Operations

The *Seed* sub-panel is the interface for placing animats into the environment (Fig. 13). Here, species may be selected, animats distributed in the environment, and pod behavior attributed to a species or sub-set of the species. In addition, a simple sound source can be added to the environment to test various programmed aversive behaviors of exposed animats.

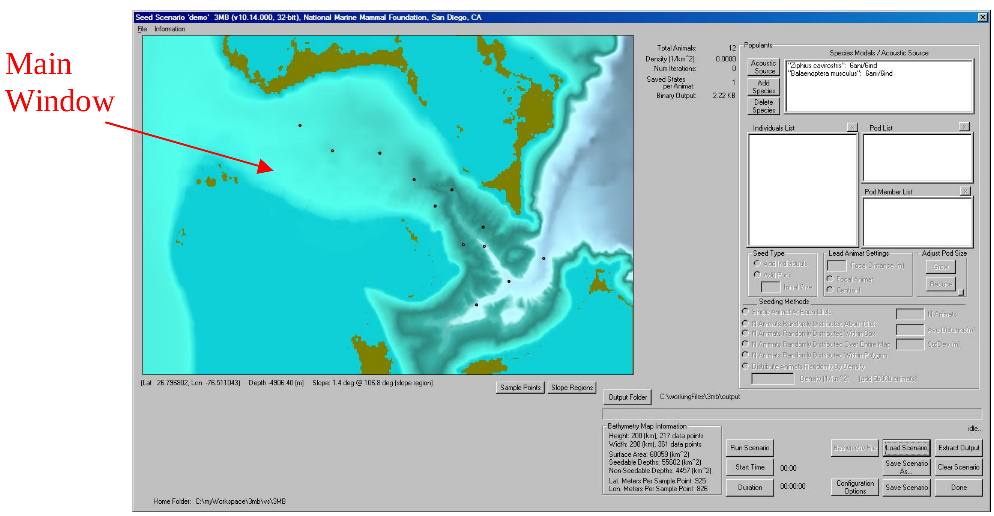


Figure 13. The Seed Sub-Panel. Within this interface the user seeds the environment with animats. (Bahamas bathymetry shown.)

The main window of the *Seed* sub-panel (Fig. 13) displays the bathymetry of the simulation environment. Land masses are displayed as yellow-brown. The bottom-center of the panel displays data about map dimensions, area covered, water and land surface area, the number of data points in the set, and the data resolution. Directly under the map location-specific information about the map (with respect to the mouse cursor location over it) is displayed and composed of coordinate, depth, and degree of bathymetric slope. The top center of the panel lists animal count, animal density (once the map is seeded) the number of saved states per animal, and calculated binary output size. The map is interactive and can be used to specify limits on animal distributions (see below).

File Drop-Down Menu

From the File drop-down menu the user can create a new scenario, load a saved scenario, save a scenario, or clear one currently in use or creation. In addition, the following special functions can be called.

Auto Generate File Name ï This function will automatically assign a unique file name to a scenario. The file name is generated based on information in the scenario configuration. The base file name, if the *Auto Generate File Name* were selected before setting any parameters, is:

s00a00000d000000[Bathymetry]Itn24

These values will be updated the next time *Auto Generate File Name* is selected, provided some parameter values have been set. The file name will adjust according to the following parameter values:

s = species count; lists the number of species in the scenario.
a = # animats; lists the number of animats in the scenario.
d = lists the duration of the simulation in seconds.
Bathymetry = lists the name of the bathymetry file selected for the scenario.
Itn *or* Ani = indicates the output file is arranged by iteration (Itn) of the simulation, or by animat (Ani).
number = number of bytes written to file per animat state.

For example, assume a scenario with one species, represented by 3 animats, set for a duration of 10 hours. The name of the bathymetry file selected for the simulation is ñBahamasò and the output configuration has been set to arrange the output by iteration and to write 24 bytes of information per reporting of the animat state. The resulting file name would then be:

s01a00003d036000[Bahamas]Itn24

Options (same as *Configuration Options* on the Seeding Panel) ï This command opens the Options panel for configuring the output of the scenario, configuring the manner in which the scenario is initially randomized, reporting characteristics of sound sources, etc. It is the same as pressing the *Options* button on the front panel. It will be discussed in more detail below.

Limit Output By ï This function limits the output of the data file to a subset of all generated data points. The first option writes only those data points that co-occur with the transmission cycle of an acoustic source (i.e. the ping cycle option). If this limit is used, the user should ensure that a sound source is also included in the simulation. Alternatively, the user can create a comma separated value file containing the list of times at which data writes to file should occur (i.e. the comma separated value file option). The times must be in seconds. These options, which may be used concurrently, are particularly useful for long runs since the standard output options can generate lengthy data files. Animats are typically updated once per second with output files similarly updated. The final alternative is to limit the output of the data file according to a fixed interval.

Extract Data from Previous Run (same as the *Extract Ouput* button on the Seeding Panel) ï This option allows the user to load binary output files from previous simulations and extract them into a space delimited text file. Text files are typically larger in size and the binary format is used as a more efficient means of outputting and storing data. (Note - This tool is useful prior to importation into spreadsheet programs, but the user should be aware that the parsing process when importing into spreadsheet programs based on space delimiters can cause mis-alignment of the column headers and associated columns of data.)

Seeding Panel Buttons

Run Scenario ï Clicking this button initiates the simulation. It is only available once the bathymetry has been selected and the environment seeded with animats.

Start time ï Clicking this button allows the user to choose the start time of the simulation. The default is 00:00:00, or midnight. The start time is set as hours and minutes and utilizes a 24-hour clock (no AM or PM qualifiers necessary).

Duration ï Clicking this button allows the user to choose the duration of the scenario, which must be entered prior to running a simulation. The time is set as hours, minutes and seconds. A maximum of 168 hours, or 7 days, is allowed for a simulation.

Bathymetry File ï Prompts the user to select and load a bathymetry file.

The bathymetry file must be written in 3-column format with latitude, longitude, and depth in meters. *If depth is provided as a negative value, the bathymetry file must end in .bth. If depth is provided as a positive value, the bathymetry file must end in .txt.* In this manner, **3MB** distinguishes between the file structures. Values must be space delimited with a carriage return between each line of entry. Depth values of 0.0 or greater (for .bth files) and 0.0 or smaller (for .txt files), are considered land masses. Several bathymetry files are provided in the **3MB** bundle and the user can open them with a text editor to observe the file structure.

Several databases for bathymetric information exist that are accessible to the public. Importation of data from many of these databases will require reformatting into the formats recognizable to **3MB**.

Note* - In order to visualize the bathymetry during the animat seeding process, the bathymetry file must be loaded prior to pressing the *Seed* button. Options for seeding the environment with animats will not appear on the *Seed* sub-panel until a bathymetry file is loaded. Further, once any animat is placed on the bathymetry map, the button (and therefore option) to load a different bathymetry map is disabled.

Configuration Options ï Clicking this button opens the Configuration Options sub-panel. Information entered into this panel is critical to configuring the output of the scenario, configuring the manner in which the scenario is initially randomized, reporting characteristics of sound sources, etc. It is the same as pressing the *Configure* button on the *File* menu. It will be discussed in more detail below.

Load Scenario ï Clicking this button calls a dialogue window from which a previously saved scenario can be loaded. This function is the same as using the *Load Scenario* function from the *File* menu.

Save Scenario As ï Clicking this button calls a dialogue window for naming and saving a scenario file. The scenario file stores all of the information necessary to recreate a scenario. This function is the same as using the *Save Scenario* function from the *File* menu.

Save Scenario ï Permits the user to save an already named but previously saved and/or loaded scenario without being prompted for a name to save the file to.

Extract Output ï Clicking this button permits a previously created binary output file to be extracted into text format. It is functionally the same as the command *Extract Data From Previous Run*, which is found on the *File* menu.

Clear Scenario ï Clicking this clears the scenario entirely. The bathymetry map and all species files and seeded animats are removed from the current scenario.

Done ï Clicking this button closes the **3MB** program.

Sample Points ï Toggles the display of points on the bathymetry map that correspond to data points in the bathymetry file.

Slope Region ï Toggles the display of slope regions of the bathymetry map on the bathymetry map display.

Output Folder ï Permits the user to define the output path of the output file.

ñHome Folderò ï A text display on the bottom of the panel showing the folder the user launched the 3MB application from. This is useful because 3MB uses .ini files that are created by 3MB and stored in this ñhomeò folder if none are already present. Ini files are used solely to save user-selected information such as save-to-folders, locations of bathymetry files, where output files are to be stored, and so on so that users need not set these options each time they run the 3MB application. Ini files are text-based; the user may open and examine all information stored inside.

Seeding the Environment with Animats

The process of seeding the environment with animats begins by pressing the *Add Species* button in the top-right corner of the sub-panel. Clicking here opens an interface window for selecting a species. Only one species can be selected at a time, but the *Add Species* button can be repeatedly used to include as many species in the scenario as is desired.

Once a species is selected, it appears in the ñSpecies Models / Acoustic Sourceò window with parentheses behind it containing the word *unpopulated* (the *Delete* button will delete a selected species from this same window, along with all animats previously seeded to the environment). Single clicking on the species name selects the species and permits it to be populated on the map. A number of options exist for seeding the environment with members of a species. Animats may be seeded as individuals or as members of a pod (as selected under ñSeeding Methodsò).

Seeding by individual ï Numerous methods are available for seeding individual animats within the environment. Each of the potential methods for seeding individuals is found under ñSeeding Methods.ò Only one method of seeding may be chosen at a time.

> <u>Single Animat at Each Clic</u>k: As the name implies, a single animat is placed at each point on the map that is clicked with the left mouse button.
>
> <u>N Animats Randomly Distributed About Click</u>: With this option, a number of animats are distributed around a point that is selected on the map with a left-click of the mouse button. The distance from the point for each animat is randomly selected from a Gaussian distribution of a given mean and standard deviation. The number of animats distributed, the average distance from the point (mean of the Gaussian distribution), and the standard deviation defining the variability in the distance are all defined to the right of the selection.
>
> <u>N Animats Randomly Distributed Within Box</u>: With this option, the user clicks and drags a rectangle on the map. The animats are randomly distributed within the box. The number of animats to be distributed is set to the right of the selection.
>
> <u>N Animats Randomly Distributed Over the Entire Map</u>: With this option, a number of animats, set in the box to the right of the selection, are randomly distributed over the entire map.
>
> <u>N Animats Randomly Distributed Within Polygon</u>: With this option, the user clicks multiple points on the map to form a polygon. Consecutive points are connected by a line and the polygon closes itself when the original and a subsequent point are placed close to one another. A left-click after the polygon is closed randomly distributes the animats within the polygon. A right-click clears

the polygon from the screen (Note* - New animats will be added to the polygon each time a left-click is made unless the polygon is cleared from the map).

Distribute Animats Randomly By Density: With this option, the density of the animats within the region of interest is entered. A left-click on the map distributes the animats according to the number of animats required to meet the density criterion (Note* - Animats are rounded to the whole animal).

Animats cannot be seeded on land and their distribution is restricted based on the depth limits that are contained in the Species Definition for the animat. Once an individual is seeded in the environment, a latitude and longitude indicating its location will appear in the ñIndividuals List.ò Additionally, a dot will appear on the map indicating the location of the individual.

Seeding by pods ï The distribution of ñpodsò provides the ability to have animats behave as a cohesive group. If the pod method of seeding is chosen, the user must first decide how big the pod should be. This is followed by selecting whether the pod maintains cohesion as a function a focal animat or as a function of the geometry of the pod.

Focal Animat: The focal animat method sets the first animat in the pod as the focal animat. All other animals in the pod maintain a distance no greater than the ñFocal Distance,ò which is determined by the user.

Centroid: In the centroid method, all members of the pod must remain within a set distance of the calculated centroid of the pod. The distance limit is user defined.

Numerous methods are available for seeding pods within the environment. Each of the potential methods for seeding pods is found under ñSeeding Methods.ò Only one method of seeding may be chosen at a time.

Animats cannot be seeded on land and their distribution is restricted based on the depth limits that are contained in the Species Definition for the animat. Once a pod is seeded in the environment, a Pod indicator appears in the ñPod List.ò Selecting the pod description in the ñPod Listò displays the latitude and longitude of each individual in the pod. Additionally, a dot will appear on the map indicating the location of each of the individuals in the pod.

If the user wishes to increase or decrease the size of the pod, the pod must first be selected from the ñPod List.ò Once selected, individuals may be added or subtracted from the pod by clicking on *Grow* or *Reduce* under the ñAdjust Pod Sizeò list. To exit from growing/reducing pod size, click on the species name in the ñSpecies Models / Acoustic Sourceò list.

Special Notes on Pods: The cohesion of pod members includes their spatial arrangement in the horizontal plane and their behavioral state. This is a change from the previous release of **3MB** in which animats in a pod were autonomous except for the spatial cohesion. If the Species Definition calls for a pod to break apart after receiving an acoustic exposure sufficient to trigger aversion, then the cohesion restraints are lifted and all animats function independently of one another.

If the lead animat settings are set to ñFocal Animat,ò pod members adopt the behavioral state of the lead animat (1^{st} animat in the ñIndividuals Listò). Pod members will follow the behavior state transition of the focal animat but transition will not occur for individual animats until they have terminated their current dive. Horizontal movement is corrected to keep animats within the bounding distance of the focal animat as defined by the ñFocal Distanceò value.

If the lead animat settings are set to ñCentroid,ò then a centroid is calculated for the original pod distribution. The centroid is then treated as an unrealized animat; it transitions behaviors and its movement patterns are dictated by the behavioral states but it is not recorded as an animat. The horizontal movements of pod members are treated as a correlated random walk with a directional bias. The directional bias is the direction that the centroid moves on each update. In all other ways, pod members governed by the centroid lead animat method follow the behavioral transitions of the unrealized centroid animat as if it were the focal animat.

Adding an Acoustic Source

Pressing the *Acoustic Source* button allows a sound source to be selected from a list of sound sources. Currently, only two sound sources are available in **3MB**, one on a static platform and one on a mobile platform. The sources are named myStationarySndSrc.src and myMobileSndSrc.src, respectively. The sources are assumed to be at the surface and spherical spreading loss is assumed to occur between animat and sound source. Furthermore, the sources are assumed to emit a 1-s ping with a source level of 235 dB re 1 µPa and a 10% duty cycle. The acoustic sources are provided as a simple means of testing aversive reaction in species - it is not meant to take the place of more sophisticated transmission loss models. The **ESME** program incorporates more sophisticated models and the user is referred to **ESME** for comprehensive modeling capabilities and simulations. The integrated **ESME** model is anticipated for release in 2011.

The Configuration Options Sub-Panel

The Options sub-panel provides many configuration options for **3MB** (Fig. 14). Here, the output file format is configured, the random seed options are set, the distance calculation method is determined, the post-simulation processing tasks are set, and memory usage and acoustic source default values are reported.

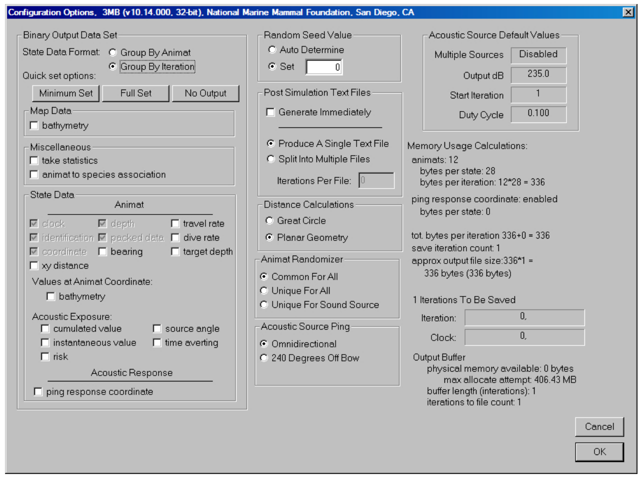


Figure 14. The Options Sub-Panel.

Binary Output Data Set

ñState Data Formatò ï Here the output file is configured for arrangement either by animat or by iteration.

ñQuick set optionsò ï permits the user to quickly select and set their an output option without having to individually consider each possible outputted state data item to be saved.

ñMap Dataò ï This selection box permits the user to include (checked) or excluded (unchecked) bathymetry data in the output file.

ñState Dataò ï Here the user selects what data points are to be outputted for each iteration in which data is outputted.

ñRandom Seed Valueò ï The user may set the random seed value to a fixed number or it can be auto-determined based on the computer clock. Setting the value to a fixed number will result in the same initialization state of a group of animats if the same scenario is run repeatedly. If Auto Determine is selected, the initialized states will randomly vary from run to run (Note* - If a Monte Carlo series is desired, the Auto Determine option should be selected to ensure that randomization occurs from simulation to simulation).

ñPost Simulation Text Filesò ï These options determine whether text files are generated immediately upon conclusion of the simulation and whether a multiple or single consolidated file is created.

ñDistance Calculationsò ï Options for using either planar geometry or great circle equations in the calculation of distances between animat and sound source (or other entity, e.g. land mass) are provided. Differences in the calculation methods are small when distances between animat and sound source are small relative to global distances.

ñAnimat Randomizerò ï By default, all animats in the scenario share a common randomizer seed. Options listed here permit each animat to have its own randomizer seed or only a sound source (if present) to have its own seed.

ñAcoustic Source Pingò ï Permits the user to decide if the sound source has an omnidirectional ping or a 240 degree, off-bow ping.

The remainder of the Options sub-panel displays default values for acoustic source parameters as well as information on the memory usage and buffering required for the simulation given its current configuration. The latter information is useful in predicting output file sizes and the demands placed on the system during the running of the simulation.

Special Notes on Options: If a user wishes to observe the bathymetry and the species names in a playback of a scenario, they should make sure that the *bathymetry* box is checked under ñMap Dataò and that the *animat to species association* is checked under ñMiscellaneous.ò

Determining Acoustic Exposure

When **3MB** is run as a stand-alone application, it may be populated with an acoustic source. **3MB** maintains positional information of the source, generates acoustic events by the source, and calculates the acoustic exposure of the animats in the simulation. When **3MB** is run as a set of library calls for an external process, the acoustic source position and duty cycle, and the exposure values for each animat in the scenario must be handled by an external process (e.g. as is performed in **ESME**).

When running **3MB** as a stand-alone application, sound sources are treated as omnidirectional. At each ping cycle of the sound source, the instantaneous acoustic exposure value for each animat is calculated assuming spherical spreading loss by the formula

$$RL = SL - 20*\log_{10}(r)$$

where SL is the root-mean-squared (rms) source level in dB *re* 1 µPa, RL is the rms received level in dB *re* 1 µPa, and r is the distance between source and receiver (animat) in meters. The SL for all sources in **3MB** is currently set to 235 dB. (Please not that the calculation does not incorporate the time lag between activation of the acoustic source and the time of reception by the animat. The exposure is considered to be instantaneous with the activation of the sound source.)

For each instantaneous acoustic exposure received, the animatsô sound exposure level (SEL) is calculated with assumed reference values of dB *re* 1 µ$Pa^{2}\cdot s$. The ñtakeò files generated by the **3MB** report this value as the cumulative acoustic exposure. The cumulative acoustic exposure is progressively calculated through the simulation using the formulae:

$$aec_0 = aei$$

$$aec_n = 10 * \log\left(10^{\frac{aec_{n-1}}{10}} + 10^{\frac{aei}{10}}\right)$$

where *aec* is the current cumulative acoustic exposure, *aei* is the instantaneous acoustic exposure, and *n* is the current iteration of the simulation. The simplifying assumption of this calculation is that the ñpingò emitted by all sound sources is a 1-s tonal signal and remains undistorted, but attenuated, at the animat.

Please note that in the ñtakeò file (*see below*), the RL and SEL used for take estimations are simply referred to as ñinstantaneousò and ñcumulativeò exposures. This approach was taken to permit modifications to the criteria for take estimates without explicit designation of the criteria in the take file (i.e., the single-ping equivalent approach vice SEL for a take estimate).

Estimating Harassment under the Marine Mammal Protection Act

Note* - The discussion below refers to old criteria and thresholds used for estimating harassment. As the development of criteria and thresholds is a continuing and dynamic process, it is not recommended to use this output for harassment estimation. Future versions of 3MB will either update the harassment estimation process or disable it.

Estimates of harassment can be made with **3MB** by employing thresholds and criteria for harassment as defined under the MMPA. However, these should be used only for exercise purposes since the criteria and thresholds used by regulatory agencies are constantly evolving. A complete discussion of the MMPA regulations and their role in regulatory policy is beyond the scope of this User Manual. The thresholds and criteria provided here are based on current/past implementations of the regulations by the U.S. government and extrapolations from the literature made by the creator of **3MB**. The implementation of these thresholds and criteria has not been formerly endorsed by the National Marine Fisheries Service and the estimation of harassments using these thresholds and criteria should not be assumed to be an accepted approach by the regulatory agency.

The thresholds and criteria used in this version of **3MB** are drawn from several sources:

1) current thresholds and criteria implemented by the U.S. Navy for mid-frequency (1-10 kHz) active sources and physiological impacts to odontocetes (U.S. Navy, 2008b);
2) thresholds and criteria drawn from the literature for physiological impacts to pinnipeds (Kastak et al., 2005), and applied according to family or sub-family;
3) current thresholds and criteria implemented by the U.S. Navy for mid-frequency (1-10 kHz) active sources and behavioral (non-physiolgical) impacts to odontocetes and pinnipeds, i.e. the ñrisk functionò (U.S. Navy, 2008b);
4) behavioral thresholds and criteria for ñsensitiveò species, as implemented by the U.S. Navy (U.S. Navy, 2008a).

The level of harassment, and thus the calculation of ñtakes,ò produces a non-overlapping hierarchy. Level A harassment is considered more severe than Level B harassment, and Level B (physiological) harassment is given precedence over Level B (behavioral) harassment. Thus, if an animat is counted as a Level A harassment, it will not also be counted as a Level B harassment. Similarly, an animat that is considered to have received Level B harassment because it exceeded the Level B (physiological) take threshold will not be double-counted because it also exceeded the Level B (behavioral) take threshold.

The MMPA defines Level A harassment as, "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." It further defines Level B harassment as, "any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild." The criteria for harassment are accordingly applied in **3MB** as:

Level A harassment = onset of permanent threshold shift (PTS)
Level B (physiological) harassment = onset of temporary threshold shift (TTS)
Level B (behavioral) harassment = significant behavioral reaction (without auditory fatigue)

The use of TTS as criterion for harassment is based on the assumption that a temporary reduction in hearing capability can impede the normal behavioral reaction of an animal to a biologically significant sound. Due to a lack of information on certain species, physiological thresholds for sea turtles and other mammals are considered to be equivalent to those used for mysticetes and odontocetes.

The thresholds for harassment are provided in Table 1. Upon each acoustic exposure of the animat, the cumulative exposure value is compared to the threshold values for physiological impacts. If the animatôs cumulative acoustic exposure equals or exceeds a take categoryôs threshold, then the animat is considered taken by that category and its ñtakeò status is updated in the output file.

The descriptor, *RF*, in Table 1refers to implementation of a ñrisk function.ò This function determines a species groupôs probability of level B (behavioral) take across a range of RLs. In **3MB**, every species belongs to a species group that implements the risk function for predicting level B (behavioral) harassment (except for the harbor porpoise (*Phocoena phocoena*), a ñsensitive speciesò). These groups can loosely be defined as mysticetes, odontocetes and pinnipeds, and other species. All species except those belonging to the mysticetes utilize the same RF. Mysticetes utilize a RF specific to their species group. The harbor porpoise, a special consideration, has a take threshold of 120 dB RL. The implementation of the risk function in calculating takes is different than that for Level A and Level B (physiological) takes.

Table 1. Harassment categories and take thresholds for the species groups implemented within **3MB**. The abbreviation, RF, refers to the ñrisk functionò implemented by the U.S. Navy for actions involving mid-frequency active sources.

Species Group	Level A Physiological Threshold $dB\ re\ 1\ \mu Pa^2\ s$	Level B Physiological Threshold $dB\ re\ 1\ \mu Pa^2\ s$	Level B Behavioral Threshold $dB\ re\ 1\ \mu Pa$
Mysticete	215	195	RF
HF Odontocete	215	195	RF
MF Odontocete	215	195	RF
Phocid Monachinae	224	204	RF
Phocid Phocinae	203	183	RF
Otariid	226	206	RF
Other Mammals	215	195	RF
Sea Turtles	215	195	RF
P. Phocoena	215	195	120

The risk function formula is:

$$Risk = \frac{1 - \left(\frac{L-B}{K}\right)^{-A}}{1 - \left(\frac{L-B}{K}\right)^{-2*A}}$$

Where L is the received level in dB *re* 1 µPa, B is the ñbasementò level in dB *re* 1 µPa, K is the increment above the basement level at which there is a risk value of 0.5 (i.e., a 50 percent chance of a harassment), and A is the risk translation sharpness parameter. The values for these variables are as follows:

B = 120
K = 45
A = 8 (for mysticetes and sea turtles) and 10 (for odontocetes, pinnipeds, and other mammals)

Upon each acoustic exposure of the animat, the risk for that exposure is calculated. The maximum risk value is preserved until a higher risk value is experienced. At the conclusion of a simulation, the risk value is summed across all animats and rounded to the nearest whole number. This value (and the fractional value) is reported as the number of Level B (behavioral) takes in the take report. On the following page, an example of the take report is provided.

<u>Take file example</u>

```
File Creation Date: 10\22\2009  15:34:24
3mb Ver (current):  5.04 (built on Oct 22 2009 at 15:33:15)
3mb Ver (file):     5.04
```

Species Count: 2
Animat Counts
Initial: 30
Additions: 0 (due to moving off map)
Final: 30
Start Time: 00:00:00
Duration: 01:00:00
Acoustic Source

----------- SPECIES MID-FREQUENCY THRESHOLD SPECIFICATIONS -------------

Species Group	LvlA Phys Threshold (dB re 1 uPa^2 s)	LvlB Phys Threshold (dB re 1 uPa^2 s)	LvlB Beh Threshold (dB re 1 uPa)
Mysticete	215.00	195.00	RF
HF Odontocete	215.00	195.00	RF
MF Odontocete	215.00	195.00	RF
Phocid (Monachinae)	224.00	204.00	RF
Phocid (Phocinae)	203.00	183.00	RF
Otariid	226.00	206.00	RF
Other Mammals	215.00	195.00	RF
Sea Turtles	215.00	195.00	RF
P. Phocoena	215.00	195.00	120.00

-------------------------- SCENARIO RESULTS ---------------------------

Takes By Species

File Name	generic_mysticete	generic_odontocete
Species	generic Mysticetes	generic HF Odontoc
Species Group	Mysticete	HF Odontocete
Animats t0/tf	(15/15)	(15/15)
Lvl B Phys	1	1
Lvl B Behv	(5.504) 6	(3.674) 4
Total Lvl B	7	5
Lvl A	0	0
Max Exposures		
Instantaneous	180.30704	181.83609
Cumulative	195.83308	195.42941
# Stranded	0	0

<u>Take file example (continued)</u>

Takes By Group

	Mysticete	HF Odontocete	MF Odontocete

Animats t0/tf	(15/15)	(15/15)	(0/0)
Lvl B Phys	1	1	0
Lvl B Behv	(5.504) 6	(3.674) 4	(0.000) 0
Total Lvl B	7	5	0
Lvl A	0	0	0

	Phocid (Monachinae)	Phocid (Phocinae)	Otariid
Animats t0/tf	(0/0)	(0/0)	(0/0)
Lvl B Phys	0	0	0
Lvl B Behv	(0.000) 0	(0.000) 0	(0.000) 0
Total Lvl B	0	0	0
Lvl A	0	0	0

	Other Mammals	Sea Turtles	P. Phocoena
Animats t0/tf	(0/0)	(0/0)	(0/0)
Lvl B Phys	0	0	0
Lvl B Behv	(0.000) 0	(0.000) 0	0
Total Lvl B	0	0	0
Lvl A	0	0	0

ANIMAT TAKE TOTALS

Lvl B Phys: 2
Lvl B Behv: 9 (9.177)
Lvl B Total: 11
Lvl A Total: 0
Total # Stranded: 0

Acoustic Aversion

Acoustic aversion is a behavioral response to acoustic source that is engaged when the threshold for aversion is exceeded. The aversion behavior is included for exploratory purposes and is not directly applicable to the regulatory calculation of a ñtake.ò The process involved should not be confused with or equated to the take calculation previously described.

Animat aversion behavior begins when an animatôs cumulative or instantaneous acoustic exposure exceeds the threshold for harassment for its species or species group. This situation can occur if:

1 ï the animatôs cumulative exposure exceeds the threshold for Level A or Level B (physiological) harassment during any given exposure

2 ï the animatôs risk value, determined from the instantaneous RL, exceeds a pre-determined risk threshold during any given exposure

To enable the latter condition, each animat is assigned a risk threshold during scenario initialization. The threshold is a randomly determined value between 0 and 1. During each acoustic exposure, the calculated risk value is compared to the risk threshold. If, during an exposure, the risk value exceeds the risk threshold for the animat, the animat engages aversive behavior. Animats belonging to species *Phocoena phocoena* engage aversion behavior when their exposure reaches or exceeds their level B (behavioral) threshold of 120 dB RL. Once an animat averts it continues to do so until it beaches, moves off the map, or the scenario ends.

A speciesô aversion behavior is defined in the **Species Builder** application. The aversion behavior can include any or all of the standard sub-models (e.g. *travel direction*, *travel rate*, and *dive depth*) plus modifications to pod cohesion and land/shallow water avoidance. The *travel direction* sub-model in the aversion behavior forces a correlated random walk with directional bias. This variant of the model assumes that the animat can localize the sound source and move away from it. The direction of bias of averting animats is set by **3MB** to a heading directly away from the coordinates at which the sound source emitted its last sound. Pods can be set to break apart upon engaging in aversion behavior. Animats operate completely independently of each other once the pod is dissolved. If the beaching option is set, animats are permitted to travel onto land or into depths they would normally avoid (i.e. the shore-following behavior is disregarded). Beaching depth is set to 2 meters, and once an animal enters water of this depth it is considered ñbeachedò and no longer participates in the simulation. Shore-following depths are a modeling parameter and are established in the creation of the Species Definition.

Off-Map Animats

When an animat strays off the map it is removed from the population and in its place a new animat is added to the population. The new animat is reseeded on the opposite side of the map and maintains the same heading and travel rate of the one replaced, plus the focal coordinate if the replaced animat was in a pod. The replaced animatôs take counts are saved and included in the take statistics of the entire population at the end of the scenario. The replacement animat is completely re-initialized across all behavioral sub-models (with the exception of the travel direction, travel rate and focal coordinate). All state variables such as cumulated and instantaneous acoustic exposure are reset to zero.

When seeding the replacement animat, there is a potential that the bathymetry depth on the opposite side of the screen will be an invalid depth due to land masses or restrictions on beaching and shore-following depths (bathymetry that is too deep due to the optional maximum bathymetrical seeding depth species modeling parameter is currently not considered when reseeding animats that go off screen). When the depth is invalid, a new valid location on the map is chosen randomly.

Shore Following

Shore following is an algorithm that temporarily alters the heading and travel rate of animats and mobile sound sources in order to prevent unintended interactions with shallow water or land masses. Animats and sound sources engage in shore-following when they are nearby water depths shallower than the limits for beaching or the limits on use of water depths programmed into the Species Definition. Beaching depth is globally set to 2 meters water depth for all animats, while shore-following depth is a species-specific modeling parameter. Animats will always engage in shore following unless they are currently engaged in the acoustic aversion behavior that is set to permit beaching.

Shore following works by verifying that the *next iteration's* movement will not take the animat into depths shallower than beaching or speciesô limits permit. Verification is accomplished by determining that the bathymetry depths at coordinates around the animat and at specific angles relative to its heading and travel rate are deeper than shore following depths and beaching depths. If they are not, then the travel rate and heading is temporarily changed during the next iteration to ensure compliance with the depth limits on the species.

Checks for shore following depths around the animat are carried out at coordinates of angles at +/-1, +/-5, +/-12, +/-24, +/ï 45, and 0 degrees relative to the animatôs current heading and current rate of travel (Fig. 15). Once a depth at or shallower than beaching or shore-following limits is detected, angle checking ceases and a different temporary heading and/or travel rate that deflects the animat away and/or prevents it from traveling too near the shallow-water coordinate is determined.

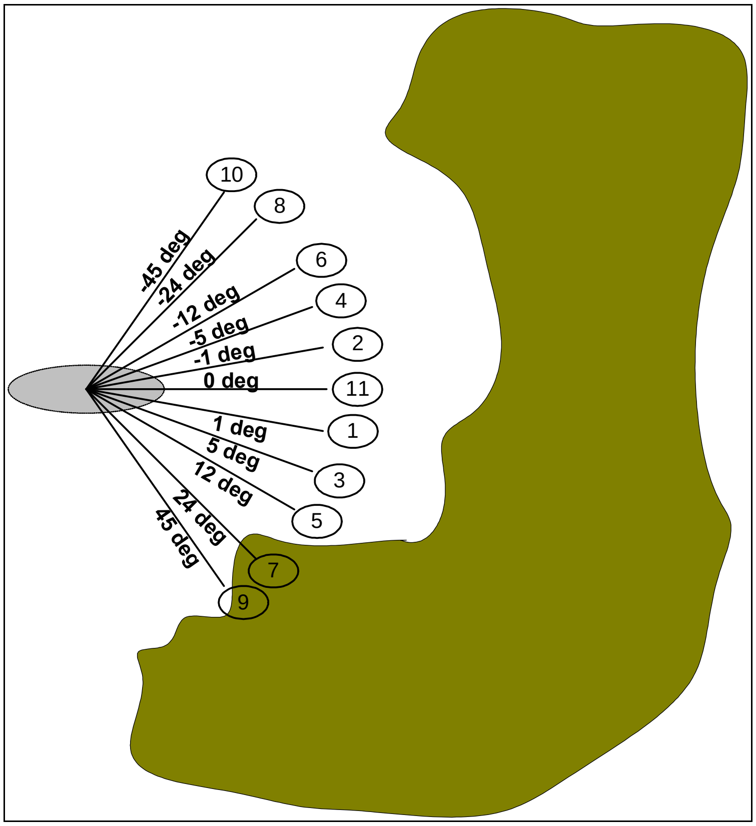


Figure 15. Forward looking check of water depths used by the shore-following algorithm.

Determining a new heading or travel rate first considers solely the animatôs heading. Upon detecting depths that are too shallow, an adjustment angle meant to deflect the animat away from the shallow coordinate is calculated as follows:

For shallow-water coordinates at relative angles positive to the animatôs heading:
    Heading adjustment = relative angle ï 90.
For negative relative angles
    Heading adjustment = 90 ï relative angle.

Figure 16 shows an example in which a calculated adjustment of ï 66 degrees resulted from a detected shore following bathymetry depth at positive 24 degrees relative to the animatôs current heading. Next a check is made to verify that at the new heading water depths that violate the limits are also avoided. If the new heading does not take the animat or acoustic source into shallow water depths, then the shore-following process ends and the animat or acoustic sourceôs next heading is temporarily (for the next iteration) set to the deflected heading.

If the check fails because the temporary heading steers the animat into impermissible depths, then the shore-following effort continues. The new heading is discarded and the animat is returned to its original heading. The shore-following process then attempts for a set number of times to find a new heading using the species modelôs direction sub-model (i.e. that is normally used to determine the animatôs heading). If this effort fails, then the process attempts to find a new heading and travel rate using both the species direction and travel rate models. The search becomes progressively more complex with successive failures, following the following pattern:

- A set number of attempts to slow the animat down in a controlled manner by reducing its current travel by 10 percent and trying to find a new heading using the species modelôs direction sub-model.
- A set number of attempts to speed up the travel rate in a controlled manner by increasing its current travel by 10 percent while trying to find a new heading using the species modelôs direction sub-model.
- Starting with the original heading and travel rate increment, the animatôs heading is incrementally changed by half a degree. At each degree increment, a reduced or increased speed is sought that will allow the animat to move without entering into impermissible depths. This process will continue for a full 360 degrees until an acceptable water depth is found.

If all attempts fail then the animat doesnôt move in the horizontal plane during subsequent iterations.

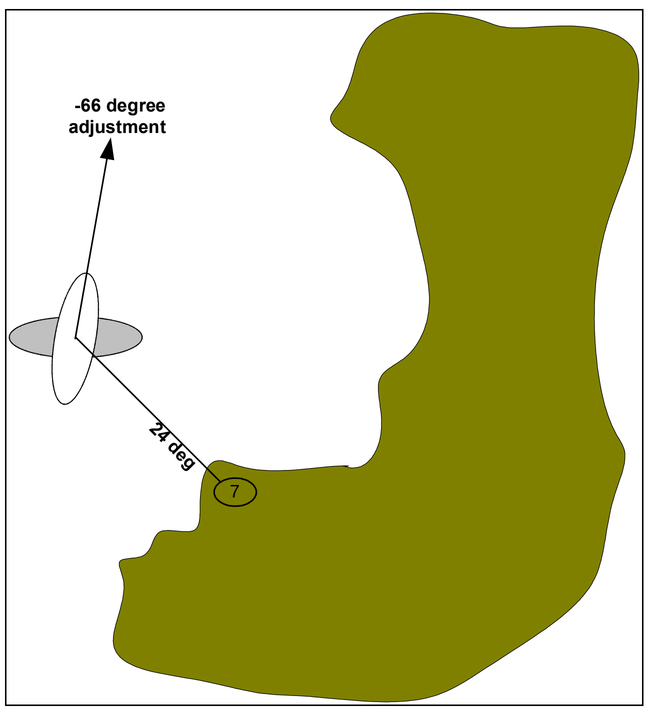


Figure 16. Adjustment of the animal heading based on probability of entering water depths shallower than permitted by limits placed on the animat (either due to beaching depths or species-specific limits defined by the user).

Animat Track Output File Naming Convention

When manually extracting binary data into individual animat track files (.trk), the user has the option to enable selecting a single animat or continuing with the normal mode of extracting all animats. This ability is useful for scenarios populated with a large number of animats when the user wants to verify output of one or a few of them. Manually extracting binary data into track files is accomplished by clicking the *Extract Data* button on the **3MB** main panel. For scenarios that output animat track files, or when extracted manually, the naming format is:

```
[ID].[offScreenCnt]_[sceName]_[speName][speNumber]_[podType][podMemship]
```

where

`ID`	is the animatôs unique identification in the scenario ranging from 0 to the number of animats in the scenario minus 1 (zero-based indexing).
`offScreenCnt`	is the file count number associated with the number of times the animat went off screen and was consequently restarted as an entirely new animat.
`SceName`	is the scenarioôs saved file name.
`SpeName`	is the name of the species the animat belongs to.
`SpeNumber`	is the species number as listed on the seeding panel of the 3MB.exe.
`PodType`	is either ñindò or ñpodò to mean the animat is either an individual or pod member
`PodMemship`	is the animatôs pod membership value. For individuals this value will always be a 1. For pods, the pod leader will always be a 1 and followers will always be greater than 1.

Consider the naming of the following animat track file sequence

00000.000_quickTest_blue whale01_ind001.trk

00000.001_quickTest_blue whale01_ind001.trk

00000.002_quickTest_blue whale01_ind001.trk

This example shows that animat 0 of a scenario named quickTest went off screen twice, was an individual, and was identified by the species named *blue whale*. Note that the ability to generate this format assumes that the *animat to species association* data set is specified to be included in the binary output. The *animat to species association* data set is specified through the *Options* panel accessible by clicking on the *Options* button on the **3MB** main panel.

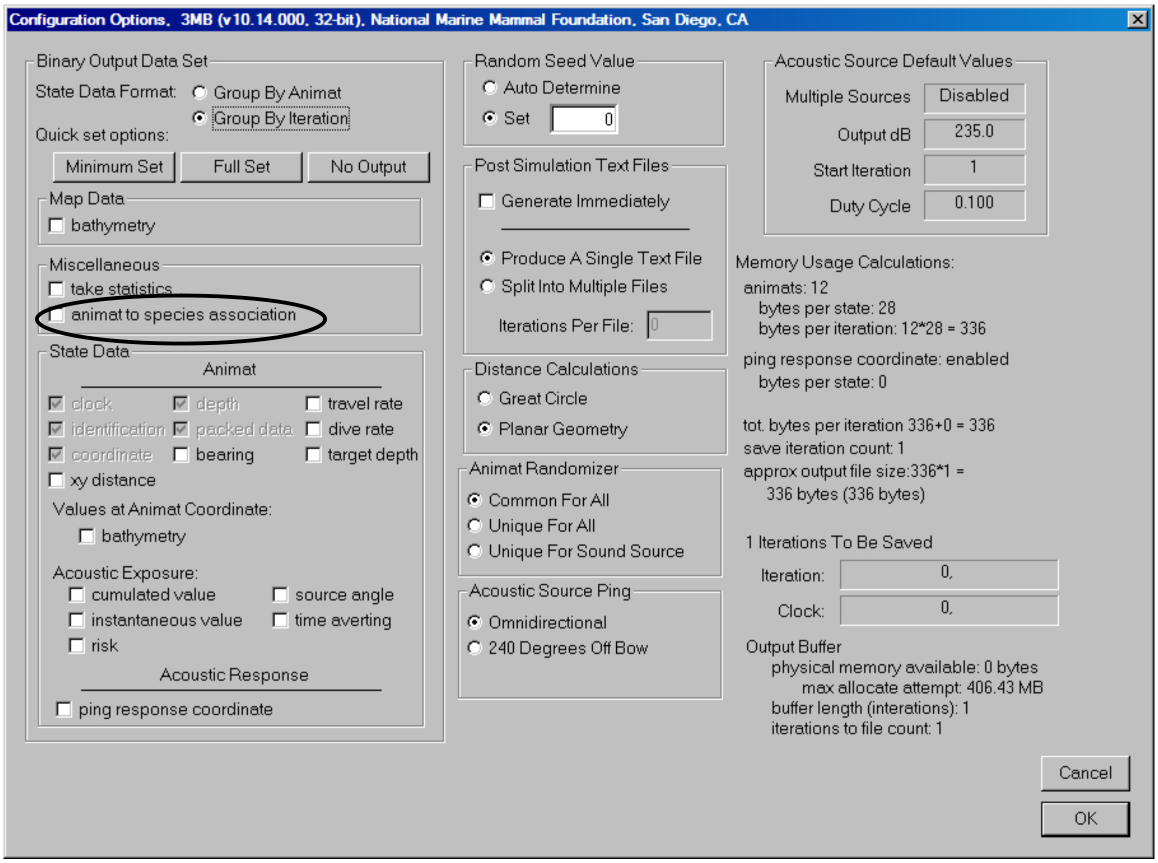


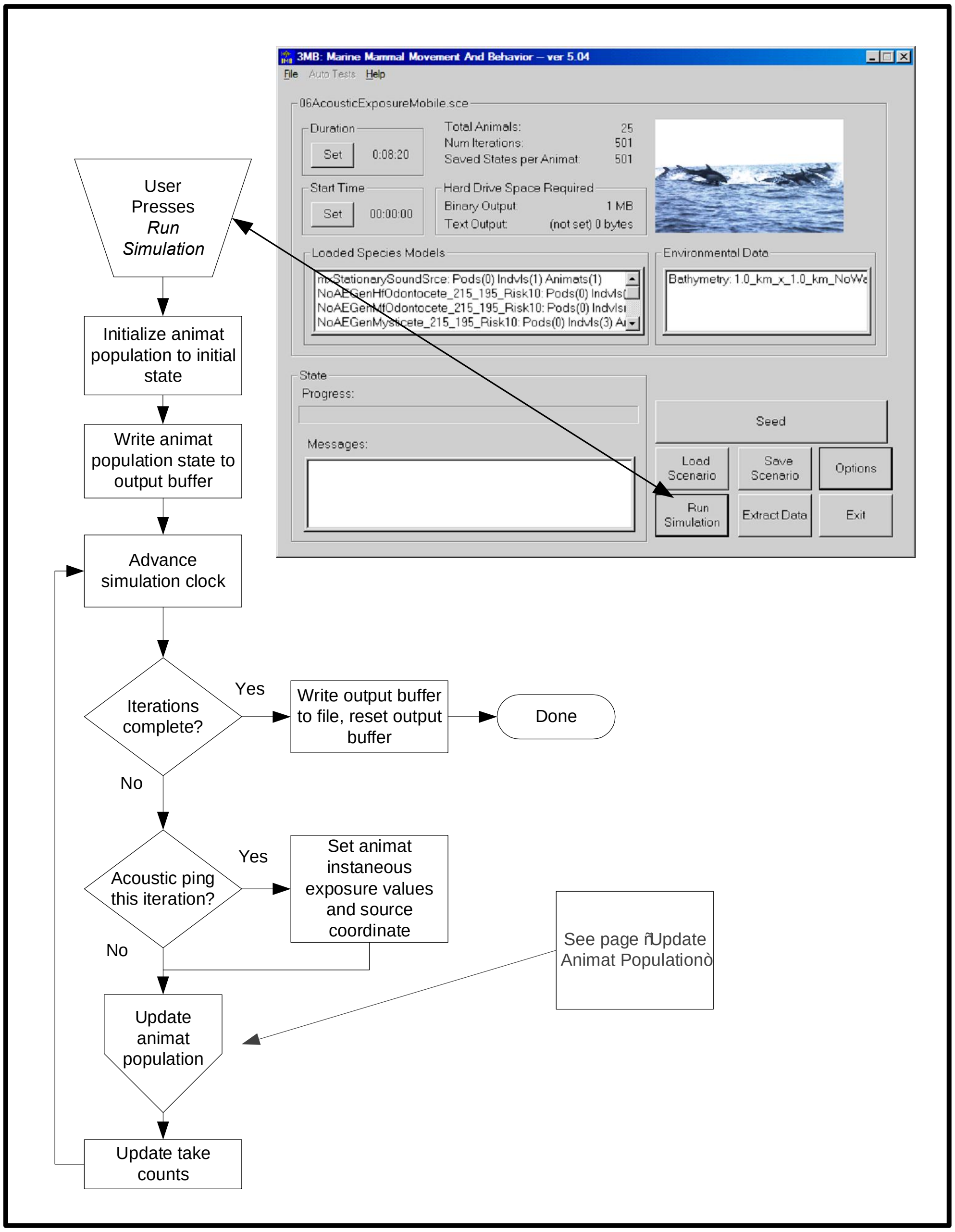
Figure 17. The Options sub-panel and the control making the animat-to-species association.

If the animat to species association data set is not included in the binary output file then the name of the extracted animat track files will simply be its order in the animat population.

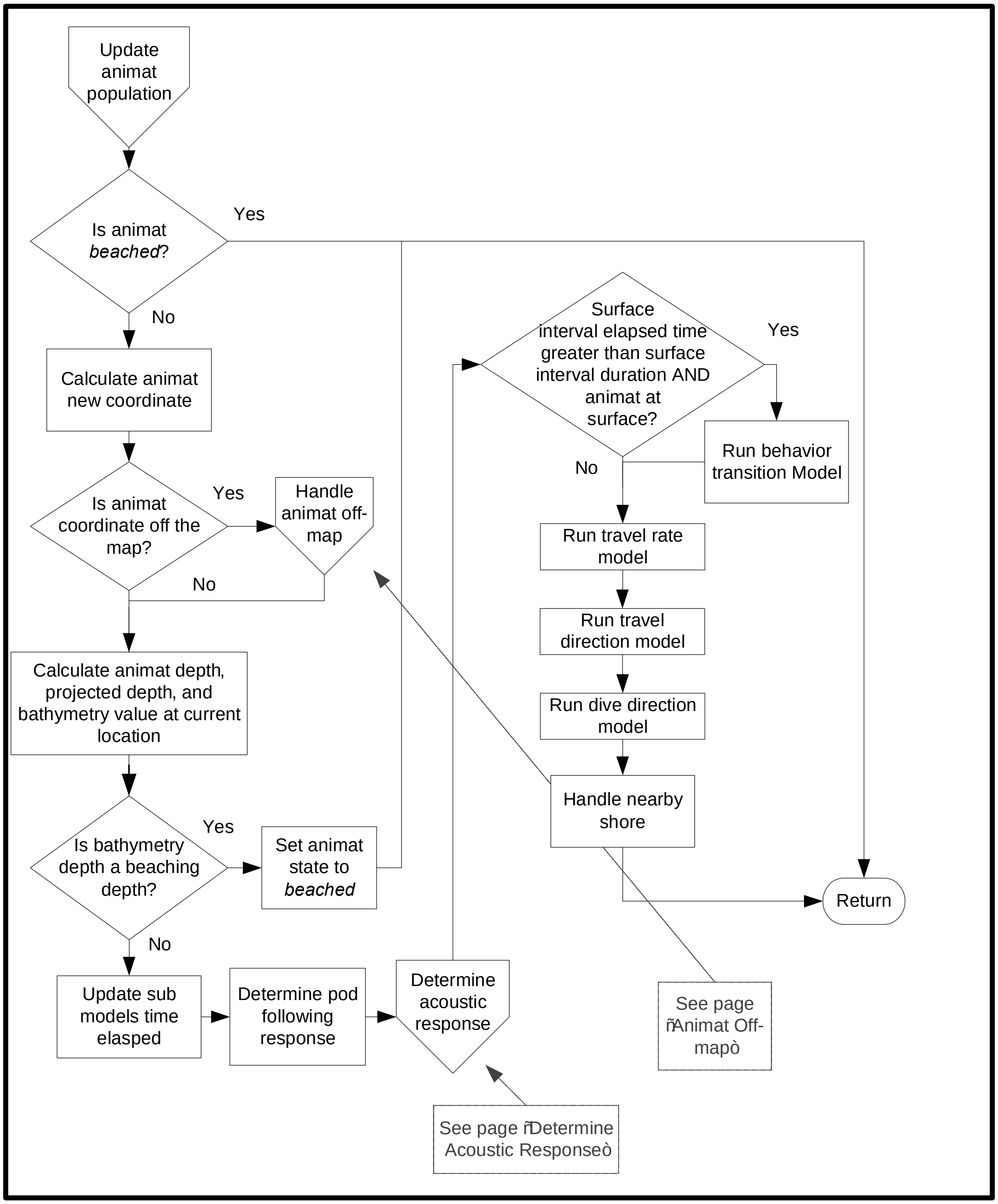
Process Flow-Charts

The following pages demonstrate the **3MB** process flow in graphical format. Each of the displays is meant to increase the userõs understanding of the order of operations within **3MB**.

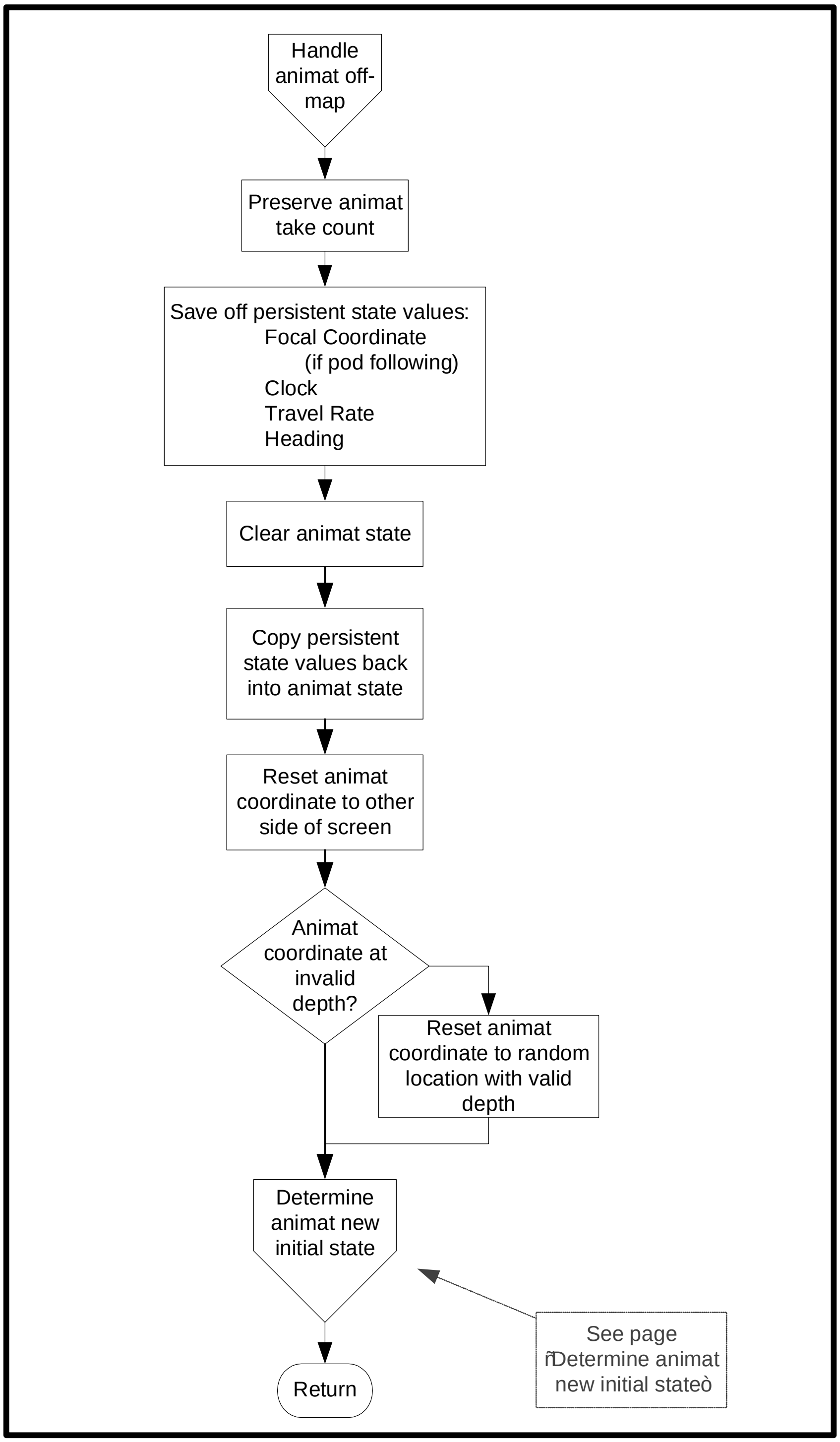
Program Flow Overview



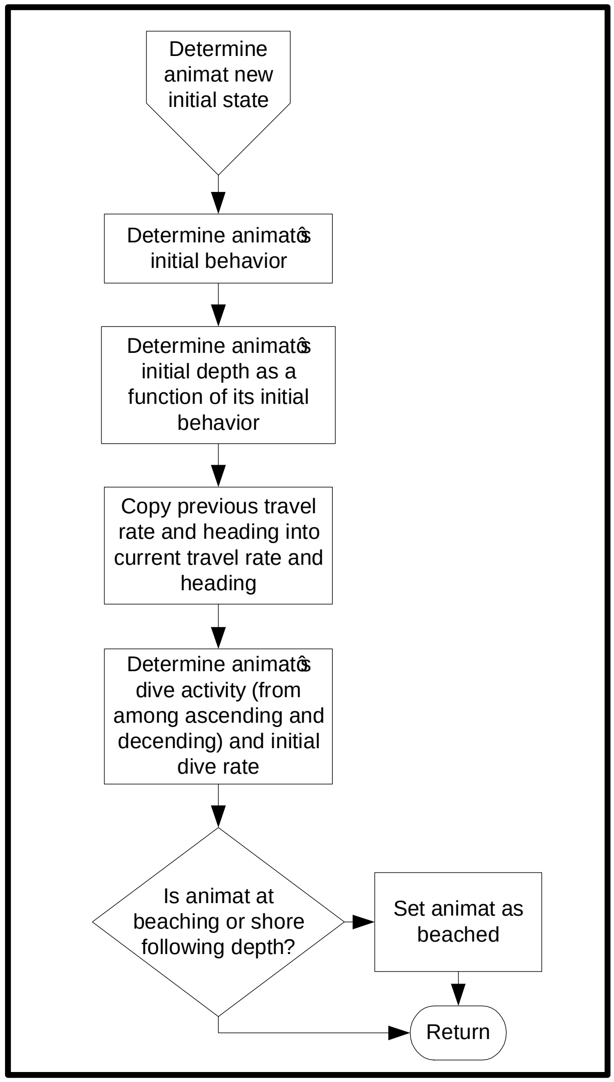
Update Animat Population



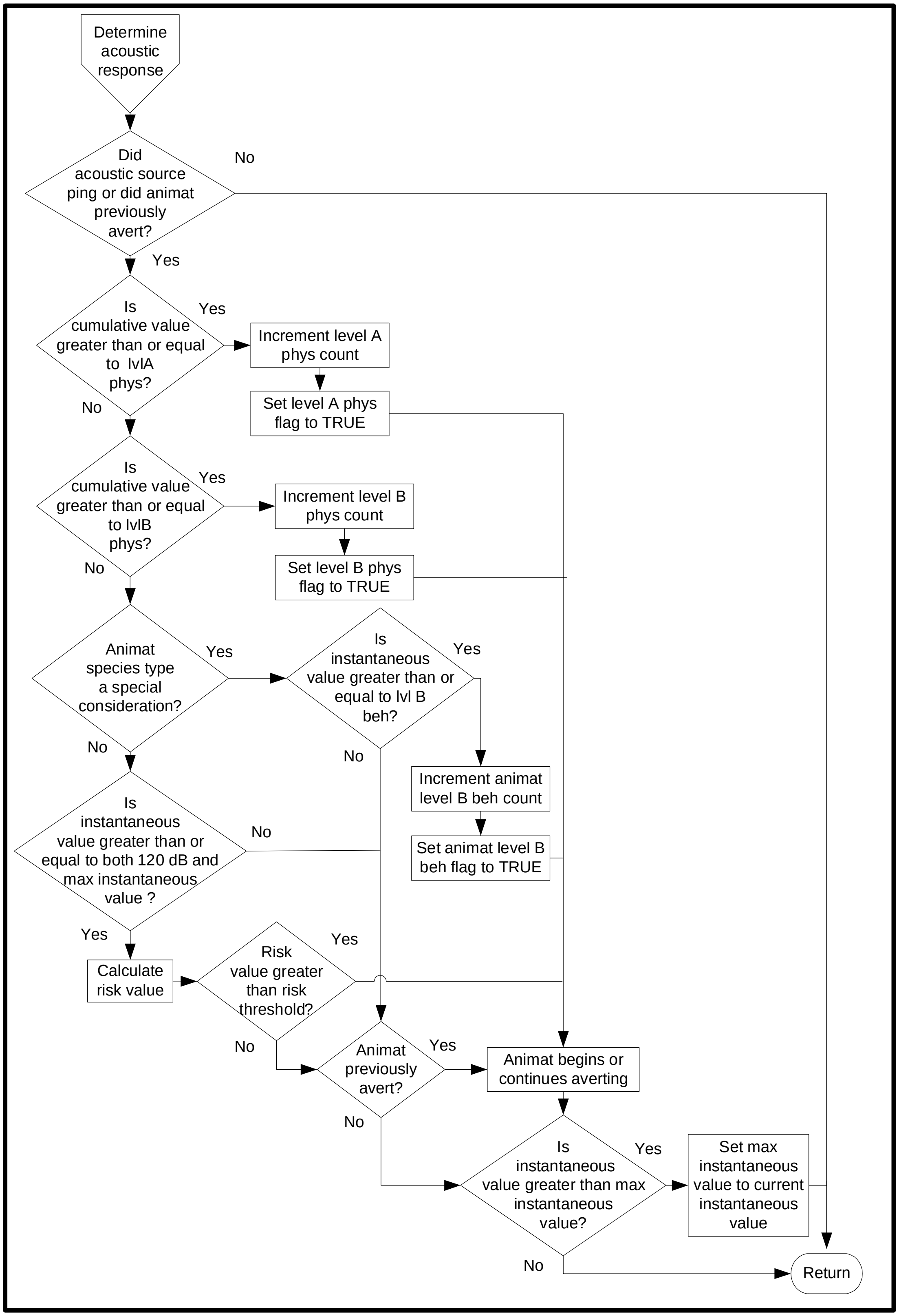
Handle Animat Off-Map



Determine Animat New Initial State



Determine Acoustic Response



Animat State Variables

General State Variables
- clock
- current behavior
- travel direction (heading)
- travel rate
- dive rate
- coordinate
- beached?
- delta X and Y
- depth
- bathy depth at
  current (current) coordinate

Pod Following State Variables
- currently engaged?
- time elapsed
- set focal distance
- current focal distance
- focal heading
- focal coordinate

Shore Following State Variables
- currently engaged?
- current heading

Acoustic Aversion State Variables
- source coordinate
- instantaneous exposure
- cumulative exposure
- relative angle to acoustic source
- desired heading away from source
- risk value
- maximum instantaneous value
- is set?
- is active?
- time elapsed
- level A physical flag
- level A physical count
- level B physical flag
- level B physical count
- level B behavioral flag
- level B behavioral count

Normal Behavior State Variables
- current behavior
  - current behavior time elapsed
  - current behavior end dice
- travel direction (heading)
  - travel direction time elapsed
  - travel direction end dice
- travel rate
  - travel rate time elapsed
  - travel rate end dice
- dive rate
  - dive rate time elapsed
  - dive end dice
- surface interval set duration
- surface interval time elapsed
- target depth
- projected depth
- reversals remaining
- reversal set leg duration
- reversal leg time elapsed
- current dive activity =
  {*surface interval,*
  bottom following,
  ascending,
  descending,
  descending reversal,
  descending reversal,
  beached}

Rights, Usage and Bug Reporting

The **3MB** program and the **Species Builder** were developed with support from the Office of Naval Research. The programs are a component of the Effects of Sound on the Marine Environment (**ESME**) modeling effort. **3MB** and the **Species Builder** are open-source. Users may contact Dr. Dorian Houser (dorian.houser@nmmf.org) for copies of the work space. Users are encouraged to provide recommendations for enhancements to the program and to report any bugs in the program they encounter. Bug reports may be sent to matt.cross@nmmf.org. In bug reporting, please specify the procedures that resulted in the error and the type of error that was encountered.

References

Houser, D. S. (2006). "A method for modeling marine mammal movement and behavior for environmental impact assessment." IEEE Journal of Oceanic Engineering **31**(1): 76-81.

Kastak, D., B. L. Southall, et al. (2005). "Underwater temporary threshold shift in pinnipeds: effects of noise level and duration." Journal of the Acoustical Society of America **118**(5): 3154-3163.

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U.S. Navy (2008b). Southern California Range Complex: Final Environmental Impact Statement/Overseas Environmental Impact Statement. Washington, DC, Department of the Navy.