Modifiable Multistock Model (M3)

Users guide

V1.3

6th January 2017

Tom Carruthers, UBC t.carruthers@oceans.ubc.ca

ICCAT GBYP gbyp@iccat.int

ICCAT Core Modelling Group

Laurie Kell, Antonio Di Natale, Doug Butterworth, Harritz Arrizabalaga, Yukio Takeuchi, Sylvain Bonhommeau, Toshi Kitakado, Clay Porch, David Die, Miguel Santos, Paul de Bruyn, Polina Levontin, Richard Hillary.

Release notes

- Initialization by SRA (v1.3)
- Fit to historical CPUE indices
- Age based-movement now estimated (v1.2).
- Fishery spool-up to fishing rates in the initial years has been added (v1.2 – now defunct).
- Fishery selectivity reparameterized (v1.0)
- Historical recruitment deviations are now estimated (v1.0)

M3 is currently subject to review. It has been fitted to the data and assumptions of the ICCAT trial specification document for ABT. Any comments, bugs or otherwise can be forwarded to t.carruthers@fisheries.ubc.ca.

M3 was compiled using ADMB 11.5 (64 bit) under Windows 10 using mingw64

1 Table of Contents

2 Introduction

M3 is a spatial, multistock, seasonal, statistical catch-at-length stock assessment model. The model predicts the distribution and movement of individuals among large discrete marine areas (a bulk transfer model, e.g. Taylor et al. 2011).

M3 was designed to be used as an operating model that could be fitted to various data to predict spatial stock structure of a multi-stock fishery (specifically Atlantic bluefin tuna). As such M3 includes several simplifications over a conventional age-structured stock assessment in order to reduce the number of calculations and ensure that the estimation problem is well defined. The two most important simplifications relate to the use of conventional tagging data and the estimation of fishing mortality rates for each fleet in spatio-temporal strata:

(1) M3 uses conventional tagging data only qualitatively to identify other possible migrations that are not observed from electronic tagging (pop-off satellite archival, archival). M3 does not include computationally intensive conditional probability calculations for all of the conventional (spaghetti, floy) tagging data that are considered to be compromised due to highly uncertain and variable reporting rates over time and among fishing fleet types.

(2) The M3 model does not attempt to estimate a fishing mortality rate for each fleet in each spatio-temporal strata (for example the Japanese longline fleet in January 1962 in area 2). Instead partial fishing mortality rates (partial Fs) are calculated by dividing observed catches by a 'master' relative abundance index for each spatio-temporal strata. The master relative abundance index is constructed by generalized linear modelling and time-area imputation (e.g. Carruthers et al. 2011) prior to the M3 run. The partial F data (by fleet, time and area) are inputs to the M3 model which then predicts fishing mortality rate by multiplying these partial Fs by a single catchability coefficient by fleet. This greatly reduces the number of estimated parameters (e.g. 4 parameters instead of 8000 for a 50 year, 4 subyear, 10 area model with 4 fleets).

Previous multi-stock models for Atlantic bluefin tuna have made use of catch-at-age composition data. However these data are very sparse and derived by approaches such as cohort slicing and therefore provide inference of fishing mortality rate that may be both biased and imprecise. M3 sidesteps this problem by fitting to length composition data. The additional requirement of this approach is an inverse age-length key (conditional probability of an individual being in a length class l given it is of age class a).

Currently the model estimates age-group specific movement and requires stock of origin data and electronic tagging data (e.g. otolith microchemistry) by age class, space, subyear and year.

The latest version of the model initializes by stock reduction analysis, removing historical catches from 1880-1959 to derive numbers at age of both stocks in 1960.

3 Model description

M3 is a fisheries assessment model based on standard equations for age-structured population dynamics (e.g. Quinn and Deriso 1999, Chapter 8) which is common to stock assessment models such as Stock Synthesis 3 (Methot and Wetzel 2013), CASAL (Bull et al. 2012), Multifan-CL (Fournier et al. 1998) and iSCAM

(Martell 2015). Similar to these assessment packages, M3 is developed using ADMB (Fournier et al. 2012) for its rapid and robust non-linear estimation performance for problems with relatively large numbers of parameters (i.e. more than 100 parameters).

The conventional age-structured accounting is somewhat more complex for a spatial multi-state model because transitions among states among years (i.e. movement probabilities) must be either specified or estimated. In the case of the M3 model this is further complicated by the additional stratification by subyear that must account for variable duration of subyears and distinguish between subyears in which there is recruitment. A full account of model equations is included in the trial specifications document (the actual model code, the ADMB template file, is included in Appendix B).

4 Formatting data for input to M3

Similarly to other fishery assessment models (e.g. Stock Synthesis, Wetzel and Methot 2011. ISCAM Martell 2016) M3 is implemented in AD Model Builder (Fournier et al. xxx). The data must be formatted into an M3.dat file in order to fit the model. Below is a description of each field of this data file.

(1) nHy: an integer value, number historical model years used for initialization by stock reduction analysis e.g. years 1864 to 1959 (a total of 96 years)
96

(2) ny: an integer value, number of model years
55

(3) ns: an integer value, number of model subyears (e.g. 4 for a seasonal model)
4

(4) np: an integer value, number of model stocks / populations (e.g. 2 for an east-west Atlantic bluefin)
4

(5) na: an integer value, number of age classes
35

(6) nr: an integer value, number of spatial areas
8

(7) nf: an integer value, number of fleets (fishing activities of similar size selectivity)
5

(8) nl: an integer value, number of length classes
38

(9) nRPT: an integer value, maximum number of time steps (subyears) that a PSAT can be recaptured (limits unnecessary calculation)
2

(10) RPTind: a matrix of integers ns rows by nRPT columns. This matrix is the correct subyear recapture index after col time steps.

1 2 3
2 3 4
3 4 1
4 1 2

(11) sdur: a vector of fractions (sum to 1) ns long that is the relative duration of each subyear.

0.25 0.25 0.25 0.25

(12) nydist: an integer value, the number annual iterations used to determine stable spatial distribution d of the stock given an estimated movement matrix M (ie to approximate d=Md).

50

(13) ml: a vector of positive real numbers nl long that are the mean length of each length class

25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195 205 215 225 235 245 255 265 275 285 295 305 315 325 335 345 355 365 375 385 395

(14) RDblock: an integer vector ny long representing the recruitment deviation blocking (e.g. 1,1,1,1,1,2,2,2,2,2,… represents the estimation of two recruitment deviations for the first and second five year block respectively).

1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4 5 5 5 5 5 6 6 6 6 6 7 7 7 7 7 8 8 8 8 8 9 9 9 9 9 10 10 10 10 10 11 11 11 11 11

(15) nRD: the number of estimated recruitment deviations (matches max(RDblock)).

11

(16) iALK: a 4D array (np, ny, na, nl) of fractions (sum to 1 over length classes) of the conditional probability of length class l given age class a.

3.322514e-07 0.001265241 0.1641068 0.7249812 0.1090873 0.0005590728 9.759096e-08 5.802269e-13 1.174987e-19 8.104296e-28 1.903902e-37 1.523424e-48 4.151871e-61 3.85402e-75 1.218515e-90 1.312185e-107 4.812893e-126 6.012627e-146 2.558405e-167 3.707843e-190 1.830292e-214 3.077275e-240 1.762217e-267 3.437156e-296 0 0 0 0 0 0 0 0 0 0 0 0 0 0

7.322951e-11 2.060831e-07 0.0001054372 0.009807099 0.1658373 0.5098227 0.2849386 0.02895199 0.0005348115 1.796049e-06 1.096556e-09 1.217134e-13 2.456074e-18 9.010304e-24 6.009421e-30 7.286533e-37 1.606218e-44 6.436992e-53 4.689825e-62 6.211916e-72 1.495855e-82 6.548604e-94 5.211983e-106 7.541408e-119 1.983796e-132 9.48717e-147 8.248435e-162 1.303772e-177 3.746508e-194 1.957253e-211 1.858927e-229 3.209763e-248 1.007578e-267 5.750154e-288 5.965892e-309 0 0 0

4.572342e-13 5.683686e-10 2.434965e-07 3.595232e-05 0.0018295 0.03208554 0.1939356 0.4039962 0.290047 0.071768 0.006120186 0.0001798746 1.821992e-06 6.360546e-09 7.652684e-12 3.173252e-15 4.534889e-19 2.233573e-23 3.791448e-28 2.218101e-33 4.47228e-39 3.107764e-45 7.442837e-52 6.14328e-59 1.747566e-66 1.713319e-74 5.789141e-83 6.741576e-92 2.705703e-101 3.742573e-111

1.784152e-121 2.93133e-132 1.659851e-143 3.239251e-155 2.178671e-167 5.050218e-180 4.034595e-193 1.110865e-206

1.618478e-14 9.843834e-12 2.82786e-09 3.836961e-07 2.458969e-05 0.0007443113 0.01064124 0.07185647 0.2291794 0.34524 0.2456421 0.08255065 0.0131031 0.0009823447 3.478481e-05 5.8177e-07 4.595672e-09 1.714679e-11 3.021708e-14 2.515118e-17 9.887809e-21 1.836022e-24 1.610244e-28 6.67024e-33 1.30505e-37 1.206005e-42 5.263892e-48 1.085178e-53 1.056649e-59 4.859556e-66 1.055598e-72 1.08302e-79 5.248199e-87 1.201214e-94 1.298572e-102 6.630528e-111 1.599065e-119 1.821462e-128

… (np x ny x na rows)

(17) lwa: a vector np long, the a parameter of the length-weight relationship $W=aL^b$
2.95e-05 1.96e-05

(18) lwb: a vector np long, the a parameter of the length-weight relationship $W=aL^b$
2.899 3.009

(19) len_age: an array (np x na x ny) of positive real numbers representing the length at age
54.39584 55.07681 76.58744 79.40297 96.88932 101.5688 115.4624 121.7662 132.4539 140.1699 147.9985 156.9392 162.2194 172.2193 175.2294 186.1425 187.1315 198.8292 198.02 210.3892 207.9814 220.9226 217.0945 230.5206 225.4316 239.2662 233.0587 247.2351 240.0364 254.4964 246.4199 261.1128 252.2598 267.1416 257.6024 272.635 262.4901 277.6406 266.9615 282.2017 271.0522 286.3577 274.7945 290.1446
…

(20) wt_age: an array (np x na x ny) of positive real numbers representing the weight at age
54.39584 55.07681 76.58744 79.40297 96.88932 101.5688 115.4624 121.7662 132.4539 140.1699 147.9985 156.9392 162.2194 172.2193 175.2294 186.1425 187.1315 198.8292 198.02 210.3892 207.9814 220.9226 217.0945 230.5206 225.4316 239.2662 233.0587 247.2351 240.0364 254.4964 246.4199 261.1128 252.2598 267.1416 257.6024 272.635 262.4901 277.6406 266.9615 282.2017 271.0522 286.3577 274.7945 290.1446
…

(21) Fec: a matrix (np x na) of positive real numbers representing the fecundity at age (sometimes SSB at age)
0.03942355 0.3598737 2.247868 9.799885 27.25873 50.05359 72.14995 93.02628 113.5565 134.1323 154.7556 175.2791 195.5246 215.3283 234.5549 253.0986 270.8815 287.8497 303.9696 319.2248 333.6126 347.1415 359.8287 371.6982 382.779 393.1037 402.7076 411.6271 419.8996 427.5623 434.6523 441.2055 447.2571 452.8408 457.9888

0.02993297 0.1558199 0.5632908 1.661912 4.280973 9.923825 20.92931 40.14014 69.63997 108.98 154.648 201.8202 246.7393 287.6492 324.3137 357.2007 386.9366 414.0713 439.0212 462.0829 483.4656 503.3204 521.762 538.8838 554.7664 569.4832 583.1034 595.6933 607.317 618.0365 627.9115 636.9999 645.3566 653.0344 660.0829

(22) spawns: an integer vector np long (0.2-1) representing the subyear in which each stock spawns (must be greater than 1)

2 2

(23) canspawn: an binary matrix (np rows by nr columns) representing the areas in which each stock may spawn.

0 0 0 0 0 0 0 0 0 1

1 0 1 0 0 0 0 0 0 0

(24) Ma: a matrix (np rows by na columns) representing the natural mortality at age of each stock

0.49 0.24 0.24 0.24 0.24 0.2 0.175 0.15 0.125 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1

0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14 0.14

(25) nCobs: an integer number representing the number of rows of Cobs data (# catch observations)

2754

(26) Cobs: an array (nCobs rows by 5 columns) in which each row is a catch observation (column 5) by year (column 1), subyear (column 2), area (column 3), fleet (column 4)

4 2 2 1 687848.1

5 2 2 1 1512417

10 2 2 1 10084.19

11 2 2 1 251642.1

… (nCobs rows)

(27) nCPUEq: an integer number representing the number of CPUE series (ie assessment CPUE indices)

4

(28) nCPUEobs: an integer number representing the number of CPUE observations

2754

(29) CPUEobs: an array (nCPUEobs rows by 6 columns) in which each row is a CPUE datum observation (column 6) by year (column 1), subyear (column 2), area (column 3), fleet (column 4) and CPUE index number (column 5) matching nCPUE above).

NOTE: For each CPUE indices (nCPUEq), time series values are normalized to have a mean of 1 across all time-area strata.

4 2 2 1 1 0.3099188

5 2 2 1 1 0.728963

10 2 2 1 1 0.03535792
11 2 2 1 1 0.8128502
… (nCPUEobs rows)

(30) nE: an integer value representing the number of effort (partial F) series (e.g. one per fleet)
14

(31) nEobs: an integer value representing the number of effort (partial F) observaitons
4479

(32) Eobs: an array (nEobs rows by 6 columns) in which each row is a partial F datum observation (column 6) by year (column 1), subyear (column 2), area (column 3), fleet (column 4) and partial F index number (column 5) matching nE above)

NOTE: For each Effort time series (nE), values are normalized to have a mean of 1 across all time-area strata.
15 1 1 1 1 0.005673338
16 1 1 1 1 0.005355517
21 1 1 1 1 0.03230617
… (nEobs rows)

(33) nCLobs: an integer number representing the number of size frequency observations
12197

(34) CLobs: an array (nCLobs rows by 6 columns) in which each row is a size frequency observations (number of individuals, column 6) by year (column 1), subyear (column 2), area (column 3), fleet (column 4) and length class (column 5).
44 3 7 1 1 295
47 2 7 3 1 33
49 2 7 3 1 16
26 3 7 4 1 770
… (nCLobs rows)

(35) HCobs: a 4D array containing historical catch observations (all fleets combined) by year, season, area and age.
0 0 0 0 0 0 0 983.3962 0 0 0 0 0 0 0 0 0 3768.771 0 0 0 0 0 0 0 0 0 27548.28 0 0 0 0 0 0 0 0 0 12803.06 0 0 0 0 0 0 0 0 0 2841.463 0 0 0 0 0 0 0 0 0 733.49 0 0 0 0 0 0 0 0 0 295.9137 0 0 0 0 0 0 0 0 0 180.618 0 0 0 0 0 0 0 0 0 140.5931 0 0 0 0 0 0 0 0 0 123.6599 0 0 0 0 …. (nHy x ns x nr x na data points)

(36) RAI: pass-through data to enable observed vs predicted master index (used to calculate partial Fs) array (nCLobs rows by 6 columns) in which each row is a size frequency observations (number of individuals,

column 6) by year (column 1), subyear (column 2), area (column 3), fleet (column 4) and length class (column 5).

44 3 7 1 1 295

(37) nI: integer value, the number of fishery-independent relative abundance indices

1

(38) nIobs: integer value, the number of fishery-independent relative abundance index observations

34

(39) Iobs: a matrix (nIobs rows by 7 columns) of the number of fishery-independent relative abundance index observations (a row per observation). Year (column 1), subyear (column 2), area (column 3), stock (column 4) index number (matching nI, column 5), index type (biomass=1, SSB=2, biomass all stocks=3, column 6), the observed relative abundance index (column 7)

18 2 1 2 1 2 3.321287

19 2 1 2 1 2 6.480129

22 2 1 2 1 2 1.199149

23 2 1 2 1 2 1.748512

… (nIobs rows)

(40) nPSAT: number of movements recorded by PSAT tags of known stock of origin

59

(41) PSAT: a matrix (nPSAT rows by 6 columns) of recorded PSAT movements of known stock of origin (a row per observation). Stock (column 1), subyear (column 2), time elapsed (subyears) til recapture (column 3), area released (column 4), area recaptured (column 5), number of tags (column 6).

2 1 2 1 1 5

2 2 2 1 2 6

1 1 2 2 2 11

2 1 2 2 2 22

… (nPSAT rows)

(42) nPSAT2: integer value, number of movements recorded by PSAT tags of unknown stock of origin

215

(43) PSAT2: a matrix (nPSAT2 rows by 4+np columns) of recorded PSAT movements of unknown stock of origin (a row per observation). Subyear (column 1), time elapsed (subyears, column 2), area released (column 3), area recaptured (column 4), probability stock 1 (column 5), probability stock 2 (column 6)….

1 2 7 7 0.99 0.01

2 1 3 4 0.83 0.17

2 1 4 3 0.65 0.35

3 3 5 6 0.98 0.02

… (nPSAT2 rows)

(44) nTag: integer value, number of movements recorded by conventional (spaghetti, floy) tags
1568

(45) Tag: a matrix (nTag rows by 10 columns) of recorded conventional tag movements (a row per observation). Year released (column 1), subyear released (column 2), area released (column 3), age released (column 4), year recaptured (column 5), subyear recaptured (column 6), area recaptured (column 7), fleet recaptured (column 8), age of recapture (column 9), number of tags (column 10).
2 1 7 4 3 2 2 1 5 10
3 2 7 8 5 2 7 1 10 13
2 4 7 4 6 2 6 1 8 3
1 1 7 4 2 2 7 1 2 8
… (nTag rows)

(46) nSOOobs: integer value, number of stock of origin observations
101

(47) SOOobs: a matrix (nSOOobs rows by 5 columns) of stock of origin frequency observations (a row per observation). Stock (column 1), year (column 2), subyear (column 3), area (column 4), number of observations (column 5).
2 50 3 5 89
1 50 3 5 8
2 50 4 5 5
2 51 3 5 51
… (nSOOobs rows)

(48) nsel: integer value, the number of estimated size selectivities (can be mirrored for multiple fleets if necessary)
3

(49) seltype: integer vector, the type of selectivity for each of the nsel selectivities, 2: logistic, 3: Thompson (dome shaped). One of these must be logistic in the current version (0.18)
3 3 2

(50) selind: integer vector, which selectivity is assigned to each fleet
1 2 2 3

(51) ratiolim: positive real number, 2 position vector with the upper and lower limits on logistic (if any) slope parameter relative to inflection point
0.1 0.4

(52) Infleclim, positive real number, 2 position vector with upper and lower limits on logistic (if any) inflection point (phrase as an age, the age at 50% selectivity).
4 15

(53) nMP: integer value, number of estimated movement parameters

52

(54) nma: integer value, number of movement age classes

3

(55) ma: age class assignment by age (np rows, na columns)

1 1 1 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
1 1 1 2 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3

(56) nmovind: number of estimated movement parameters minus viscosity

44

(57) movind: matrix of integer values (nmovind x 4 columns), the location of estimated movement parameters. Stock (column 1), subyear (column 2), area to (column 3), area from (not used if gravity model, column 4)

1 1 3 999
1 2 3 999
1 3 3 999
1 4 3 999
… (nmovind rows)

(58) nmov1: integer value, the number of initial non-estimated movement parameters

8

(59) mov1: matrix of integer values, the location of initial non-estimated movement parameters. Stock (column 1), subyear (column 2), area to (column 3), area from (not used if gravity model, column 4)

1 1 2 999
1 2 2 999
1 3 2 999
1 4 2 999
… (nmov1 columns)

(60) movtype: integer value, the type of movement parameterization 1:gravity 2:markov matrix

1

(61) CobsCV: vector of positive real numbers nf long, the lognormal CV of the observed catches by fleet

0.2 0.2 0.2 0.2

(62) CPUEobsCV: vector of positive real numbers nf long, the lognormal CV of the CPUE indices (if complex=1)

0.2 0.2 0.2 0.2

(63) IobsCV: vector of positive real numbers nI long, the lognormal CV of the fishery independent indices.
0.2

(64) RDCV: positive real number, the CV of the penalty on recruitment deviations.
0.295161

(65) SSBprior: vector of length np, that is a prior mean for current spawning biomass for each stock
12901650 6640433

(66) SSBCV: lognormal standard deviation of the SSB prior
0.025

(67) nLHw: an integer value indicating the number of likelihood components for the global objective function
12

(68) LHw: a vector of real numbers representing the relative weight of the various likelihood components (1 catch, 2 cpue, 3 FIindex, 4 Lcomp, 5 SOO, 6 PSAT, 7 PSAT2, 8 RecDev, 9 mov, 10 sel, 11 SRA penalty, SSB prior):
0.005 0.001 1 5e-04 5 1 1 10 2 1 200 0

(69) muR_ini: vector of positive real numbers ns long, initial values for mean recruitment over assessment time period
1.4e+07 1750000

(70) sel_ini: matrix (nf x nl) of positive real numbers, initial values for length selectivity
0 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
… (nsel rows)

(71) selpar_ini: matrix (nf x 3) of real numbers, the initial values for selectivity parameters
-5 0 -1
-5 0 -1
-1 -1 99
… (nsel rows)

(72) lnF_ini: a vector of positive real values, nCobs long of initial fishing mortality rate estimates
6.907755 -6.907755 -6.907755 -6.907755 -6.907755 -6.907755 … (nCobs values)

(73) ilnRD_ini: matrix ns x na of initial recruitment deviations years=1 ages=2:na
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(74) lnRD_ini: a matrix ns x ny of recruitment deviations after initial year

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(75) mov_ini: a 4D array of initial movement probabilities np x ns x nr (area from) x nr (area to)

0 0 0 0 0 0 0 0
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
0 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571 0.1428571
… (np x ns x nr rows)

(76) qCPUE_ini: vector of real values nf long that are the initial values for log catchability (used to convert partial Fs to fishing mortality rate or scale CPUE to real abundance)

-4.60517 -4.60517 -4.60517 -4.60517

(77) lnqI_ini: vector of real numbers nI long that are the initial values for fishery independent catchability

0

(78) D_ini: pass through vector (np long) of simulated (or reference) stock depletion (SSB relative to SSB0)

0.213 0.368

(79) complexRD: integer switch for determining whether there should be full estimation of recruitment deviations in each year (1: yes, 0: block recruitment deviations)

0

(80) complexF: integer switch for determining whether F's will be estimated for all years or whether the partial F approach will be used.

0

(81) nF: integer value the number of estimated fishing mortality rates (1 if complex F =0)

1

(82) debug: integer switch determining whether the model should be run with initial values (for debugging and checking calculations against simulations)(0: no debug, 1: debug)

0

(83) verbose: integer switch determining whether the model should print output to the prompt (0:no output, 1:run with printouts)
0

(84) datacheck: a value for initially checking whether the data were read in to M3 incorrectly.
991199

5 Running M3

The M3 model currently runs as a maximum-likelihood estimator only. It follows that it can be run from the command prompt:

```
C:/M3/M3
```

or alternatively from other software such as R (from the R console prompt):

```
system("C:/M3/M3.exe", wait=T, show.output.on.console = T)
```

6 Outputting data and model estimates from M3

The M3 model produces a number of output files, including an M3.rep report file, a maximum likelihood estimate of model parameters M3.par file and an estimated variance-covariance matrix for those parameters M3.cov.

6.1 Reading the report file

The report file can be read from R using the R function M3read() of the ABTMSE package producing a list object with identical names to those above.

6.2 Reading the parameter and variance-covariance files

The easiest approach to reading these files is provided here in an R function read.fit() which is adapted from code of Anders Nielson. The code operates on the M3 root directory and automatically writes the MLE parameter estimates of the M3.par file to a list position 'est' and the variance-covariance matrix to the position 'cov'. The list also contains positions for the objective function value 'nlogl' and parameter names 'names'.

```
read.fit<-function(file="C:/M3"){
  ret<-list()
  parf<-paste(file,"M3.par",sep="/")
  parfile<-as.numeric(scan(parf, what='', n=16, quiet=TRUE)[c(6,11,16)])
  ret$nopar<-as.integer(parfile[1])
  ret$nlogl<-parfile[2]
  ret$maxgrad<-parfile[3]
  cfile<-paste(file,'M3.cor', sep='/')
  lin<-readLines(cfile)
```

```
  ret$npar<-length(lin)-2
  ret$logDetHess<-as.numeric(strsplit(lin[1], '=')[[1]][2])
  sublin<-lapply(strsplit(lin[1:ret$npar+2], ' '),function(x)x[x!=''])
  ret$names<-unlist(lapply(sublin,function(x)x[2]))
  ret$est<-as.numeric(unlist(lapply(sublin,function(x)x[3])))
  ret$std<-as.numeric(unlist(lapply(sublin,function(x)x[4])))
  ret$cor<-matrix(NA, ret$npar, ret$npar)
  corvec<-unlist(sapply(1:length(sublin), function(i)sublin[[i]][5:(4+i)]))
  ret$cor[upper.tri(ret$cor, diag=TRUE)]<-as.numeric(corvec)
  ret$cor[lower.tri(ret$cor)] <- t(ret$cor)[lower.tri(ret$cor)]
  ret$cov<-ret$cor*(ret$std%o%ret$std)
  return(ret)
}

Output<-read.fit("C:/M3")
```

7 Future additions

Versions 1.4 may include:

- Dynamic calculation of inverse age-length key
- Fractional movement model (ie perfectly mixed just redistributes individuals with no viscosity)
- Conditional stock of origin assignment to electronic tagging observations of unknown stock of origin based on model estimated stock composition by time-area strata (what is the probability of stock 1 given this path through spatio-temporal strata?)
- A switch to calculate recruitment based on SSB in the spawning area only versus stock wide

8 Appendix. Model specification

8.1 Estimated parameters

The majority of parameters estimated by the model relate to movement probabilities and annual recruitment deviations (Table 1). The number of estimated parameters can be reduced substantially by limiting estimation to only those movements that have been recorded or are considered credible. For example, given a quarterly time step (e.g. Jan-Mar, April-Jun etc.) and the spatial definitions of the 2015 data preparatory meeting (Anon. 2015, Figure 1), an evaluation of conventional tagging for Atlantic bluefin tuna data reveals that less than 80 parameters of the 224 possible are required to characterize all of the possible movements recorded by these tagging data.

8.2 Transition equations

These are documented in the trial specifications document.

8.3 Appendix B. Model code

The M3.tpl file is available here.