Species Distribution Builder

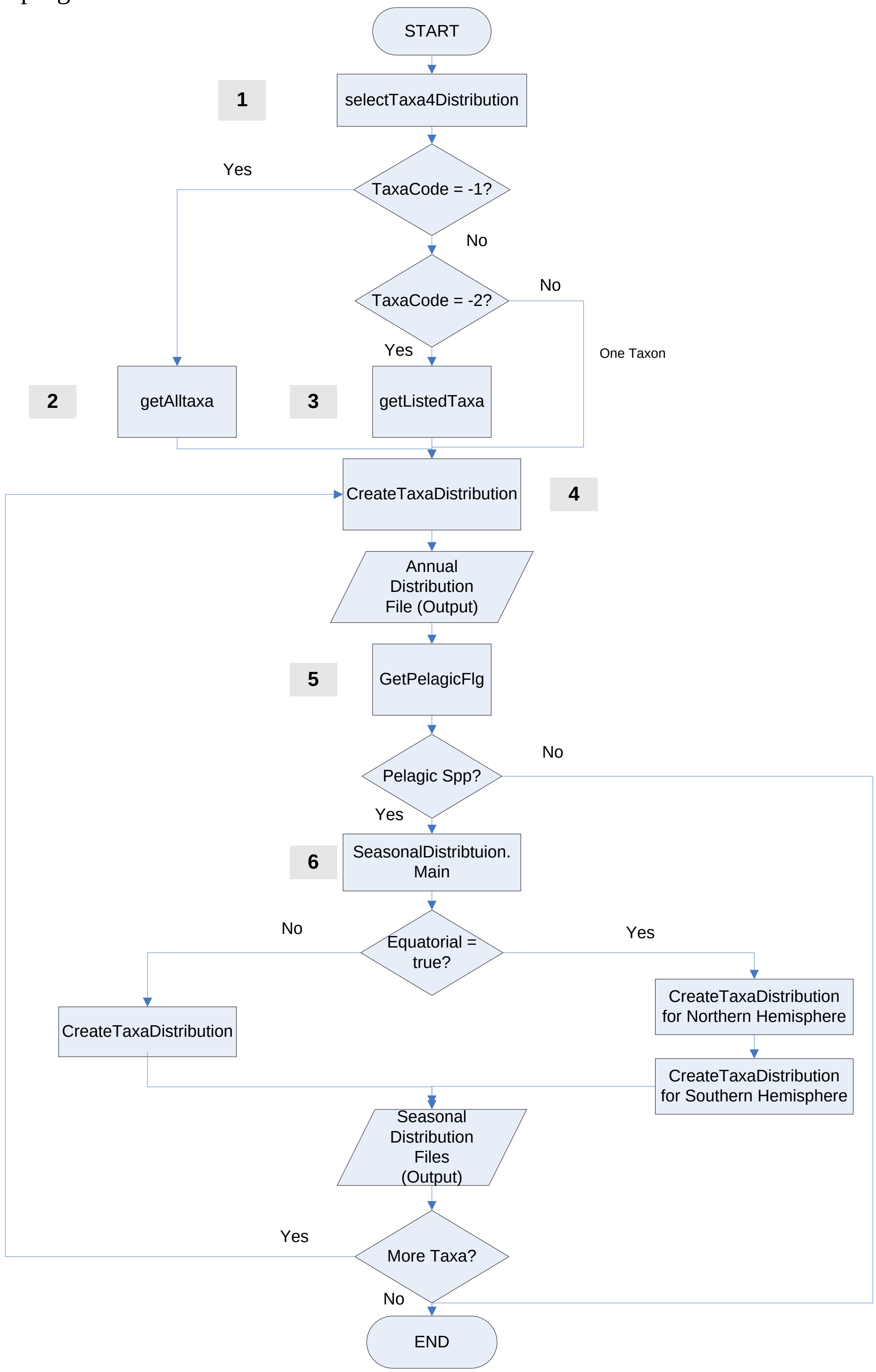
A. *Goal of the program:*
To build distribution files for commercial taxa.

B. *Input parameters:*

Data	Format	Location
World cell data	mdb (World Table)	`C:\SAUPDATA\WORLD\World2.mdb`
Taxon Parameters	mdb (`QryAllTaxon`)	`C:\SAUPDATA\TAXON\TaxonTable.mdb`
Habitat data	mdb (TaxonHabitat Table)	`C:\SAUPDATA\TAXON\TaxonTable.mdb`
Summer SST	CSV file	`C:\SAUPDATA\TEMPERATURE\SummerSST.txt`
Winter SST	CSV file	`C:\SAUPDATA\TEMPERATURE\WinterSST.txt`
Annual SST	CSV file	`C:\SAUPDATA\TEMPERATURE\AnnualSST.txt`
Bathymetry	CSV file	`C:\SAUPDATA\Bathy\Bathy.txt`
Word water data (percentage of water in each cell)	CSV file	`C:\SAUPDATA\WORLD\WorldWater.txt`

C. *Outline of the Entire process:*
Figure 1 outlines the process for predicting the distribution of commercial taxa.

Figure 1. Flow diagram showing main sub-routines and functions of the species distribution program.



D. *Details of subroutines and functions:*

1. **selectTaxa4Distribution( )**
In this subroutine, we get the taxa parameters based on the selection of the user. If the user input -1 for taxacode, then the distribution files of all the taxa in the TaxonTable would be created. If the user input -2 for taxacode, then the program would only create the distribution files for those taxa on the list prepared by the user. Only a single distribution file would be created if the user just entered the Taxon Key of a particular taxon. In the meantime, we will set the values of the various flags based on different criteria. For example, if the taxon is a pelagic species, then flgPelagic would be set to true.

2. **getAllTaxa( )**
Return taxon key of all commercial taxa from the TaxonDist table.

3. **getListedTaxa( )**
Get the taxon key of all the taxa listed in the ToDoTaxa.txt file

4. **CreateTaxaDistribution( )**
It is the main function for building the distribution. This function computes the parameters and calculates abundance in each cell. Please refer to Figure 2 for details.

5. **GetPelagicFlg**
Return pelagic flag of a particular taxon.

6. **SeasonalDistribution.Main( )**
The subroutine of this module would return the new latitudinal limits in each season.
The temperature range within the distribution range of each species in different seasons (Winter and Summer) were first compared with the annual temperature and then we can determine where the species will shift to in different seasons. The extent of shift is determined by the aspect ratio and invertebrate movement ability which are combined to form a new index called Motility (Figure 3).

Figure 2. Flow diagram of the createTaxaDistribution subroutine.

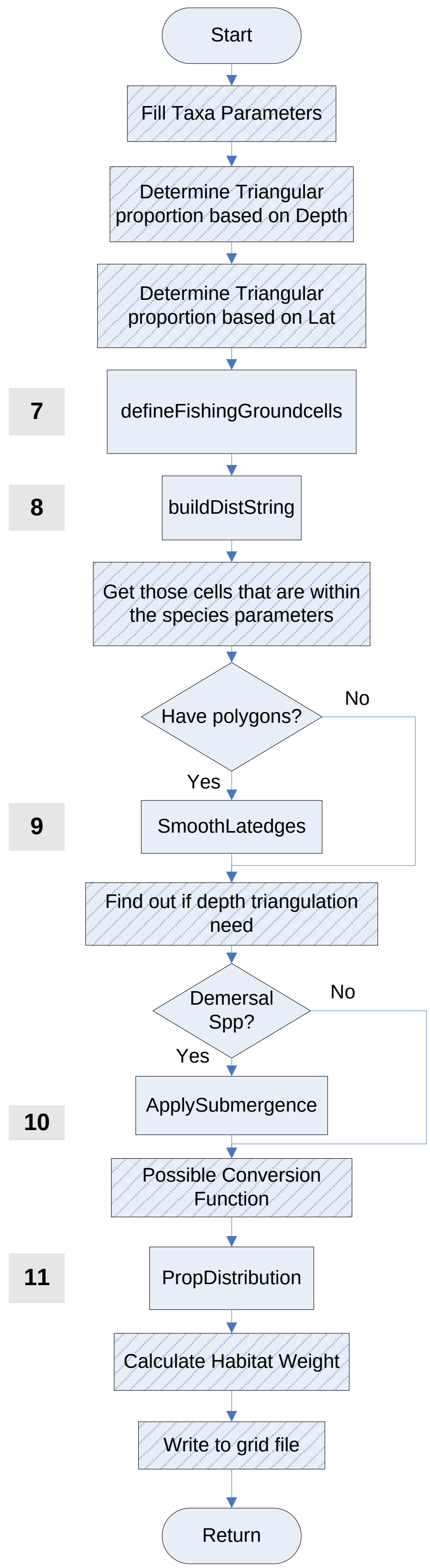
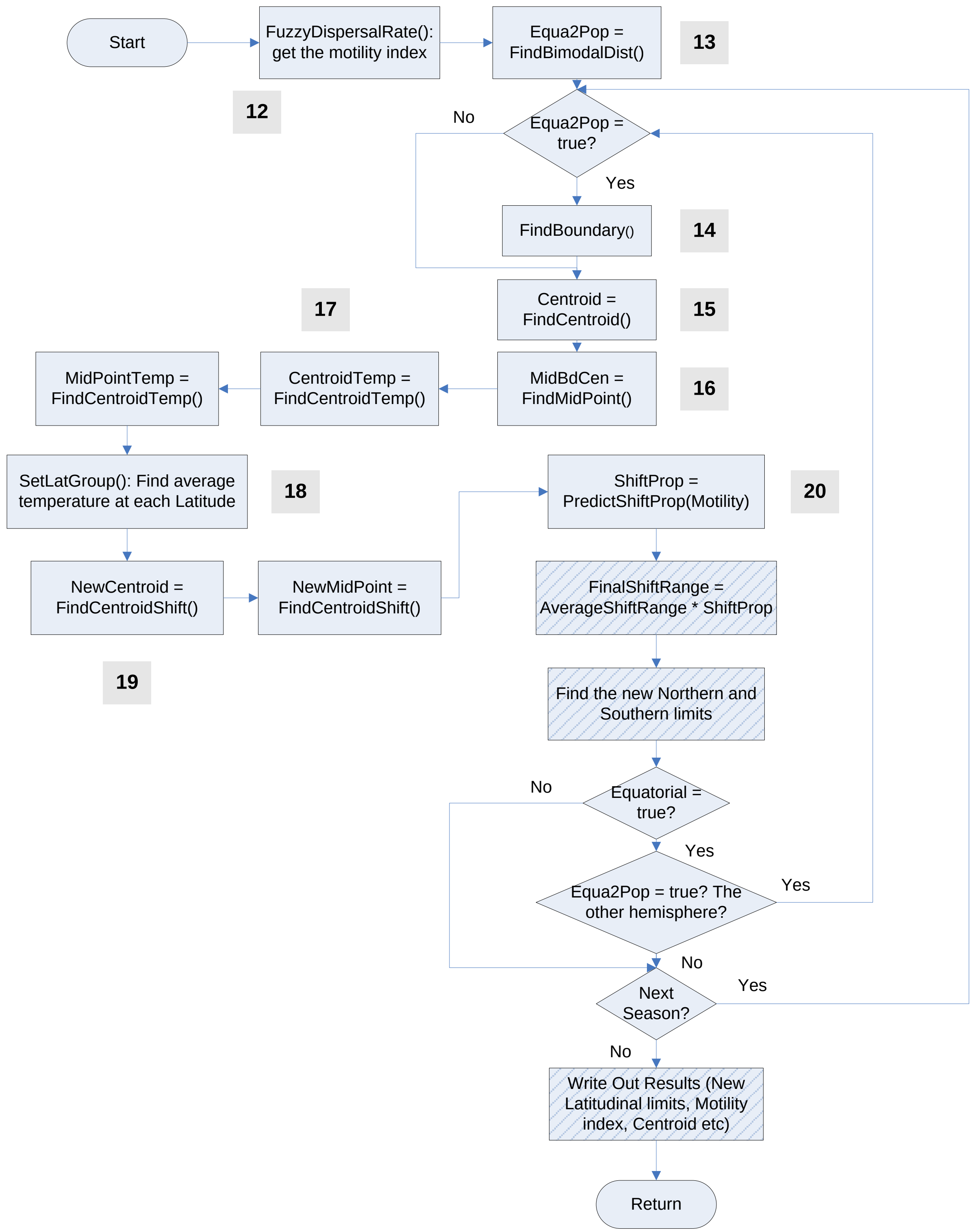


Figure 3. Flow diagram of the Main( ) subroutine in SeasonalDistribution Module.



D. *Details of subroutines and functions (continued):*

7. DefinefishingGroundCell( )
Determine and define fishing ground polygons using the coordinates from the FishCode and FishGrdCoord tables.

8. buildDistString( )
Build SQL for cell selection.
Note: Polygon has priority over FAO area filter and the code was designed in a way which would not allow the FAO string to be blank.. If Polyflg is false (i.e. no polygon for this taxon) and FAOstring is nothing, then FAOstring = all FAO areas. If Polyflg = true, FAO string also equals to all FAO areas as the polygon will select the appropriate area within these FAO areas.

9. SmoothLatedges( ) (Created by William)
A routine to smooth the edges of latitudinal distributions of pelagic taxa. Assume a linear decrease from 1/5 of latitudinal distance between edge and equator. (will be added more by William).

10. ApplySubmergence( )
Return the coefficients a and c for the submergecne equation. The submergence equation will be used for determining the minimum and maximum depth of a taxon at different latitude.

$$Depth = A + C * Lat$$

where Lat is the latitude at each cell.

Please see Figure 4 for the details of this subroutine.

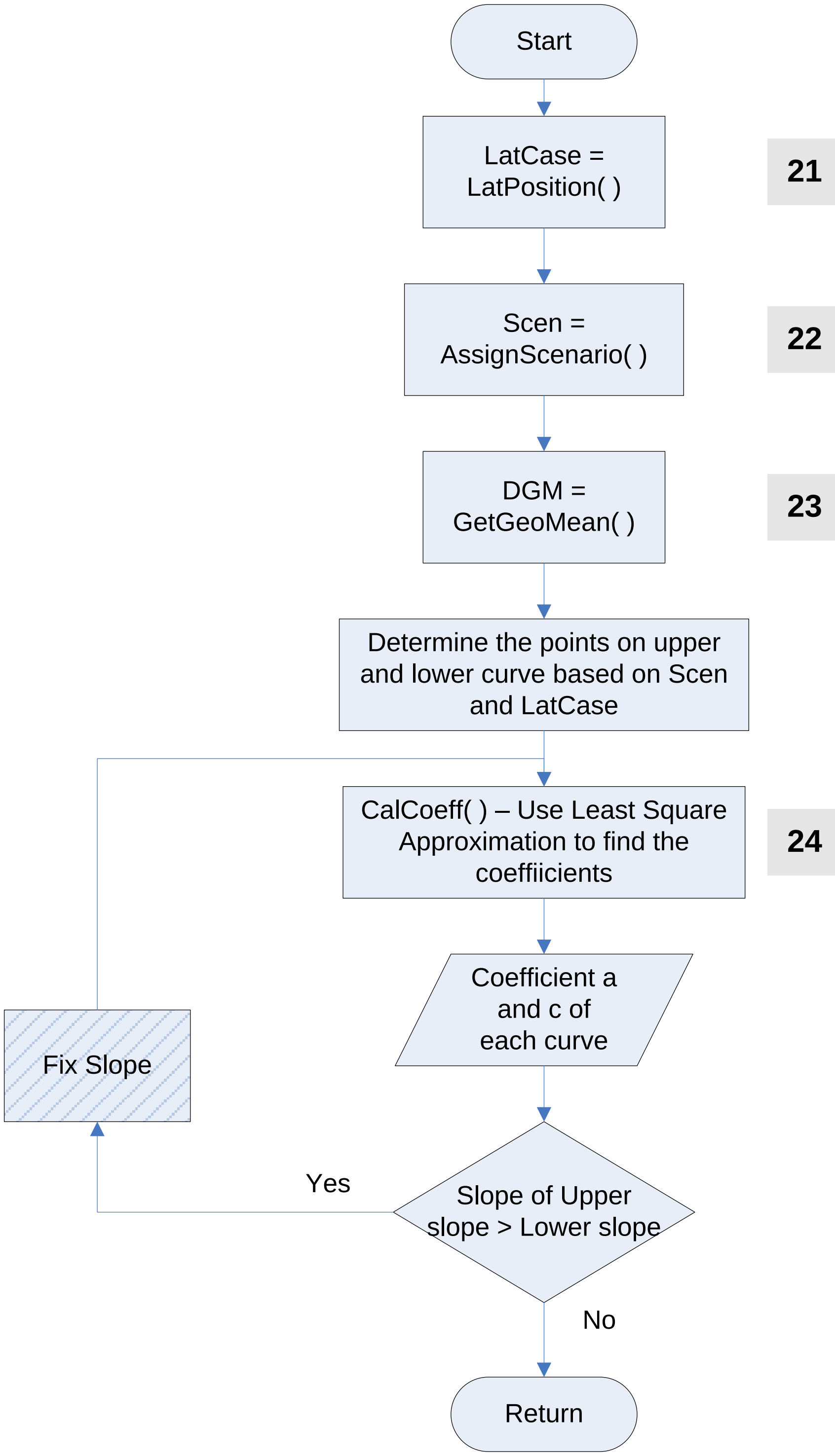
11. PropDistribution( )
Makes sure the cell values are proportional and add to 1.

12. FuzzyDispersalRate( )
Function to calculate the motility index using a fuzzy logic expert system. Parameters pass to this function are fish length, aspect ratio and an index representing the movement ability of the species if it is an invertebrate.

13. FindBimodalDist( )
Function to check whether there are two separate subpopulations in the Northern and Southern hemisphere. If it is true, return Equa2Pop = true.

14. FindBoundary( )
Function to find the Southern limit in the Northern hemisphere and Northern limit in the Southern hemisphere if Equa2Pop = true for this species.

Figure 4. Flow diagram of the ApplySubmergence( ) subroutine.



D. *Details of subroutines and functions (continued):*

15. FindCentroid( )
Function to find the centroid of each pelagic species. Return the latitude of the centroid.

16. FindMidPoint( )
Function to find the mid point between the centroid and the southern/northern limit. Return the latitude of the mid point.

17. FindCentroidTemp( )
Function to find the average temperature at the same latitude as or at the latitiude close to the centroid/mid-point.

18. SetLatGroup( )
Set latitudinal group and find the average temperature of each group.

19. FindCentroidShift( )
Compare the temperature at centroid with the annual temperature data at all other latitudes and find out where the temperature at centroid shift to.

20. PredictShiftProp( )
Function to calculate the shift proportion of each species base on the Motility index calculated from the FuzzyDispersalRate function. The species will move to the new boundary if the motility index = 100%. The species will not move at all if the motility index = 0.

21. Submergence.LatPosition( )
Assign the species to different cases:

Case 1 = both lat_N and lat_S are in Northern Hemisphere, min depth is at lat_N whereas max_depth is at lat_S

Case 2 = both lat_N and lat_S are in Southern Hemisphere, min depth is at Lat_S whereas max_depth is at Lat_N

Case 3 = Lat_N is in Northern Hemisphere and Lat_S is in Southern Hemisphere, Min depth is at Lat_N whereas max depth is at Lat zero (i.e. abs(Lat_N)>Abs(Lat_S))

Case 4 = Lat_N is in the Northern Hemisphere and Lat_S is in the Southern Hemisphere, Min depth is at Lat_S whereas max depth is at Lat zero (i.e. abs(Lat_N)<abs(Lat_S))

Case 5 = Lat_N is in the Northern Hemisphere and Lat_S is in Southern Hemisphere. When abs(Lat_N) = abs(Lat_S), min depth is at either Lat_S/Lat_N and max depth is at lat zero.

Case 6 = Lat_N or/and Lat_S is/are 90 deg and/or Max Depth = 9999.

22. Submergence.AssignScenario( )
Assign different scenarios to each taxon:
Scenario 1: LatN>=60 OR LatN<=-60 OR LatS <=-60 OR LatS >=60
Scenario 2: LatN<60 OR LatN > -60 OR LatS > -60 OR Lat< 60

23. Submergence.GetGeoMean( )
Function to get the geometric mean between the minimum and maximum depth.

24. Submergence.CalCoeff( )
Use Least Square Approximation to find a & c (coefficients of equation).

25. getLatVal( )
Fucntion to get latitude weight value for a cell.

26. getDepthVal( )
Function to get depth weight value for a cell.

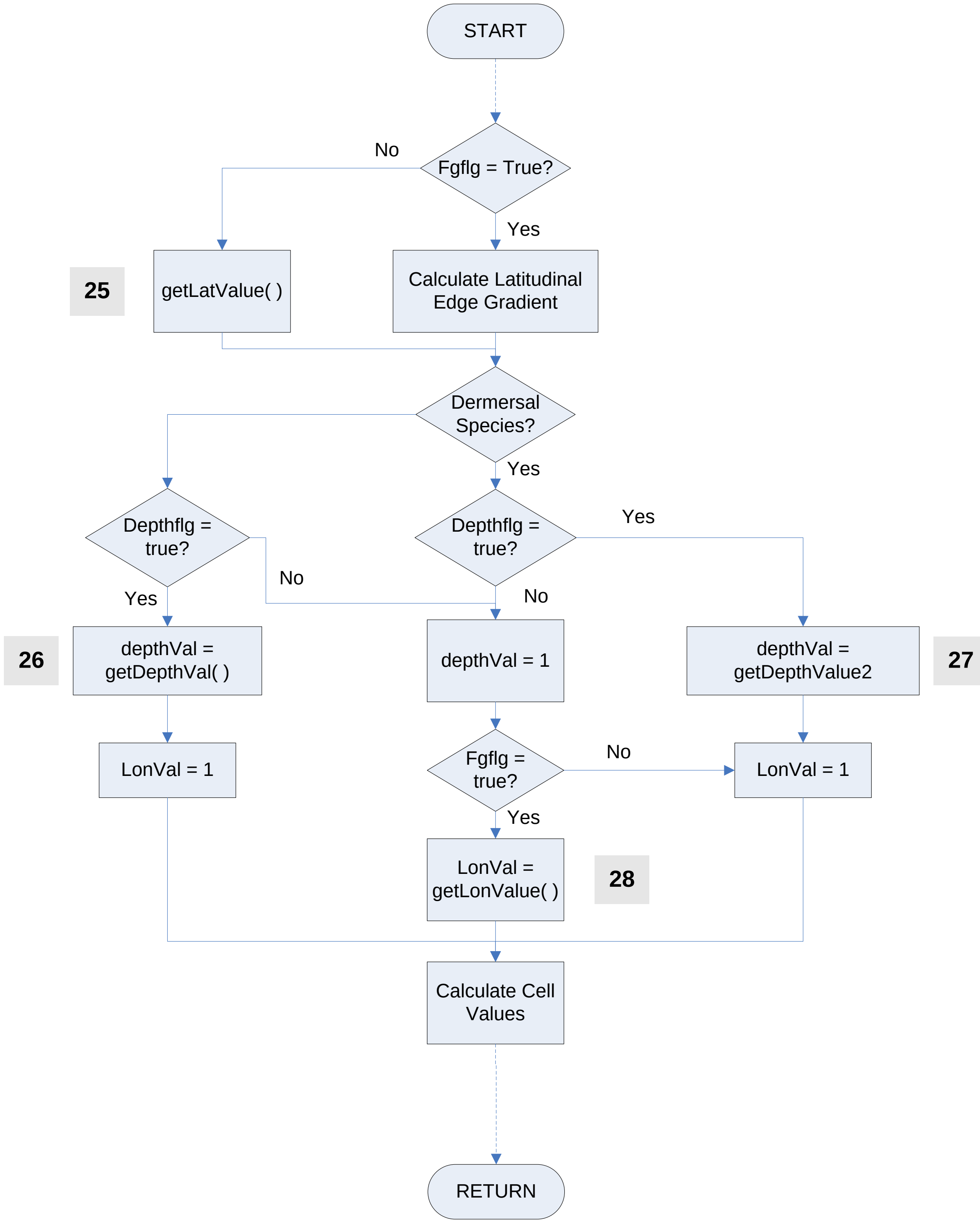
27. getDepthVal2( )
Similar to getDepthVal( ) function but this function compute the minimum and maximum depth at that latitude using the coefficients a and c from ApplySubmergence( ) function. Only use this function for dermersal species.

28. getLatVal( )
Function to get longitudinal weight value for a cell.

E. Details of some steps within the subroutines or fucntions:

a. Possible Conversion Function:
This function is found in the CreateTaxaDistribution( ) subroutine and it is used for calculating different parameters which will be used for computing cell values in each cell (Figure 5).

Figure 5. Flow diagram showing the details of possible conversion function in createTaxaDistribution( ) function.



F. *Output of the program:*

Output Data	Format	Locations
Species Distribution file	CSV	`C:\Temp\gridfiles\`
Pelagic Species		
Summer Species Distribution file	CSV	`C:\Temp\Summer\`
Winter Species Distribution file	CSV	`C:\Temp\Winter\`
Motility Index	CSV	`C:\Temp\Motility\motility.txt`
Centroid info of one species (new centroid, centroid temperature, new mid point, mid-point temperature etc)	CSV	`C:\Temp\Motility\Centroid.txt`
Lat Shift info of all species in Summer (with new centroid, centroid temperature, new mid point, mid-point temperature etc)	CSV	`C:\Temp\Summer\SummerRec.txt`
Lat shift info of all species in Winter (with new centroid, centroid temperature, new mid point, mid-point temperature etc)	CSV	`C:\Temp\Summer\WinterRec.txt`

G. *Appendix*

Details for shifting the pelagic species distribution range in different seasons

When the ocean temperature changes, the species distribution range shift. Since species usually occupy the regions with its suitable temperature, we assume the distribution range shifts to the north in summer (July to September) whereas the distribution range shifts to the south in winter (January to March).

Centroid of the Distribution Range

In order to predict the seasonal shift of the whole distribution range, the centroid of the total distribution range was first computed by:

$$C = \frac{\sum_{i=1}^{n} A_i L_i}{\sum_{i=1}^{n} A_i}$$

where C is the latitude of the centroid of original distribution range, A_i is the species abundance in each cell, L_i is the latitude of individual cell, and n is the total number of cells.

For species with distribution range extended beyond the equator, only centroid in the southern hemisphere would be taken in summer and centroid in the northern hemisphere would be taken in winter.

Sea Surface Temperature at the Centroid

Sea surface temperature (SST) at the centroid in each season was found. In the meantime, the latitudes along the whole distribution range were arranged into groups and the average SST in each latitudinal group was computed for each season.

Summer
The annual SST value at the centroid was compared with the SST at all the latitudinal groups in summer, and then we could find out where the SST at the centroid would shift to during summer.

Winter
The annual SST value at the centroid was compared with the SST at all the latitudinal groups in winter, and then we could find out where the SST at the centroid would shift to during winter.

Centroid Shift

The shift in latitude (in degree) of the centroid could then be calculated by subtracting the latitude of the old centroid by that of new centroid. In summer, the centroid was predicted to move northward whereas the centroid was predicted to move southward in winter.

Shift in Distribution Range

The actual shift in the distribution range was determined by the Motility Index. This index ranges from 0 to 100. Species with higher index value have a higher motility, which means higher ability to move, and vice versa. For species with motility index equals to 100, the northern and southern boundaries of the species will change by the whole latitudinal shift in the centroid. This index was calculated by using fuzzy logic system and the input parameters were fish body length, aspect ratio of caudal fin and an index which represents the movement ability of invertebrate species.

Shift in the distribution range was then calculated by:

$$S = CS * M / 100$$

where S is the actual shift in distribution range (in degree), CS is the latitudinal shift in centroid and M is the motility index.

Summer
Species move northward within its total distribution range in summer. The southern bound of the distribution range would shift to the north but the northern bound would be kept unchanged. The southern bound in summer was calculated by:

$$SL' = SL + S$$

where SL' is the latitude of the southern bound in summer, SL is the latitude of the original southern bound and S is the actual shift in distribution range in summer.

Winter
Species move southward within its total distribution range in winter. The northern bound of the distribution range would shift to the south but the southern bound would be kept unchanged. The northern bound in winter was calculated by:

$$NL' = NL - S$$

where NL' is the latitude of the northern bound in winter, NL is the latitude of the original northern bound and S is the actual shift in the distribution range in winter.