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APPLICATION OF AN ATLANTIC BLUEFIN TUNA OPERATING MODEL TO GENERATE PSEUDODATA FOR STOCK ASSESSMENT TESTING

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SUMMARY

We developed a simulation model to represent the spatial dynamics of Atlantic bluefin tuna and to test the performance of alternative stock assessment models. A simulation framework previously developed to explore how stock mixing affects the resource and fisheries was conditioned on the available information for Atlantic bluefin tuna and used to generate pseudodata with the same properties as the information available for stock assessment. The analytical framework was a stochastic, age-structured, stock-overlap model that was seasonally and spatially explicit with movement of eastern- and western-origin tuna informed by fishery-independent telemetry information. The operating model was conditioned with 1970 abundance at age, 1970-2013 age-1 abundance, and fishing mortality at age from the 2014 ICCAT stock assessments, which were modified to reflect decisions from the 2017 data preparatory meeting. The operating model is well-suited to test the current virtual population analyses for eastern and western Atlantic bluefin tuna fisheries and can be used to test alternative estimation models as well as the performance of alternative management procedures.

RÉSUMÉ

Nous avons mis au point un modèle de simulation pour représenter la dynamique spatiale du thon rouge de l'Atlantique et tester les performances de modèles d'évaluation des stocks alternatifs. Un cadre de simulation précédemment élaboré afin d'explorer comment le mélange des stocks affecte la ressource et les pêcheries a été conditionné à l'information disponible pour le thon rouge de l'Atlantique et utilisé pour générer des pseudo-données dotées des mêmes propriétés que les informations disponibles pour l'évaluation des stocks. Le cadre analytique a été un modèle stochastique, structuré par âge, de chevauchement de stocks qui était saisonnièrement et spatialement explicite, le mouvement des thons d'origine orientale et occidentale provenant des informations télémétriques indépendantes des pêcheries. Le modèle opérationnel a été conditionné avec l'abondance à l'âge de 1970, l'abondance à l'âge-1 de 1970-2013 et la mortalité par pêche à l'âge de l'évaluation des stocks de 2014 de l'ICCAT, qui a été modifié pour tenir compte des décisions de la réunion de préparation des données de 2017. Le modèle opérationnel est bien adapté pour tester les analyses actuelles de population virtuelle pour les pêcheries de thon rouge de l'Atlantique Est et Ouest et peut servir à tester des modèles d'estimation alternatifs ainsi que les performances de procédures de gestion alternatives.

RESUMEN

Se desarrolló un modelo de simulación para representar la dinámica espacial del atún rojo del Atlántico y para probar el funcionamiento de modelos de evaluación de stock alternativos. Se condicionó un marco de simulación, desarrollado previamente para explorar el modo en que la mezcla del stock afecta al recurso y a las pesquerías en función de la información disponible para el atún rojo del Atlántico, y se utilizó para generar pseudo datos con las mismas propiedades que la información disponible para la evaluación de stock. El marco analítico fue un modelo estocástico, estructurado por edad, de solapamiento de stock estacional y espacialmente explícito con movimiento de atún de origen oriental y occidental e información de telemetría independiente de la pesquería. El modelo operativo fue condicionado con abundancia por edad de 1970, abundancia de edad 1 1970-2013 y mortalidad por pesca por edad de la evaluación de stock de ICCAT de 2014, que se modificó para reflejar las decisiones

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de la reunión de preparación de datos de 2017. El modelo operativo está bien adaptado para probar los análisis actuales de la población virtual para las pesquerías de atún rojo del Atlántico occidental y oriental, y puede utilizarse para probar modelos de estimación alternativos, así como el rendimiento de procedimientos de ordenación alternativos.

KEYWORDS

Atlantic bluefin tuna, population dynamics, operating model,
simulation testing, stock mixing, stock assessment, management strategy evaluation

Background

Genetics, otolith chemistry, and conventional and electronic tagging data support the existence of at least two spawning populations of bluefin tuna in the Atlantic that exhibit spatial overlap in their distributions and mixing across the management boundary (Mather *et al.* 1995, Block *et al.* 2005, Boustany *et al.* 2008, Rooker *et al.* 2008, Galuardi *et al.* 2010, Rooker *et al.* 2014, Siskey *et al.* 2016). The western population is known to spawn in the Gulf of Mexico and the eastern population is known to spawn in the Mediterranean Sea (Block *et al.* 2005, Carlsson *et al.* 2004, Rooker *et al.* 2008a,b, Galuardi *et al.* 2010). There is new evidence of spawning in the Slope Sea (Richardson *et al.* 2016), but additional documentation of spawning in conjunction with population dynamics modeling is needed to understand the implications of this finding (Walter *et al.* 2016). Bluefin tuna are assessed and managed as two distinct eastern and western stocks by the International Commission for the Conservation of Atlantic Tunas (ICCAT) with the management boundary approximately at the 45º west meridian. Although stock assessments that incorporate mixing have been explored in the past (Porch *et al.* 1995, 1998, 2001; Porch and Turner 1999; ICCAT 2008), the most recent assessments apply virtual population analysis and assume no mixing (ICCAT 2014). The 2017 benchmark assessment of Atlantic bluefin tuna plans to address uncertainty associated with stock mixing.

Simulation testing of alternative assessment models and management strategies is needed to understand the implications of stock mixing of Atlantic bluefin tuna. This approach involves building an operating model to simulate both the natural and human aspects of the managed fishery resource system, wherein the simulated status of the resource triggers action based on management strategies, and subsequent management decisions in-turn affect fishing activities and feedback on the resource (Sainsbury *et al.* 2000, Bunnefeld *et al.* 2011). Simulation testing can be an effective tool in identifying management procedures that can minimize adverse ecological and harvest impacts of mixed stock resource management (Kerr and Goethel 2014). A key aspect of this work is developing an operating model to generate realistic pseudodata for testing alternative management strategies. The 7-zone, seasonal operating model developed by Kerr *et al.* (2016) served as a basis for aspects of the operating model described here. This model was modified for application in generating pseudodata with the typical quantity and quality available for stock assessment of Atlantic bluefin tuna.

1. Methods

The bluefin tuna operating model includes two spawning populations, with the eastern population originating in the Mediterranean Sea and the western population originating in the Gulf of Mexico. The operating model is age structured (ages 1-29) and simulates movement of fish across seven geographic zones (Figure 1) and over four seasonal quarters (quarter 1 = spring). The model assumes that bluefin from one area move to another, but return to their natal area to spawn. The operating model was iterated over the 44 year time span (1970-2013) that is common to both eastern and western stock assessments. Model output is generated at the seven zone, four quarter, population-of-origin scale and summarized at an annual time step and stock area to align with the input requirements for stock assessment testing. The model was written in the R statistical programming environment (R Development Core Team, 2016).

Model Conditioning

The simulations described by Kerr *et al.* (2016) were conditioned on estimates of abundance, fishing mortality and movement from the Multi-stock Age-Structured Tag-integrated assessment model (MAST, Taylor *et al.* 2011), which does not have sufficient flexibility to consider the scenarios being considered by ICCAT. For example, configurations of MAST with early maturity for both stocks did not converge (Kerr *et al.* 2016). Fortunately, exploratory VPAs using stock composition estimates to derive stock-of-origin catch showed that abundance and fishing mortality estimates from the current VPA approach were relatively robust to stock mixing (Cadrin *et al.* 2017). Therefore, we conditioned the operating model using information from VPA methods that were modified to address revised assumptions of natural mortality and maturity, and we assumed fishery-independent movement rates.

Tag-based simulation methods were applied to inform movement of bluefin tuna in the model (Galuardi *et al.* 2014, in press). Seasonal movement transition matrices were produced by performing simulations based on electronic tagging data from Atlantic bluefin tuna collected by the Large Pelagics Research Center's database, AZTI Technalia, the Grande Bluefin Year Program, and the National Marine Fisheries Service (USA). Seasonal movement matrices (with elements T in equation 5) were derived from size based simulations that described the movement of fish across seven zones in the operating model. The simulation model used movements and positional uncertainty from groups of tagged individuals and simulations were carried out according to a stochastic advection-diffusion process model (Sibert *et al.* 2003).

Several parameters of the operating model were informed by stock assessment models for eastern and western bluefin tuna stocks (ICCAT 2014, Zarrad *et al.* 2017) which were revised to reflect decisions from the recent Report of the 2017 ICCAT Bluefin Tuna Data Preparatory Meeting (ICCAT 2017). Based on our decisions to incorporate revised natural mortality and maturity assumptions in the operating model, as well as revisions to the estimation methods (e.g., estimating the F-ratio for the oldest age, Zarrad *et al.* 2017), the current stock assessments using virtual population analysis (VPA) were re-run to produce revised series of recruitment, initial abundance, and fishing mortality-at-age for conditioning the operating model (Appendices A and B). Eastern and western VPAs were rerun using the same settings as the 2014 western assessment and the Zarrad *et al.* (2017) revised eastern assessment, with adjustments only to the maturity and natural mortality.

The Report of the 2017 ICCAT Bluefin Tuna Data Preparatory Meeting supported use of a common lifetime natural mortality for both stocks derived from maximum age using the Then *et al.* (2015) method, re-scaled to a vector of age-based M using the Lorenzen (1996) method. Note that this new vector (Figure 2, solid blue line) was significantly greater than the natural mortality for eastern and western stocks assumed in the previous ICCAT assessment (2014; Figure 2, grey lines). The data preparation workshop concluded that the new vector for both stocks is an improvement over the previous stock-specific assumptions (ICCAT 2017).

Maturity at age for eastern and western bluefin tuna was informed by the Report of the 2017 ICCAT Bluefin Tuna Data Preparatory Meeting (ICCAT 2017). We assumed that maturity determines the contribution to the spawning stock (i.e., Vector 1 as described in ICCAT 2017, Figure 3). We assumed a common maturity schedule for both eastern and western origin bluefin that is aligned with the current schedule used for the East Atlantic and Mediterranean (i.e., 50% maturity at age 4 and 100% maturity at age 5; Corriero *et al.* 2005).

Weight at age for the western population was informed by the growth curve adopted by the ICCAT Bluefin Tuna Data Preparatory Meeting (Ailloud *et al.* 2017, ICCAT 2017). Although, the Data Preparatory group did not make a decision for the eastern stock, they did note that the western growth function fit the eastern growth data reasonably well. Accordingly, we used the same growth function for both eastern and western origin bluefin. We used the single length-weight relationship for the Atlantic (ICCAT 2013) to derive weight at age from length at age.

In the operating model, initial population abundance-at-age within the respective spawning zone (Mediterranean and Gulf of Mexico) of western and eastern bluefin populations was set equal to the estimated abundance at age in 1970 to 2013 derived from revised eastern and western stock assessment (Appendices A and B). Because of differences between the age structure in east and west stock assessments (i.e., use of plus groups) and the operating model age structure (ages 1-29), adjustment of the stock assessment output was needed prior to input to the operating model. To adjust the stock assessment derived abundance at age, we assumed a constant F at age for the plus group (i.e., assumed the F_{10+} for ages 10-29 in the east and F_{16+} for ages 16-29 in the west) and an equilibrium age structure within the plus group. We calculated the relative abundance of an equilibrium age distribution (D_a) within the plus group (F_{a+}) such that the sum of abundance at age (N_a) for age classes greater than the plus group equals the VPA estimates of plus group abundance (N_{a+}).

Eqn. 1
$$D_a = \frac{e^{(-(F_{a+}+M_a)a-a+)}}{\sum_a e^{(-(F_{a+}+M_a)a-a+)}}$$

Eqn. 2
$$N_a = N_{a+} D_a$$

The time series of recruitment (age-1 abundance) estimated from the revised stock assessments informed the operating model (Figure 4, Appendices A and B). Both recruitment time series start in 1970 as input for the OM (i.e., excluding 1950-1969 for eastern bluefin tuna). In the context of the operating model, recruits originated within the respective spawning area of each population and recruitment occurred in spring (quarter 1).

Fishing mortality estimated from the stock assessments differed in temporal and spatial scale from fishing mortality in the operating model (i.e., annual fishing mortality rates by stock area from the stock assessment and quarterly rate by geographic zone in the operating model). Fishing mortality for each geographic area in the operating model was calculated from the partial catch-at-age reported in ICCAT stock assessments (ICCAT 2014). We assigned each fleet to a geographic zone within the operating model based on the primary area in which each operates (Figure 1, Table 1). The western fisheries and zones were relatively well-aligned, but several eastern fleets fish in multiple areas, so some simplifying assumptions were made. At the largest scale, western fisheries contribute catch and F for zones 1-3 and eastern fisheries contribute to zones 4-7. We also partitioned fishing by each fleet across quarters based on the months reported for each fishery (ICCAT 2014). Fishing mortality estimated for western and eastern fisheries in 2014 (Appendices A and B) was adjusted by dividing annual estimates into seasonal quarters.

Fishing mortality at age was partitioned to zones using the partial catch-at-age of each fleet assigned to each zone (**Table 1**):

Eqn: 3
$$F_{a,y,z} = F_{a,y} \frac{c_{a,y,z}}{\sum c_{a,y,z}}$$

The resulting $F_{a,y,z}$ sum to the annual F's from the VPAs. We approximated quarterly proportions (P_q, **Table 1**) based on expert knowledge on fleet operation that were used to derive quarterly F's assuming that the seasonal pattern is similar over years.

Eqn. 4
$$F_{y,q,a,z} = F_{a,y,z} P_q$$

Deterministic population dynamics and harvest were simulated with the operating model over the seven geographic zone and years 1970 to 2013.

Eqn. 5
$$N_{y,a,q,z,p} = N_{y,a,q-1,y,z,p} T_{z\to z' a,q,p} e^{-[M_{a,q,p}+F_{y,a,q,z}]}$$

Eqn. 6
$$SSB_{y,q,z,p} = \sum_{a=1}^{a=29} N_{y,a,q,z,p} W_{a,p} B_{a,p}$$

Eqn.7
$$Y_{y,g} = \sum\nolimits_{\substack{West\ z=1:3 \\ East\ z=4:7}} \sum_{a=1}^{a=29} \sum_{q=1}^{q=4} \sum_{p=1}^{p=2} N_{a,q,y,z,p} \frac{F_{y,a,q,z}}{M_{a,q,p} + F_{y,a,q,z}} \left[1 - e^{-(M_{a,q,p}+F_{y,a,q,z})}\right] W_{a,p}$$

Parameter Descriptions

$B_{a,p}$	Maturity-at-age of a population
$F_{q,g,z}$	Quarterly gear-specific fishing mortality across geographic zones
$M_{a,q,p}$	Quarterly natural mortality-at-age
$N_{a,q,y,z,p}$	Number of fish at age, quarter, year, zone, and population
$SSB_{q,y,z,p}$	Spawning stock biomass across quarter, year, zone and population
$T_{z\to z',a,q,p}$	Proportional movement of fish from one zone to another zone at age, quarter, and population
$W_{a,p}$	Weight-at-age of a population
$Y_{q,y,z,p}$	Yield across quarter, year, zone and population

Observation Model

Pseudodata was generated from the operating model with measurement error (ε; e.g., Deroba *et al.* 2015) to derive overall catch at age, partial catch at age for each fishery, and survey indices with observation error.

Eqn. 8

$$C_{y,a,g} = \left(\sum_{\substack{West\ z=1:3 \\ East\ z=4:7}} \sum_{q=1}^{q=4} \sum_{p=1}^{p=2} N_{a,q,y,z,p} \frac{E_{y,g} S_{a,g} Q_g}{M_{a,q,p} + E_{y,g} S_{a,g} Q_g} \left[1 - e^{-(M_{a,q,p} + E_{y,g} S_{a,g} Q_g)}\right] \right) * e^{\varepsilon_{y,a,g}}$$

Eqn. 9

$$C_{y,a} = \left(\sum\nolimits_{\substack{West\ z=1:3 \\ East\ z=4:7}} \sum_{g=1}^{g=x} \sum_{q=1}^{q=4} \sum_{p=1}^{p=2} N_{a,q,y,z,p} \frac{F_{y,a,q,z}}{M_{a,q,p} + F_{y,a,q,z}} \left[1 - e^{-(M_{a,q,p} + F_{y,a,q,z})}\right] \right) * e^{\varepsilon_{y,a}}$$

Eqn. 10

$$I_{y,g} = \left(Q_g \sum\nolimits_{a=1}^{a=29} S_{a,g} N_{y,a} \right) * e^{\varepsilon_{y,g}}$$

Parameter Descriptions

$C_{y,a}$	Catch at age of fish across years
$C_{y,a,g}$	Fleet specific partial catch at age of fish across years
$E_{y,g}$	Effort by fleet across years
$I_{y,g}$	Index value (e.g., catch per unit effort) of a given fleet by year
Q_q	Catchability of a given fleet (time invariant)
$S_{a,g}$	Selectivity of fish at age by fleet

Fleet specific partial catch at age was calculated as a function of fleet selectivity, catchability and effort. Average fleet selectivity at age from the 2014 ICCAT stock assessment (ICCAT 2014) was used to inform fleet selectivity within the operating model. Because the age span of the stock assessments and operating model differed, selectivity at age for the plus group was used for all ages in the operating model that equated to the plus group (Figure 5). Fleet catchability from the revised stock assessment (Appendices A and B) was used to inform calculation of partial catch at age (PCAA) in the operating model.

Fleet specific effort was calculated for fleets using the following equation:

Eqn. 11

$$E_{y,g} = \frac{C_y}{CPUE_g}$$

using fleet specific catch-per-unit-effort (CPUE) is the standardized CPUE as reported by ICCAT (2014, and references therein). When these inputs where not available for a particular fleet, the following equation was used:

Eqn. 12

$$E_{y,g} = \frac{\sum PCAA_y}{CPUE_g}$$

Partial catch at age for all but two indices was derived from the operating model according to Eqn. 8. The maturity vector was used as the partial catch-at-age for the larval index (as in Sensitivity Run 22 in the 2014 assessment) and the partial catch-at-age from the 2014 assessment was used for the tagging index, in which all fish ages 1 to 3 are equally vulnerable to the fishery (ICCAT 2014). Error terms in catch at age and partial catch at age were normally distributed and derived from an exploratory statistical catch-at-age analysis (Maguire *et al.* 2017).

Indices of abundance ($I_{y,g}$) were calculated from third quarter abundance (fall), except for the indices that measured relative abundance in spawning areas (Mediterranean Sea or Gulf of Mexico), in which case the abundance was taken from the first quarter (spring) to reflect the spawning period. Error in the indices of abundance included in the assessment was the average lognormal residual variation from the VPA input data files (Appendices A and B).

Further detail on simulation of pseudodata for eastern and western Atlantic fisheries and associated simulation testing of VPAs is described by Morse *et al.* (in press).

2. Results and Discussion

Deterministic simulations from the operating model emulated the overall trend in SSB and catch from the revised stock assessment models for eastern and western stocks (Figure 6; Appendices A and B), although at a higher magnitude (Figure 7). The pseudodata generated from the operating model for testing stock assessments included stock specific catch-at-age (Figure 8), partial-catch-at-age (Figures 9 and 10), and survey indices (Figures 11 and 12). This data was used as a basis for testing the current stock assessment method of separate VPAs that assume no stock mixing (Morse *et al.* in press).

The operating model also allowed us to compare the population and stock view of the resource (Figure 13 and 14). This comparison indicated that the western stock view of SSB and yield was of higher magnitude than the population view of the resource, whereas the eastern stock and population view was very similar (Figure 13 and 14). The difference in perception for the western resource results from eastern origin fish that occur in the western stock areas being attributed to the western resource.

Uncertainty in parameters and initial conditions of the model will be considered as we expand upon application of the operating model for the purpose of producing pseudodata. Further elaboration of this work for testing alternative stock assessment models and management strategy evaluation is planned for the next year, in collaboration with NOAA scientists and other ICCAT scientists.

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References

Ailloud, L.E., Lauretta, M.V., Hoenig, J.M., Hanke, A.R., Golet, W.J., Allman, R. and Siskey, M.R. 2017. Improving growth estimates for western Atlantic Bluefin tuna using an integrated modeling approach. Fisheries Res. 191: 17-24.

Block, B.A., Teo, S., Walli, A., Boustany, A., and Stokesbury, M.J.W., Farwell, C.J., Weng, K.C., Dewar, H., and Williams, T.D. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature 434: 1121–1123. doi:10.1038/nature03463.

Boustany, A.M., Reeb, C.A., and Block, B.A. 2008. Mitochondrial DNA and electronic tracking reveal population structure of Atlantic bluefin tuna (*Thunnus thynnus*). Mar. Biol. 156(1): 13–24.

Bunnefeld, N., Hoshino, E., Milner-Gulland, E.J. 2011. Management strategy evaluation: a powerful tool for conservation? Trends Ecol. Evol. 26: 441-447.

Cadrin S., Morse, M., Kerr, L., Secor, D. and Siskey, M. (in press). Exploratory Stock Assessment of Eastern and Western Stock-of-Origin Atlantic Bluefin Tuna Accounting for Stock Composition. ICCAT SCRS/2017/174: 71p.

Carlsson, J., McDowell, J.R., Píndaro, D.-J., Carlsson, J.E., Boles, S.B., Gold, J.R., and Graves, J.E. 2004. Microsatellite and mitochondrial DNA analyses of Atlantic bluefin tuna (*Thunnus thynnus thynnus*) population structure in the Mediterranean Sea. Mol. Ecol. 13: 3345-3356.

Corriero, A., Karakulak, S., Santamaria, N., Deflorio, M., Spedicato, D., Addis, P., Desantis, S., Cirillo, F., Fenech-Farrugia, A., Vassallo-Agius, R., de la Serna, J. M., Oray, Y., Cau, A., Megalofonou, P. and De Metrio, G. (2005), Size and age at sexual maturity of female bluefin tuna (*Thunnus thynnus* L. 1758) from the Mediterranean Sea. Journal of Applied Ichthyology, 21: 483–486. doi:10.1111/j.1439-0426.2005.00700.x

Galuardi, B., Cadrin, S.X., Kerr, L., Miller, T.J., and Lutcavage, M. 2014. Using electronic tag data to provide transition matrices for movement inclusive population models. SCRS/2014/177.

Galuardi, B., Cadrin, S.X., Arregi I., Arrizabalaga H., Di Natale A., Brown, C., Lauretta, M. and Lutcavage, M. (in press). Atlantic bluefin tuna area transition matrices estimated from electronic tagging and SATTAGSIM. SCRS/2017/045: 19p.

ICCAT. 2013. 2013 inter-sessional meeting of the tropical tuna species group (Tenerife, Spain - March 18 to 21, 2013).

ICCAT. 2008. Report of the 2008 Atlantic bluefin tuna stock assessment session (Madrid, Spain – June 23 to July 4, 2008)

ICCAT. 2014. Report of the 2014 Atlantic bluefin tuna stock assessment session (Madrid, Spain – September 22 to 27, 2014).

ICCAT. 2017. Report of the 2015 ICCAT Bluefin data preparatory meeting. (Madrid, Spain – March 6-11, 2017).

Kerr, L.A., Cadrin,S. X., Secor, D. H. Nathan G. Taylor. 2016. Modeling the implications of stock mixing and life history uncertainty of Atlantic bluefin tuna. Canadian Journal of Fisheries and Aquatic Sciences, DOI: 10.1139/cjfas-2016-0067

Kerr, L.A., and Goethel, D.R. 2014. Simulation modelling as a tool for synthesis of stock identification information. In "Stock Identification Methods" (Cadrin, S.X., Kerr, L.A., and Stefano, M., Eds.), pp. 501-533. London: Elsevier.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. J. Fish Biol. 49: 627–647.

Maguire J.-J., Hanke, A., Melvin, G. and Cadrin, S.X. 2017. An investigation of bluefin tuna data in the west Atlantic with ASAP.

Mather, F.J., Mason, J.M., and Jones, A.C. 1995. Historical Document: Life history and fisheries of Atlantic bluefin tuna. NOAA, Technical Memorandum. NMFS-SEFSC-370. Available from:http://ia802605.us.archive.org/0/items/historicaldocume00math/historicaldocume00math.pdf

Morse, M.R., Kerr, L.A., and Cadrin, S.X. (in press). Simulating virtual population analysis of mixed Atlantic bluefin tuna stocks. ICCAT Document SCRS/2017/178: 13p.

Porch, C., V. Restrepo, S. Turner and G. Scott. 1995. Virtual population analyses of Atlantic bluefin tuna incorporating movement and tagging data. ICCAT Collective Volume of Scientific Papers. ICCAT 44, 183–208.

Porch, C.E. and Turner, S.C. 1999. Virtual population analyses of Atlantic bluefin tuna with alternative models of trans-Atlantic migration. ICCAT Coll. Vol. Sci. Pap. 49: 291-305.

Porch, C., Turner, S.C., and Powers, J.E. 2001. Virtual population analyses of Atlantic bluefin tuna with alternative models of transatlantic migration: 1970-1997. Collected Volume of Scientific Papers ICCAT, 52: 1022-1045.

Richardson, D.E., Marancik, K.E., Guyon, J.R., Lutcavage, M.E., Galuardi, B., Lam C.H., Walsh H.J., Wildes S., Yates, D.A., Hare, J.A. 2016. Discovery of a spawning ground reveals diverse migration strategies of Atlantic bluefin tuna (*Thunnus thynnus*). Pros. Nat. Acad. Sci. 113(12): 3299-3304.

Rooker, J.R., Arrizabalaga, H., Fraile, I., Secor, D.H., Dettman, D.L., Abid, N., Addis, P., Deguara, S., Karakulak, F.S., Kimoto, A., Sakai, O., Macías, D. and Santos, M.N.. 2014. Crossing the line: migratory and homing behaviors of Atlantic bluefin tuna. Marine Ecology Progress Series 504:265-276.

Rooker, J.R., Secor, D.H., DeMetrio, G., Kaufman, A.J., Rios, A.B., Ticina, V., and Rodriquez-Marin, E. 2008. Evidence of trans-Atlantic movement and natal homing in bluefin tuna from stable isotopes in otoliths. Mar. Ecol. Prog. Ser. 368: 231–239.

Sainsbury, K.J., Punt, A.E., and Smith, A.D. M. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. ICES J. Mar. Sci. 57: 731-741.

Sibert, J.R., Musyl, M.K., and Brill, R.W. 2003. Horizontal movements of bigeye tuna near Hawaii from archival tagging data. Fish. Oceanogr. **12**: 141–151.

Siskey, M.R., Wilberg, M.J., Allman, R.J., Barnett, B.K. ,and Secor, D.H. 2016. Forty years of fishing: changes in age structure and stock mixing in northwestern Atlantic bluefin tuna (*Thunnus thynnus*) associated with size-selective and long-term exploitation. ICES J. Mar. Sci. doi:10.1093/icesjms/fsw115

Taylor N., McAllister, M., Lawson, G., Carruthers, T. and Block, B. 2011. Atlantic Bluefin Tuna: A Novel Multistock Spatial Model for Assessing Population Biomass. PLoS ONE 6(12):e27693.doi:10.1371/journal.pone.0027693.

Then, A.Y., Hoenig, J.M., Hall, N.G. and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. Mar. Sci. 72: 82-92.

Walter, J.F.III, Porch, C.E., Lauretta, M.V., Cass-Calay, S.L., and Brown C.A. 2016. Implications of alternative spawning for Bluefin tuna remain unclear. PNAS doi/10.1073/pnas/1605962113.

Zarrad R., Walter, J., and Lauretta, M. 2017. VPA-2BOX model diagnostics used in the 2014 assessment of eastern Atlantic bluefin tuna. Collect. Vol. Sci. Pap. ICCAT 73(1): 318-322.

Table 1. Assignment of fleets to seven geographic areas in the operating model (Figure 1 caption) and proportion of fishing mortality assumed to take place across quarter-year based on predominant regions and months of operation.

VPA Index	Fleet	Zone	Q1	Q2	Q3	Q4
Western Fisheries						
1	'CAN_GSL'	2	0.00	0.00	0.67	0.33
2	'CAN_SWNS'	3	0.00	0.00	0.67	0.33
3	'US_RR<145'	3	0.00	0.20	0.60	0.20
4	'US_RR_66_114'	3	0.00	0.20	0.60	0.20
5	'US_RR_115_144'	3	0.00	0.20	0.60	0.20
6	'US_RR_145_177'	3	0.00	0.20	0.60	0.20
7	'US_RR>195'	3	0.00	0.20	0.60	0.20
8	'US_RR>195_COMB'	3	0.00	0.20	0.60	0.20
9	'US_RR>177'	3	0.00	0.20	0.60	0.20
10	'JLL_AREA_2_(WEST)'	3	0.00	0.25	0.50	0.25
13	'LARVAL_ZERO_INFLATED'	1	1.00	0.00	0.00	0.00
14	'GOM_PLL_1-6'	1	0.60	0.40	0.00	0.00
15	'JLL_GOM'	1	0.60	0.40	0.00	0.00
Eastern Fisheries						
1	'ESPMarTrap'	7	0.70	0.10	0.10	0.10
2	'JLL EastMed'	5	0.50	0.00	0.00	0.50
3	'Nor PS'	6	0.00	0.00	0.50	0.50
4	JP LL NEA'	4	0.25	0.00	0.25	0.50
5	'SP BB1'	5	0.00	0.25	0.50	0.25
6	'SP BB2'	5	0.00	0.25	0.50	0.25
7	'SP BB3'	5	0.00	0.25	0.50	0.25
8	'JP LL NEA2'	4	0.25	0.00	0.25	0.50

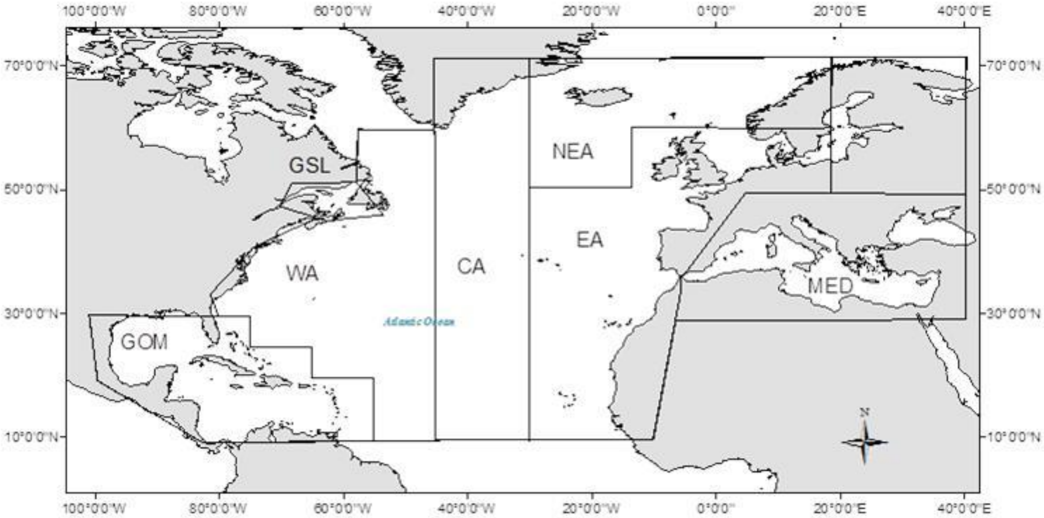


Figure 1. Geographic zones within operating model, including Gulf of Mexico (GOM, zone 1), Gulf of St. Lawrence (GSL, zone 2), western Atlantic (WA, zone 3), central Atlantic (CA, zone 4), eastern Atlantic (EA, zone 5), northeast Atlantic (NEA, zone 6), and Mediterranean Sea (MED, zone 7; see Kerr et al. 2016 for full description of zones).

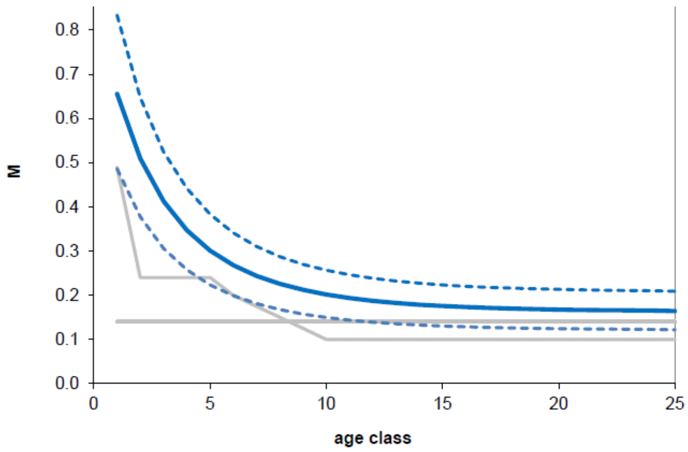


Figure 2. Comparison between the natural mortality (M) vectors used in the 2015 update stock assessment (gray lines) with the proposed Lorenzen mortality function (blue solid line) with +/- 0.05 plotted (dashed blue lines; ICCAT 2017).

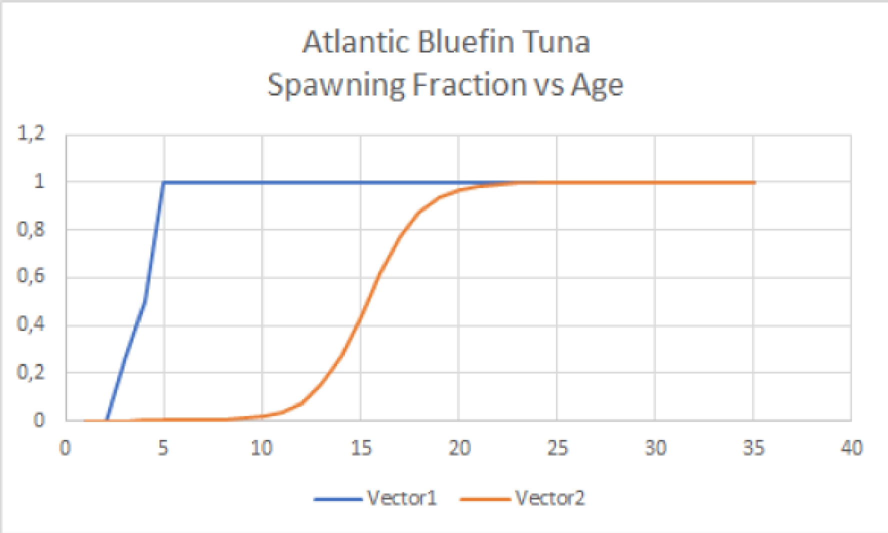


Figure 3. Alternative vectors of the proportion of fish contributing to the spawning output of the Atlantic bluefin tuna (East and West stocks) as a function of age (ICCAT 2017). Vector 1 assumes that maturity alone determines contribution to the spawning stock and is similar to the vector currently used for the East Atlantic and Mediterranean (Corriero et al., 2005). Vector 2 is based on Diaz, 2011 and assumes that only fish actually on the main spawning grounds in the western Atlantic in the Gulf of Mexico contribute to the spawning stock.

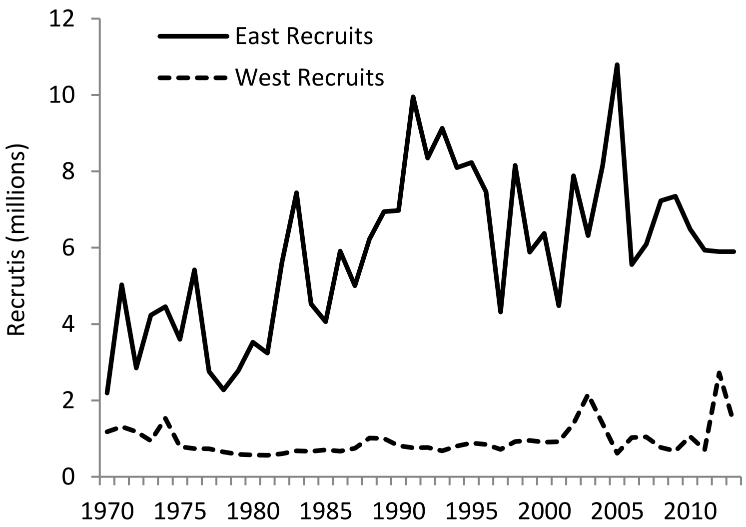


Figure 4. Time series (1970-2013) of recruitment used to condition OM from revised VPA stock assessments (Appendices A and B).

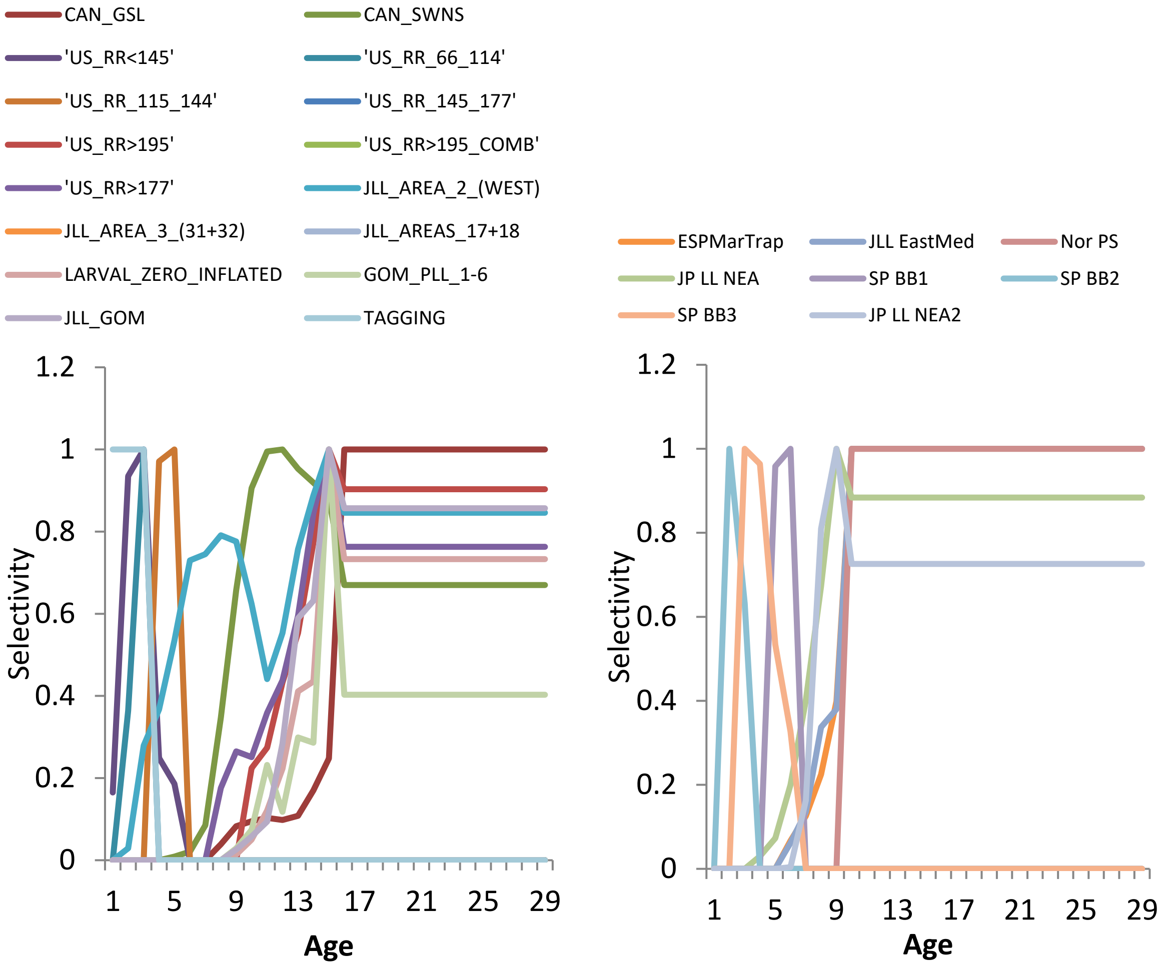


Figure 5. Average selectivity at age for western fisheries (left panel) and eastern fisheries (right panel) from the 2014 ICCAT stock assessment as utilized in the operating model. Note that selectivity at age for the plus group was used for all ages in the operating model that equated to the plus group.

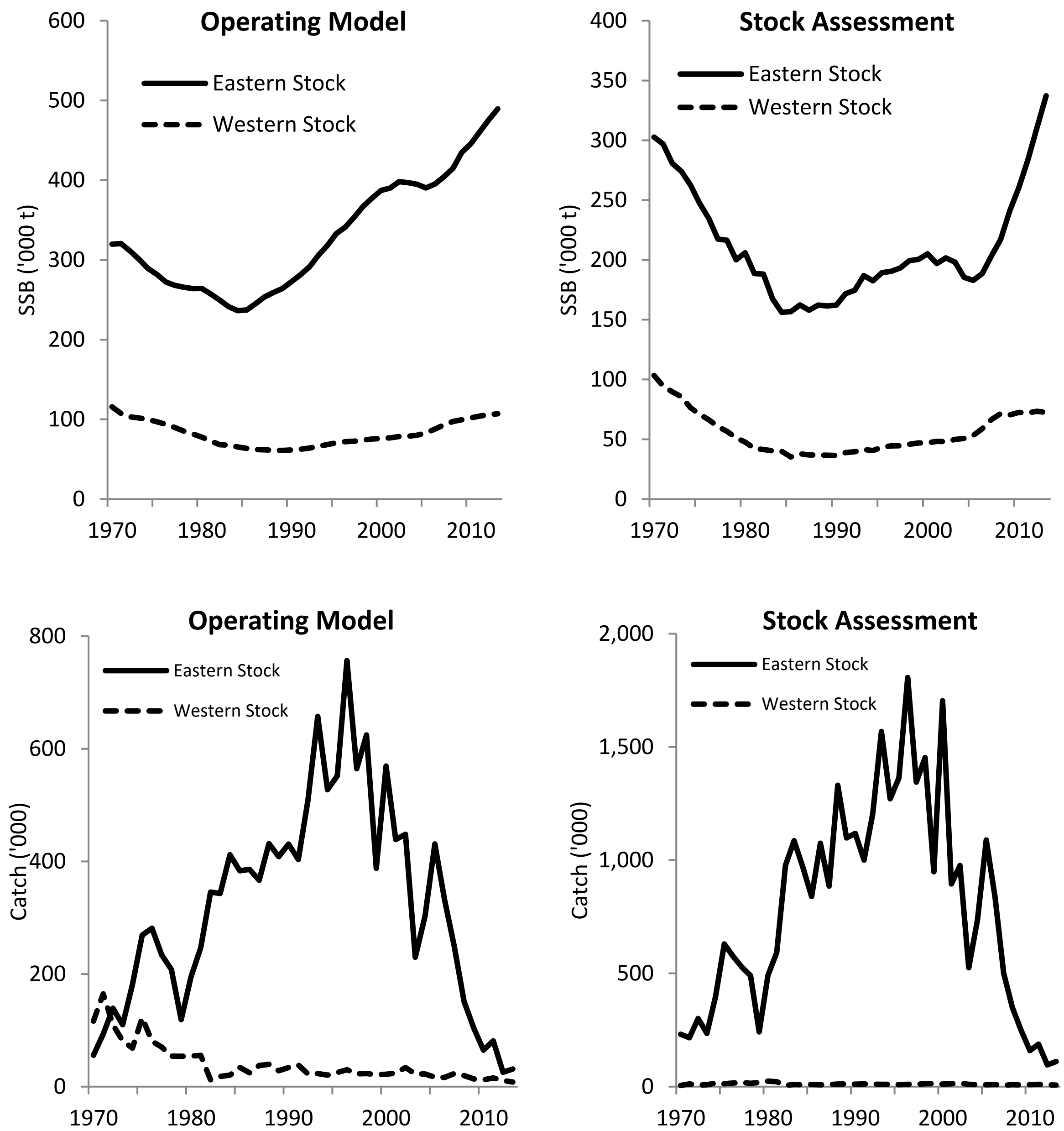


Figure 6. Deterministic operating model output of eastern and western stock bluefin tuna spawning stock biomass(top left panel) compared to output of the revised VPA stocks assessments (top right panel, Appendices A and B) and eastern and western stock bluefin tuna catch in numbers (bottom left panel) compared to output of the revised VPA stocks assessments (bottom right panel).

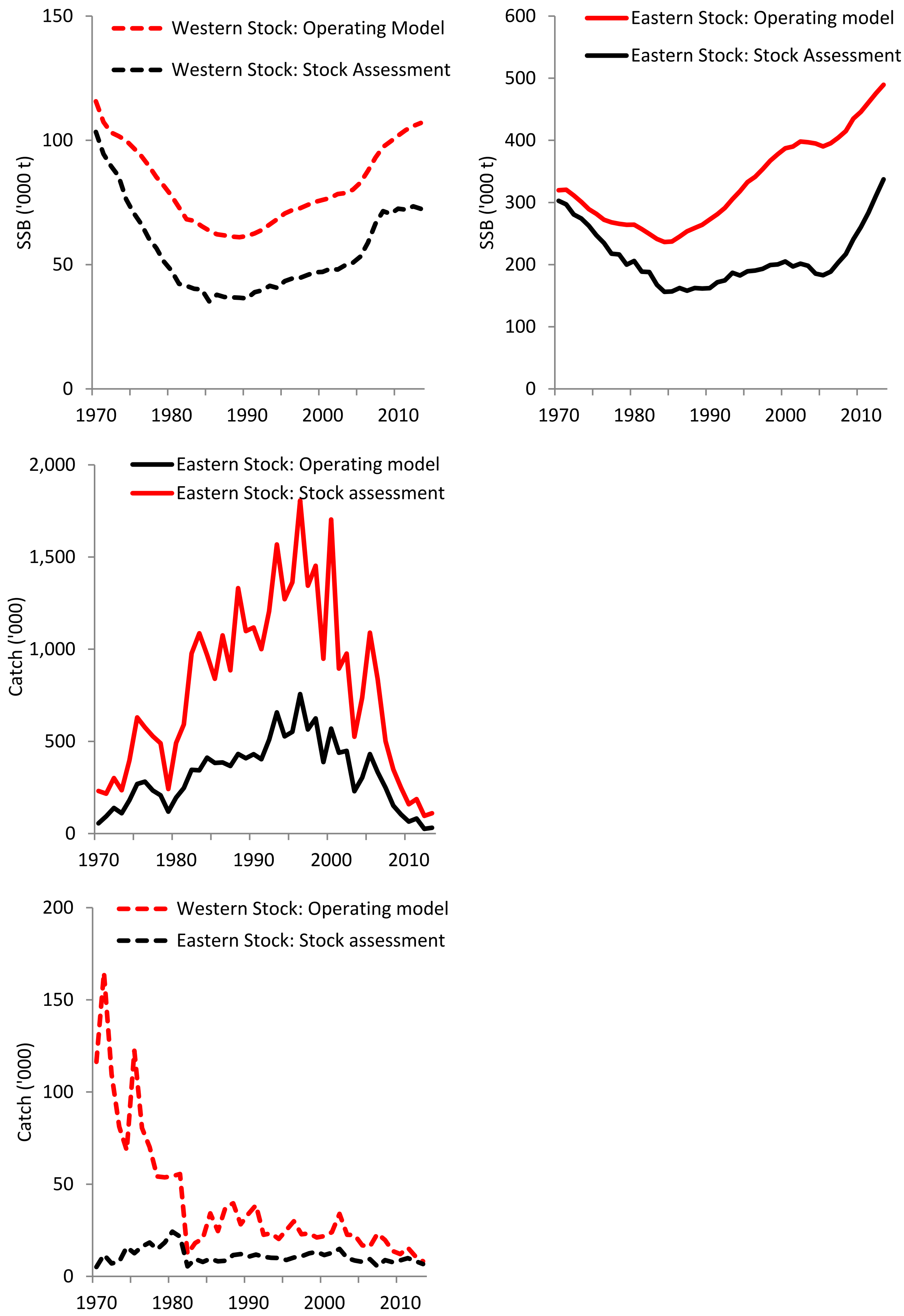


Figure 7. Comparison of spawning stock biomass (top panels) and catch (bottom panels) of eastern and western stock bluefin tuna based on the deterministic operating model and the revised VPA stocks assessments (Appendices A and B).

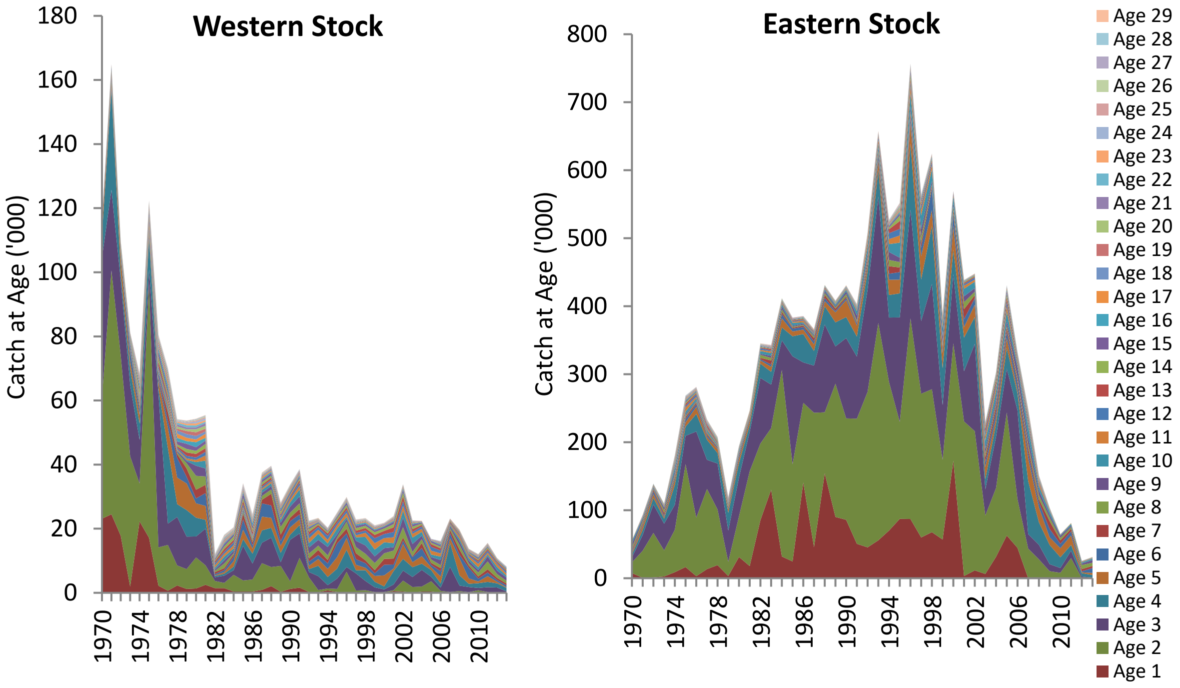


Figure 8. Deterministic operating model output of Atlantic bluefin tuna catch at age for the western stock (left panel) and eastern stock (right panel) over time.

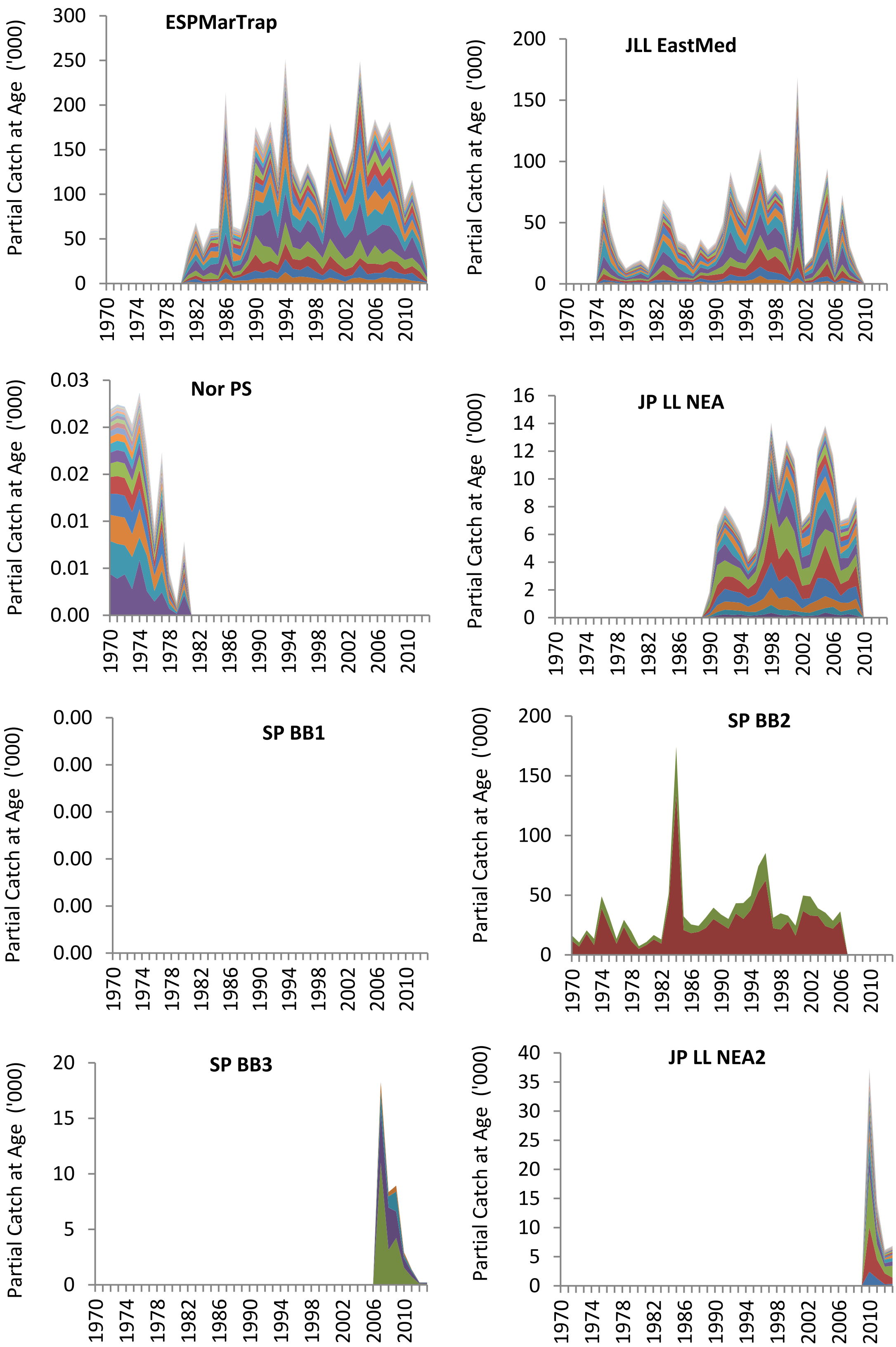
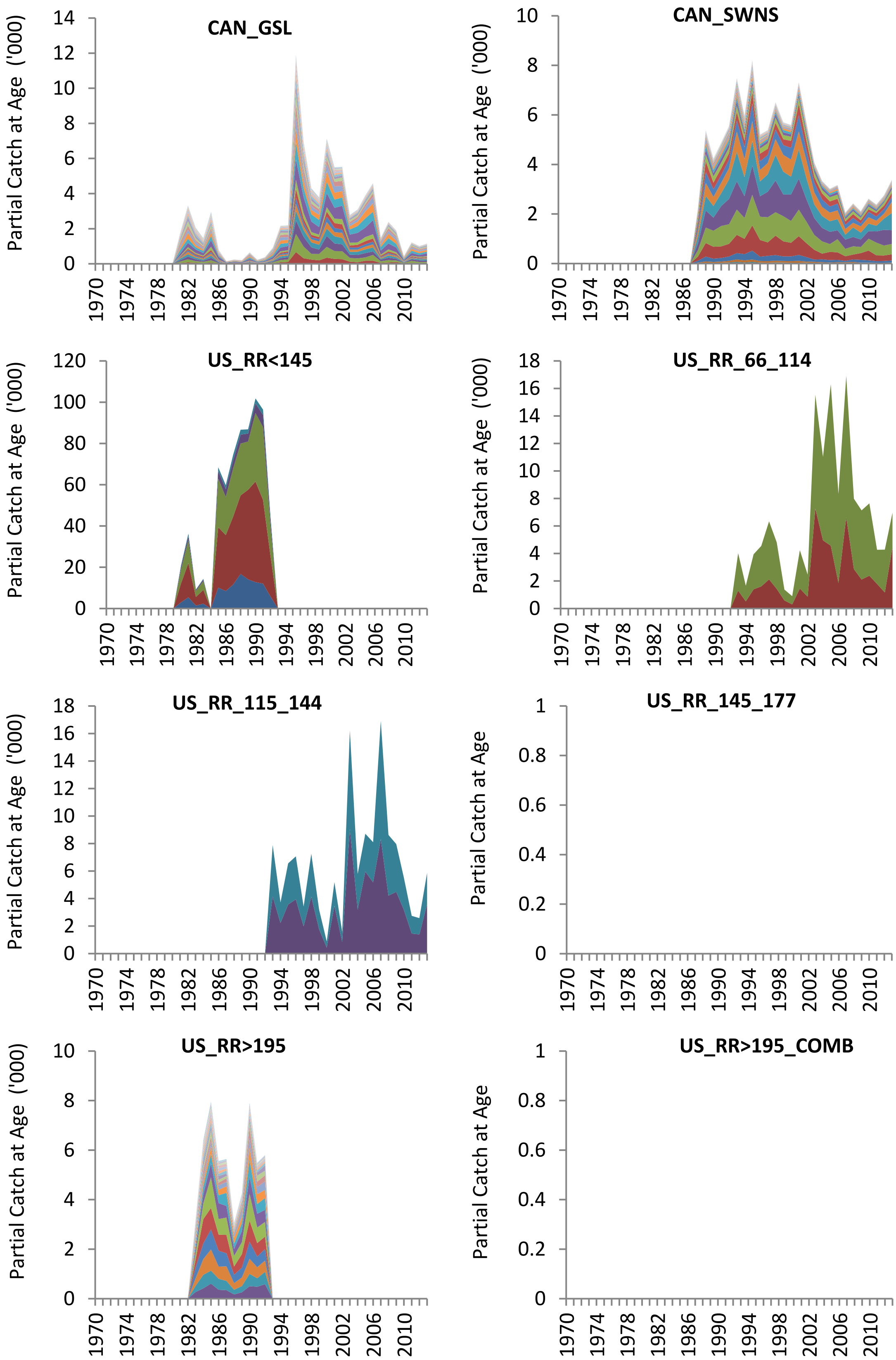


Figure 9. Deterministic observation model output of Atlantic bluefin tuna partial catch at age for the eastern stock.


CAN_GSL
Partial Catch at Age ('000)
CAN_SWNS
Partial Catch at Age ('000)
US_RR<145
Partial Catch at Age ('000)
US_RR_66_114
Partial Catch at Age ('000)
US_RR_115_144
Partial Catch at Age ('000)
US_RR_145_177
Partial Catch at Age
US_RR>195
Partial Catch at Age ('000)
US_RR>195_COMB
Partial Catch at Age
1970 1974 1978 1982 1986 1990 1994 1998 2002 2006 2010

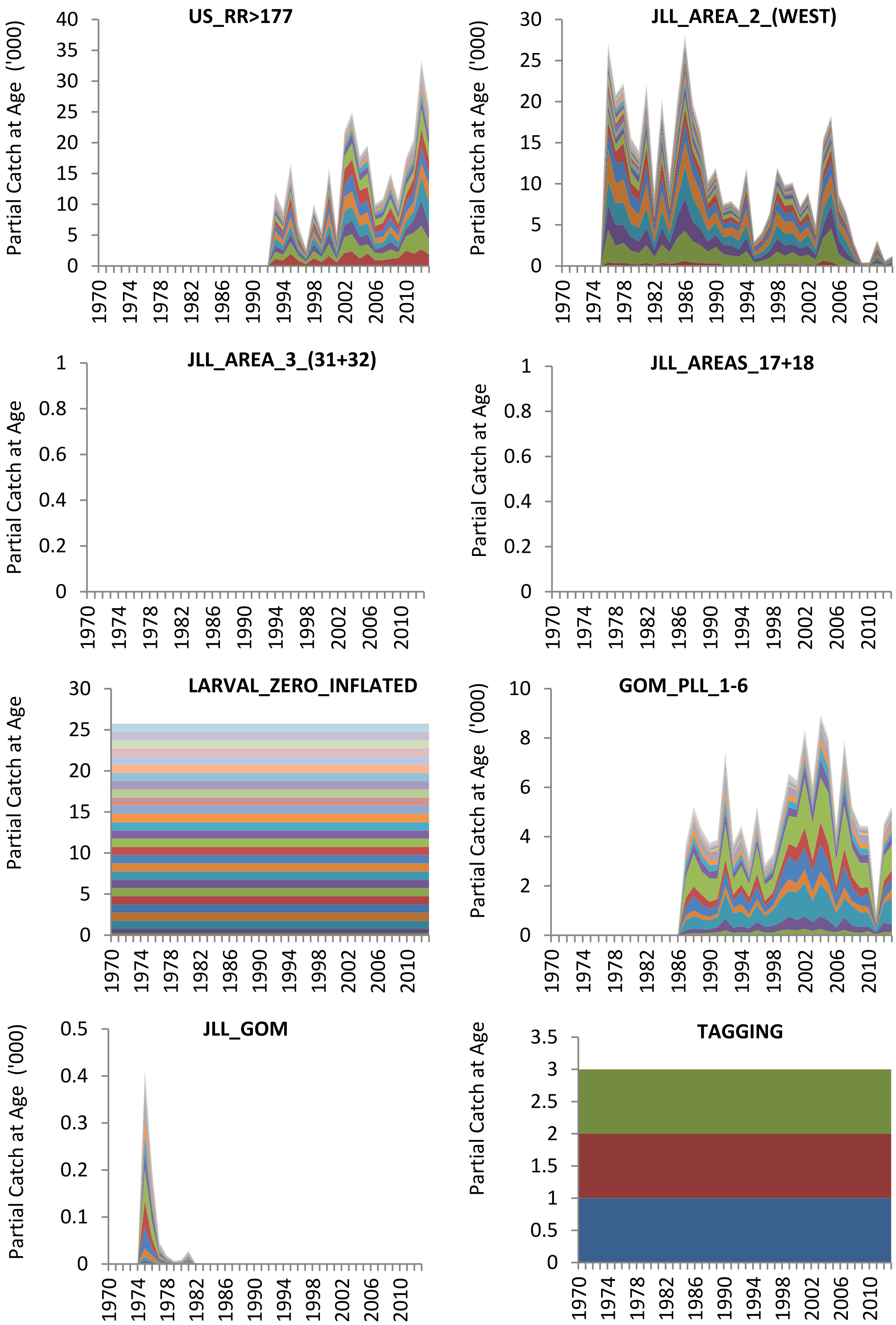
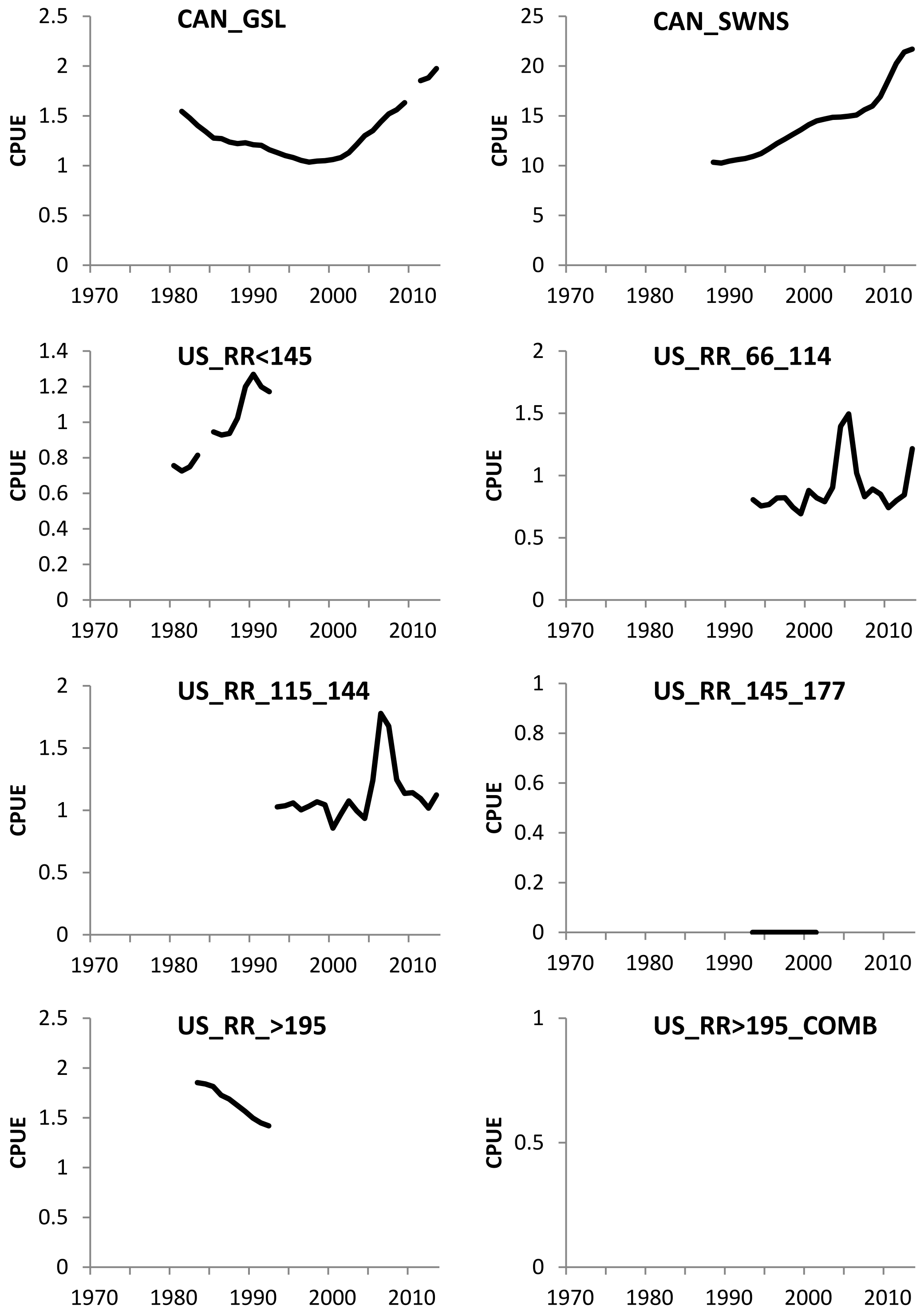


Figure 10. Deterministic observation model output of Atlantic bluefin tuna indices of abundance for the western stock.


CAN_GSL
CAN_SWNS
US_RR<145
US_RR_66_114
US_RR_115_144
US_RR_145_177
US_RR_>195
US_RR>195_COMB
CPUE
1970
1980
1990
2000
2010

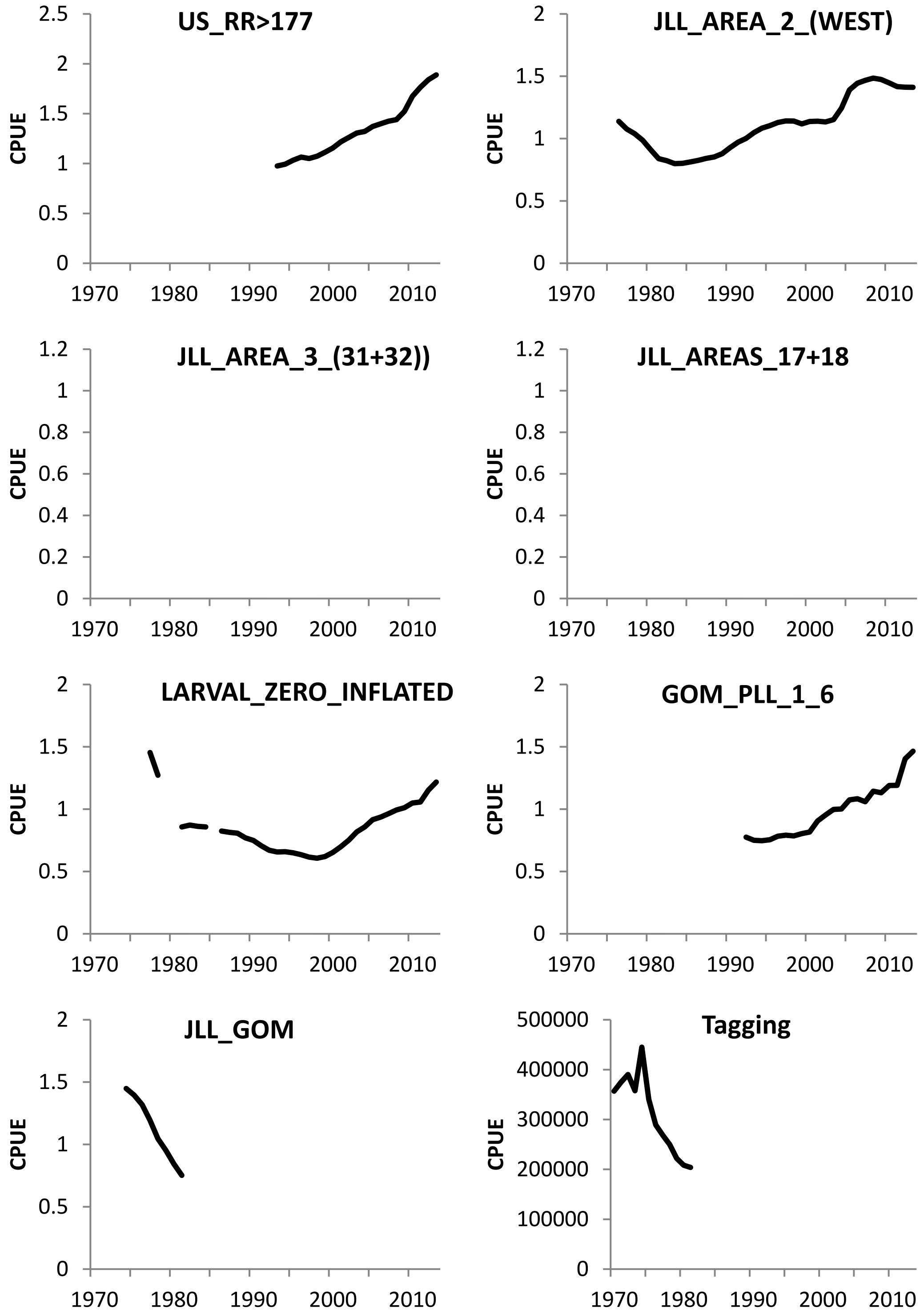


Figure 11. Deterministic observation model output of Atlantic bluefin tuna indices of abundance for the western stock.

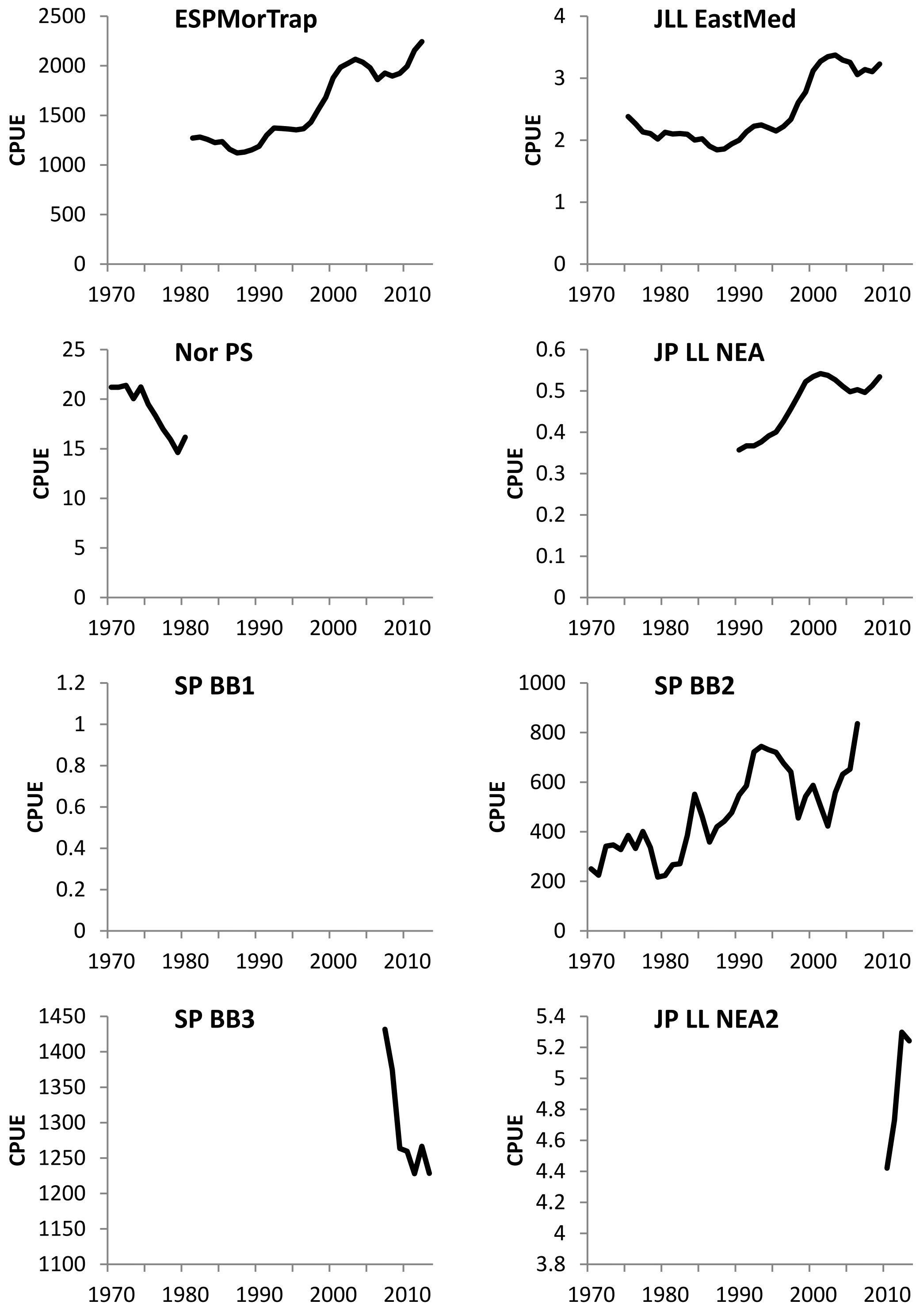


Figure 12. Deterministic observation model output of Atlantic bluefin tuna indices of abundance for the eastern stock.

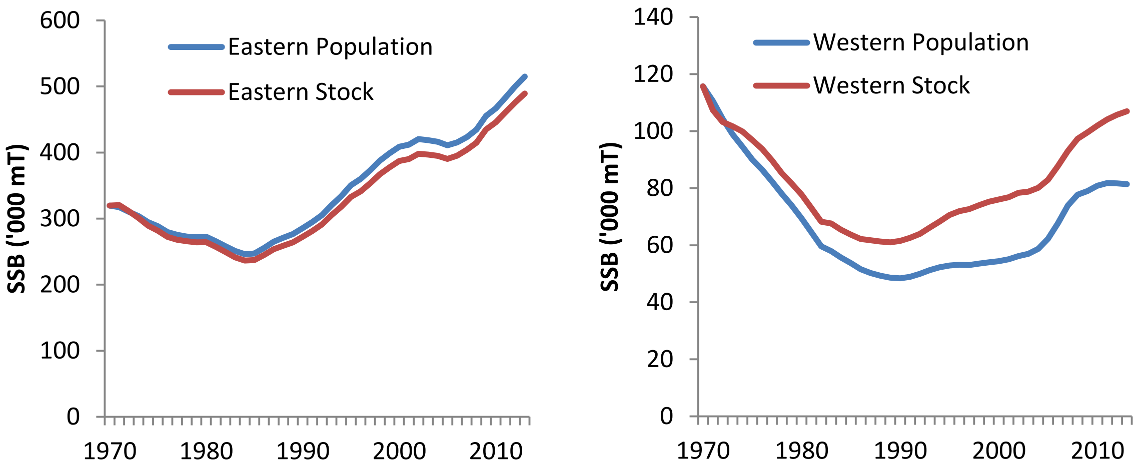


Figure 13. Population and stock view of the eastern (left panel) and western (right panel) bluefin tuna resource from the operating model.

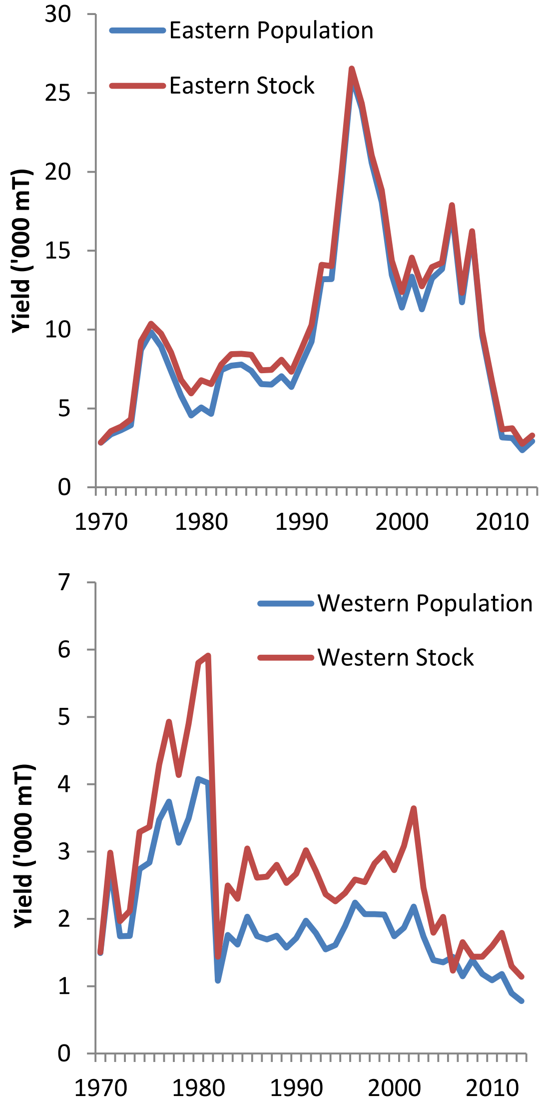


Figure 14. Population and stock view of the eastern (left panel) and western (right panel) bluefin tuna yield from the operating model.

Appendix A. VPA of western Atlantic Bluefin tuna used to condition the operating model.

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VPA-2BOX

SUMMARY STATISTICS AND DIAGNOSTIC OUTPUT

****

BFT West 1970-2013 ReRun

6/7/2017 0:00 2:45:00 PM

===

Total objective function = 2388.17

(with constants) = 2624.33

Number of parameters (P) = 28

Number of data points (D)= 257

AIC : 2*objective+2P = 5304.67

AICc: 2*objective+2P(...)= 5311.79

BIC : 2*objective+Plog(D)= 5404.04

Chi-square discrepancy = #NAME?

Loglikelihoods (deviance)= -2014.5 (4011.84)

effort data = -2014.5 (4011.84)

Log-posteriors = 0

catchability = 0

f-ratio = 0

natural mortality = 0

mixing coeff. = 0

Constraints = 2.11

terminal F = 2.11

stock-rec./sex ratio = 0

Out of bounds penalty = -375.77

TABLE 1 FISHING MORTALITY RATE FOR BFTW

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1970	0.07	0.377	0.564	0.233	0.086	0.016	0.007	0.002	0.001	0.004	0.012	0.01	0.015	0.021	0.025	0.025
1971	0.066	0.404	0.311	0.52	0.01	0.016	0.021	0.033	0.021	0.011	0.015	0.027	0.029	0.031	0.034	0.034
1972	0.053	0.216	0.196	0.036	0.085	0.035	0.002	0.009	0.012	0.007	0.003	0.009	0.031	0.038	0.033	0.033
1973	0.007	0.174	0.125	0.057	0.047	0.076	0.015	0.02	0.032	0.027	0.007	0.011	0.018	0.037	0.026	0.026
1974	0.051	0.053	0.088	0.038	0.042	0.042	0.027	0.037	0.024	0.019	0.035	0.017	0.016	0.073	0.097	0.097
1975	0.078	0.282	0.029	0.091	0.009	0.014	0.011	0.014	0.027	0.039	0.052	0.055	0.045	0.041	0.065	0.065
1976	0.01	0.067	0.292	0.017	0.028	0.013	0.005	0.006	0.05	0.056	0.031	0.043	0.123	0.12	0.095	0.095
1977	0.003	0.077	0.053	0.221	0.077	0.038	0.044	0.018	0.02	0.056	0.103	0.08	0.054	0.107	0.121	0.121
1978	0.012	0.036	0.115	0.044	0.105	0.103	0.026	0.01	0.017	0.02	0.024	0.049	0.057	0.048	0.149	0.149
1979	0.007	0.041	0.09	0.085	0.133	0.034	0.056	0.048	0.016	0.018	0.036	0.069	0.146	0.163	0.168	0.168
1980	0.008	0.07	0.065	0.075	0.061	0.031	0.057	0.129	0.116	0.035	0.039	0.074	0.124	0.185	0.228	0.228
1981	0.015	0.043	0.126	0.038	0.078	0.072	0.07	0.073	0.088	0.115	0.063	0.094	0.143	0.209	0.245	0.245
1982	0.008	0.016	0.011	0.006	0.003	0.009	0.014	0.014	0.013	0.025	0.041	0.035	0.051	0.055	0.069	0.069
1983	0.007	0.01	0.022	0.008	0.01	0.016	0.018	0.041	0.044	0.043	0.044	0.046	0.054	0.102	0.141	0.141
1984	0.002	0.027	0.011	0.016	0.03	0.036	0.023	0.015	0.025	0.038	0.05	0.061	0.068	0.081	0.106	0.106
1985	0.002	0.02	0.075	0.021	0.054	0.083	0.06	0.024	0.02	0.026	0.034	0.055	0.089	0.105	0.136	0.136
1986	0.002	0.021	0.04	0.028	0.02	0.025	0.033	0.027	0.018	0.02	0.023	0.035	0.071	0.095	0.155	0.155
1987	0.004	0.047	0.051	0.042	0.052	0.073	0.035	0.051	0.053	0.056	0.033	0.039	0.053	0.075	0.093	0.093
1988	0.007	0.031	0.07	0.034	0.045	0.063	0.085	0.06	0.055	0.065	0.063	0.051	0.066	0.081	0.105	0.105
1989	0.001	0.032	0.008	0.03	0.032	0.028	0.043	0.082	0.083	0.074	0.077	0.082	0.076	0.102	0.118	0.118
1990	0.005	0.009	0.074	0.015	0.031	0.037	0.028	0.046	0.085	0.107	0.079	0.082	0.073	0.072	0.113	0.113
1991	0.007	0.043	0.04	0.02	0.022	0.028	0.043	0.057	0.072	0.101	0.105	0.107	0.1	0.091	0.098	0.098
1992	0.001	0.02	0.01	0.006	0.011	0.021	0.022	0.052	0.076	0.057	0.087	0.126	0.138	0.145	0.1	0.1
1993	0.001	0.003	0.023	0.026	0.019	0.017	0.034	0.041	0.074	0.097	0.066	0.07	0.082	0.079	0.084	0.084
1994	0.003	0.003	0.006	0.017	0.027	0.021	0.018	0.041	0.1	0.06	0.074	0.082	0.075	0.091	0.073	0.073
1995	0.001	0.004	0.019	0.023	0.032	0.063	0.02	0.013	0.031	0.096	0.073	0.066	0.068	0.084	0.111	0.111
1996	0.001	0.026	0.008	0.041	0.036	0.017	0.028	0.046	0.021	0.029	0.082	0.086	0.09	0.089	0.119	0.119

1997 0 0.003 0.029 0.007 0.017 0.022 0.028 0.049 0.049 0.038 0.034 0.064 0.092 0.121 0.128 0.128

1998 0.001 0.003 0.016 0.024 0.007 0.019 0.015 0.039 0.083 0.089 0.058 0.052 0.094 0.123 0.119 0.119

1999 0 0.001 0.011 0.013 0.017 0.011 0.017 0.047 0.05 0.086 0.087 0.094 0.102 0.138 0.133 0.133

2000 0 0.001 0.004 0.01 0.035 0.042 0.03 0.039 0.043 0.055 0.066 0.069 0.081 0.103 0.126 0.126

2001 0.002 0.001 0.01 0.028 0.011 0.017 0.031 0.053 0.028 0.042 0.071 0.111 0.102 0.105 0.127 0.127

2002 0.001 0.015 0.018 0.028 0.041 0.02 0.017 0.072 0.081 0.078 0.063 0.074 0.128 0.113 0.126 0.126

2003 0 0.005 0.02 0.024 0.016 0.018 0.007 0.03 0.07 0.069 0.055 0.032 0.059 0.088 0.093 0.093

2004 0.001 0.003 0.02 0.017 0.025 0.034 0.024 0.04 0.03 0.043 0.042 0.048 0.044 0.043 0.066 0.066

2005 0.002 0.009 0.004 0.011 0.01 0.01 0.011 0.021 0.029 0.027 0.054 0.073 0.069 0.048 0.066 0.066

2006 0 0.003 0.004 0.005 0.015 0.025 0.017 0.022 0.038 0.055 0.044 0.054 0.052 0.054 0.076 0.076

2007 0 0.001 0.043 0.04 0.008 0.014 0.02 0.014 0.015 0.012 0.026 0.024 0.03 0.031 0.043 0.043

2008 0 0.002 0.009 0.021 0.039 0.008 0.019 0.039 0.032 0.028 0.03 0.029 0.028 0.03 0.052 0.052

2009 0 0.001 0.008 0.007 0.014 0.038 0.01 0.01 0.028 0.03 0.029 0.026 0.029 0.036 0.056 0.056

2010 0 0.004 0.004 0.01 0.005 0.012 0.008 0.016 0.013 0.035 0.048 0.032 0.03 0.048 0.055 0.055

2011 0 0.001 0.009 0.012 0.016 0.013 0.014 0.041 0.023 0.014 0.028 0.034 0.035 0.036 0.047 0.047

2012 0 0.001 0.007 0.01 0.005 0.006 0.01 0.023 0.023 0.022 0.031 0.027 0.034 0.031 0.044 0.044

2013 0 0 0.003 0.007 0.002 0.008 0.008 0.017 0.024 0.014 0.016 0.027 0.035 0.031 0.035 0.035

==

TABLE 2 ABUNDANCE AT THE BEGINNING OF THE YEAR [BY AREA] FOR BFTW

==

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

1970 1178274 417529 354599 98653 91708 100548 73574 79813 92546 71812 40513 47613 47647 38618 25837 56597

1971 1312795 573438 172027 132582 55613 62353 75511 56892 62641 74977 58561 32776 38978 38807 31271 67129

1972 1180978 641453 229787 82823 56105 40808 46846 57614 43284 49716 60702 47219 26381 31298 31103 79415

1973 941157 584418 310508 124124 56842 38172 30088 36403 44905 34668 40440 49531 38682 21154 24927 89304

1974 1528537 487730 294939 180019 83422 40179 27016 23092 28059 35259 27635 32870 40501 31405 16862 92946

1975 785667 758454 277629 177401 123402 59255 29412 20477 17512 22210 28317 21841 26714 32948 24132 83260

1976 738411 379539 343594 177147 115252 90641 44616 22657 15884 13818 17484 22020 17102 21111 26156 84045

1977 733998 381559 213062 168527 123926 83030 68269 34571 17719 12245 10701 13881 17444 12510 15483 83691

1978 649898 382110 212175 132752 96175 85019 61034 50888 26712 14085 9477 7907 10599 13672 9296 73392

1979 586194 335330 221395 124207 90389 64166 58522 46309 39635 21288 11304 7572 6223 8279 10773 59502

1980 567745 304013 193264 133004 81219 58625 47363 43077 34708 31629 17114 8931 5846 4448 5816 49642

1981 562764 294084 170267 118963 87861 56633 43403 34841 29775 25042 25017 13471 6856 4273 3058 36886

1982 602116 289327 169086 98631 81546 60218 40222 31505 25471 22097 18276 19226 10142 4915 2866 26106

1983 680148 311772 170942 109877 69763 60201 45568 30894 24437 20380 17640 14365 15355 7971 3848 22579

1984 664728 352602 185331 109832 77560 51155 45207 34868 23328 18953 15987 13827 11349 12028 5953 19177

1985 705114 346218 206192 120411 76922 55739 37678 34392 27029 18441 14938 12456 10760 8772 9168 18870

1986 672408 367550 203770 125717 83917 53968 39177 27623 26410 21478 14705 11817 9745 8142 6534 20450

1987 745898 350341 216195 128681 87037 60935 40174 29512 21148 21016 17241 11765 9440 7508 6126 19294

1988 1012570 387741 200755 135009 87803 61198 43263 30197 22052 16258 16270 13658 9354 7407 5763 19338

1989 1000042 525106 225715 123006 92890 62167 43848 30942 22362 16920 12475 12507 10733 7240 5651 18878

1990 814344 521469 305428 147065 84948 66656 46168 32723 22432 16677 12869 9461 9527 8226 5406 18214

1991 757603 423002 310394 186394 103167 61040 49026 34952 24585 16706 12270 9738 7206 7324 6329 17615

1992 765054 392585 243257 195851 130084 74762 45305 36567 25968 18549 12363 9045 7235 5390 5528 18124

1993 678727 398977 231082 158286 138517 95351 55912 34517 27316 19503 14343 9282 6592 5214 3856 17880

1994 805174 354031 238768 148305 109742 100665 71545 42098 26063 20572 14488 10993 7160 5023 3985 16686

1995 885299 418880 212043 155888 103763 79143 75254 54704 31773 19124 15866 11016 8372 5495 3792 16050

1996 847719 461502 250504 136716 108457 74419 56712 57455 42493 24961 14229 12075 8532 6465 4180 14829

1997 715176 442174 269971 163244 93405 77485 55833 42949 43147 33720 19862 10734 9161 6447 4891 14100

1998 920012 373177 264678 172245 115413 68049 57843 42289 32180 33312 26580 15716 8324 6908 4723 13964

1999 952978 480046 223409 171103 119677 84941 50958 44383 31996 24002 24941 20541 12338 6266 5051 13856

2000 907120 497425 287835 145225 120234 87150 64146 39033 33307 24677 18025 18725 15466 9210 4516 13825

2001 916568 473488 298480 188274 102381 85988 63807 48496 29536 25853 19117 13809 14451 11799 6869 13510

2002 1393366 477477 284052 194183 130356 75000 64507 48155 36180 23281 20300 14575 10224 10788 8789 14988

2003 2160139 726798 282465 183353 134415 92647 56117 49367 35263 27046 17639 15606 11193 7436 7964 17502

2004 1387720 1127491 434365 181957 127433 97970 69448 43417 37671 26650 20670 13672 12503 8725 5633 19382

2005 617206 723874 675001 279815 127342 92047 72258 52807 32807 29639 20900 16229 10778 9893 6910 19554

2006 1027144 321698 430935 441519 197014 93409 69535 55669 40675 25838 23631 16216 12476 8321 7796 20690

2007 1042607 536068 192696 282142 312795 143850 69562 53218 42842 31738 20024 18523 12707 9798 6521 22062

2008 765852 544241 321709 121237 193033 229907 108250 53107 41276 34210 25666 15971 14953 10199 7858 22861

2009 674932 399749 326209 209534 84529 137519 174100 82724 40159 32389 27242 20402 12831 12024 8187 24361

2010 1057619 352294 239879 212571 148137 61775 101028 134217 64442 31666 25727 21667 16440 10304 9592 25701

2011 708512 552077 210710 156936 149765 109198 46607 78073 103898 51580 25028 20076 17347 13197 8124 27901

2012 2720743 369872 331091 137145 110366 109188 82261 35809 58949 82267 41649 19928 16045 13855 10522 28703

2013 1410379 1420270 221797 216051 96599 81361 82824 63456 27533 46677 65897 33066 16047 12824 11106 31340

2014 736248 852660 145283 152726 71394 61626 63986 49070 21778 37675 53118 26626 12809 10286 34219

==

TABLE 3 CATCH OF BFTW

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1970	58920	104298	127233	17510	6528	1430	463	161	43	259	435	436	655	732	593	1299
1971	62033	152003	37948	46241	456	865	1357	1661	1180	758	805	797	1030	1090	968	2078
1972	45351	98312	33605	2514	3963	1222	92	470	465	292	185	403	730	1053	929	2372
1973	5065	73591	29957	5877	2254	2443	387	652	1270	829	265	506	643	696	587	2103
1974	55806	19939	20430	5639	2972	1448	640	739	595	609	869	516	600	2027	1425	7855
1975	43303	147653	6554	13155	907	709	283	253	419	775	1290	1058	1080	1202	1395	4813
1976	5532	19427	71850	2576	2743	1062	200	117	702	679	480	844	1802	2179	2176	6992
1977	1508	22182	9014	28496	7931	2699	2592	546	309	607	947	971	830	1157	1619	8751
1978	5564	10530	18969	4889	8281	7341	1392	447	405	252	208	348	536	588	1181	9324
1979	2828	10585	15537	8581	9754	1861	2843	1946	554	349	359	458	771	1137	1525	8423
1980	3246	16081	9991	8124	4129	1552	2327	4658	3447	973	599	584	620	685	1088	9286
1981	6290	9814	16530	3729	5692	3462	2613	2191	2271	2470	1392	1101	833	737	611	7370
1982	3608	3652	1517	523	245	460	490	391	297	500	662	600	458	239	176	1603
1983	3474	2463	3091	771	615	860	705	1102	953	773	682	585	739	705	463	2717
1984	1126	7240	1691	1493	2005	1577	927	451	521	642	702	743	676	858	551	1775
1985	776	5395	12162	2131	3523	3880	1957	728	480	436	457	612	834	794	1066	2194
1986	967	5898	6478	2914	1437	1177	1136	657	436	381	303	366	607	670	863	2701
1987	2326	12579	8766	4517	3830	3741	1240	1316	985	1037	507	414	441	492	501	1578
1988	4935	9303	11087	3821	3362	3299	3132	1575	1064	926	902	619	546	523	526	1765
1989	842	12925	1542	3104	2519	1480	1621	2160	1615	1090	835	900	716	641	575	1921
1990	2993	3583	17800	1798	2207	2135	1141	1308	1646	1534	885	681	611	522	531	1789
1991	4111	14055	10072	3081	1944	1484	1836	1727	1536	1457	1110	902	628	583	544	1514
1992	589	6088	1922	1053	1187	1332	871	1639	1723	935	932	980	849	663	481	1577
1993	416	1066	4385	3482	2276	1429	1644	1232	1749	1641	831	569	472	360	286	1326
1994	2052	720	1235	2140	2516	1828	1154	1519	2232	1082	937	793	469	399	257	1076
1995	933	1347	3242	2979	2860	4258	1310	609	883	1584	1015	637	505	402	366	1549

1996 526 9349 1676 4657 3341 1122 1385 2318 806 636 1015 909 671 502 429 1522

1997 249 1103 6392 928 1338 1502 1357 1816 1851 1138 605 609 736 672 537 1548

1998 341 889 3486 3483 652 1136 756 1436 2321 2586 1353 725 681 731 486 1437

1999 102 560 1946 1849 1760 799 743 1817 1402 1803 1879 1677 1096 735 577 1583

2000 98 287 1053 1174 3599 3127 1661 1321 1275 1204 1051 1140 1093 824 489 1497

2001 1430 361 2402 4352 987 1303 1748 2227 735 960 1193 1319 1282 1068 753 1481

2002 847 5559 4081 4528 4581 1305 990 2962 2542 1576 1124 949 1124 1056 957 1632

2003 283 2704 4521 3661 1874 1466 327 1314 2155 1633 853 444 585 570 648 1424

2004 814 2674 6944 2586 2752 2907 1454 1522 999 1018 769 582 492 336 331 1139

2005 721 4890 2470 2561 1083 840 688 977 840 703 992 1041 653 424 405 1146

2006 211 630 1245 1746 2452 2004 1063 1073 1373 1253 914 775 572 397 520 1380

2007 65 258 6687 9284 2119 1794 1214 664 575 353 469 402 341 270 253 856

2008 85 788 2292 2102 6401 1614 1797 1829 1190 850 677 415 376 272 364 1059

2009 72 222 2192 1194 987 4540 1559 713 986 876 705 476 337 387 409 1217

2010 66 1097 840 1830 635 632 691 1901 730 995 1094 629 439 438 471 1262

2011 3 560 1617 1592 2055 1261 556 2789 2172 643 624 614 540 431 343 1178

2012 110 404 1854 1212 466 606 692 718 1231 1614 1144 476 489 388 419 1143

2013 48 268 557 1254 196 555 588 957 601 599 923 792 509 352 354 999

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TABLE 4 SPAWNING STOCK FECUNDITY AND RECRUITMENT OF BFTW

===

spawning recruits

year biomass from VPA

1970 103377 1178274

1971 94529 1312795

1972 89654 1180978

1973 85584 941157

1974 76301 1528537

1975 70815 785667

1976 66312 738411

1977 60597 733998

1978 56637 649898

1979 51211 586194

1980 47600 567745

1981 42261 562764

1982 41443 602116

1983 40290 680148

1984 39997 664728

1985 35207 705114

1986 37858 672408

1987 36953 745898

1988 36799 1012570

1989 36681 1000042

1990 36390 814344

1991 38902 757603

1992 39642 765054

1993 41448 678727

1994 40620 805174

1995 43352 885299

1996 44428 847719

1997 44646 715176

1998 45846 920012

1999 46902 952978

2000 47059 907120

2001 48311 916568

2002 47996 1393366

2003 49799 2160139

2004 50734 1387720

2005 53202 617206

2006 58841 1027144

2007 66463 1042607

2008 71498 765852

2009 70407 674932

2010 72487 1057619

2011 72120 708512

2012 73421 2720743

2013 72437 1410379

===

TABLE 5 FITS TO INDEX DATA FOR BFTW

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5.1 CAN_GSL

Lognormal dist.

average numbers

Ages 8 - 16

log-likelihood = -12.1

deviance = 22.07

Chi-sq. discrepancy= 7.84

	Residuals	Standard	Q	Untransfrmd	Untransfrmd	Chi-square		
Year	Observed	Predicted	(Obs-pred)	Deviation	Catchabil.	Observed	Predicted	Discrepancy
1981	0.645	0.311	0.334	1.034	2.32E-05	1.32	0.945	0.017
1982	-0.144	0.123	-0.266	1.034	2.32E-05	0.6	0.783	0.159
1983	0.799	0.014	0.785	1.034	2.32E-05	1.54	0.703	0.042
1984	0.205	-0.061	0.266	1.034	2.32E-05	0.85	0.651	0.029
1985	-1.193	-0.075	-1.119	1.034	2.32E-05	0.21	0.643	0.342
1986	-1.06	-0.061	-0.999	1.034	2.32E-05	0.24	0.651	0.321
1987	-0.772	-0.092	-0.68	1.034	2.32E-05	0.32	0.632	0.258
1988	-0.268	-0.109	-0.159	1.034	2.32E-05	0.53	0.621	0.131

1989 -0.064 -0.141 0.077 1.034 2.32E-05 0.65 0.602 0.07

1990 -1.294 -0.17 -1.124 1.034 2.32E-05 0.19 0.585 0.343

1991 -0.064 -0.185 0.122 1.034 2.32E-05 0.65 0.576 0.06

1992 0.739 -0.176 0.915 1.034 2.32E-05 1.45 0.581 0.112

1993 0.262 -0.183 0.445 1.034 2.32E-05 0.9 0.577 0.004

1994 -1.019 -0.204 -0.816 1.034 2.32E-05 0.25 0.565 0.287

1995 0.039 -0.194 0.233 1.034 2.32E-05 0.72 0.571 0.036

1996 -2.159 -0.175 -1.983 1.034 2.32E-05 0.08 0.581 0.442

1997 -1.673 -0.167 -1.506 1.034 2.32E-05 0.13 0.586 0.396

1998 -1.06 -0.169 -0.891 1.034 2.32E-05 0.24 0.585 0.302

1999 -0.5 -0.181 -0.319 1.034 2.32E-05 0.42 0.578 0.172

2000 -0.772 -0.184 -0.589 1.034 2.32E-05 0.32 0.576 0.238

2001 -0.871 -0.172 -0.699 1.034 2.32E-05 0.29 0.583 0.263

2002 -0.431 -0.115 -0.317 1.034 2.32E-05 0.45 0.618 0.172

2003 0.181 -0.038 0.218 1.034 2.32E-05 0.83 0.667 0.038

2004 0.444 0.025 0.419 1.034 2.32E-05 1.08 0.71 0.006

2005 0.406 0.054 0.353 1.034 2.32E-05 1.04 0.731 0.014

2006 0.498 0.104 0.394 1.034 2.32E-05 1.14 0.769 0.009

2007 1.191 0.166 1.025 1.034 2.32E-05 2.28 0.818 0.21

2008 0.921 0.208 0.713 1.034 2.32E-05 1.74 0.853 0.02

2009 1.307 0.281 1.026 1.034 2.32E-05 2.56 0.918 0.211

2011 1.675 0.503 1.173 1.034 2.32E-05 3.7 1.145 0.417

2012 2.093 0.516 1.577 1.034 2.32E-05 5.62 1.161 1.764

2013 1.938 0.546 1.391 1.034 2.32E-05 4.81 1.196 0.961

Selectivities by age

Year 8 9 10 11 12 13 14 15 16

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1981 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1982 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1983 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1984 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1985 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1986 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1987 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1988 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1989 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1990 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1991 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1992 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1993 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1994 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1995 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1996 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1997 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1998 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

1999 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2000 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2001 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2002 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2003 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2004 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2005 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2006 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2007 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2008 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2009 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2011 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2012 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

2013 0.039 0.083 0.095 0.103 0.098 0.108 0.17 0.248 1

5.2 CAN_SWNS

Lognormal dist.

average numbers

Ages 5 - 16

log-likelihood = -3.27

deviance = 4.79

Chi-sq. discrepancy= 2.73

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1988 0.423 -0.298 0.721 1.034 7.05E-05 13.86 6.738 0.022

1989 0.361 -0.333 0.695 1.034 7.05E-05 13.03 6.504 0.016

1990 0.305 -0.36 0.666 1.034 7.05E-05 12.32 6.331 0.01

1991 0.047 -0.367 0.414 1.034 7.05E-05 9.51 6.287 0.007

1992 0.036 -0.36 0.396 1.034 7.05E-05 9.41 6.336 0.009

1993 -0.399 -0.333 -0.066 1.034 7.05E-05 6.09 6.509 0.107

1994 -0.221 -0.281 0.06 1.034 7.05E-05 7.28 6.853 0.075

1995 -0.254 -0.2 -0.054 1.034 7.05E-05 7.04 7.433 0.104

1996 -0.49 -0.105 -0.385 1.034 7.05E-05 5.56 8.171 0.189

1997 -0.706 -0.045 -0.661 1.034 7.05E-05 4.48 8.68 0.254

1998 -0.133 -0.028 -0.105 1.034 7.05E-05 7.95 8.826 0.117

1999 0.176 -0.041 0.217 1.034 7.05E-05 10.82 8.71 0.039

2000 -0.667 -0.053 -0.614 1.034 7.05E-05 4.66 8.61 0.244

2001 0.032 -0.048 0.079 1.034 7.05E-05 9.37 8.655 0.07

2002 0.236 -0.042 0.278 1.034 7.05E-05 11.49 8.704 0.027

2003 0.561 -0.029 0.59 1.034 7.05E-05 15.9 8.816 0.002

2004 0.008 0 0.008 1.034 7.05E-05 9.15 9.075 0.088

2005 0.15 0.042 0.108 1.034 7.05E-05 10.55 9.468 0.063

2006 0.25 0.089 0.161 1.034 7.05E-05 11.66 9.924 0.051

2007 0.043 0.151 -0.107 1.034 7.05E-05 9.48 10.554 0.117

2008 0.408 0.218 0.19 1.034 7.05E-05 13.65 11.284 0.044

2009 0.152 0.311 -0.159 1.034 7.05E-05 10.57 12.393 0.131

2010 0.011 0.451 -0.439 1.034 7.05E-05 9.18 14.245 0.203

2011 0.139 0.547 -0.408 1.034 7.05E-05 10.43 15.679 0.195

2012 0.062 0.567 -0.505 1.034 7.05E-05 9.66 16.005 0.218

2013 -0.531 0.548 -1.079 1.034 7.05E-05 5.34 15.71 0.335

Selectivities by age

Year	5	6	7	8	9	10	11	12	13	14	15	16
1988	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1989	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1990	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1991	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1992	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1993	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1994	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1995	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1996	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1997	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1998	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
1999	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2000	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2001	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2002	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2003	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2004	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2005	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2006	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2007	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2008	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2009	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2010	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2011	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2012	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67
2013	0.009	0.021	0.085	0.347	0.658	0.906	0.995	1	0.953	0.919	0.883	0.67

5.3 US_RR<145

Lognormal dist.

average numbers

Ages 1 - 5

log-likelihood = -1.33

deviance = 1.86

Chi-sq. discrepancy= 1.51

Year	Observed	Predicted	Residuals (Obs-pred)	Standard Deviation	Q Catchabil.	Untransfrmd Observed	Untransfrmd Predicted	Chi-square Discrepancy
1980	-0.148	-0.175	0.027	1.034	1.63E-06	0.8	0.779	0.083
1981	-0.841	-0.237	-0.604	1.034	1.63E-06	0.4	0.732	0.242
1982	0.817	-0.224	1.041	1.034	1.63E-06	2.1	0.741	0.228
1983	0.179	-0.165	0.345	1.034	1.63E-06	1.11	0.786	0.016
1985	-0.387	-0.058	-0.329	1.034	1.63E-06	0.63	0.876	0.175
1986	-0.174	-0.031	-0.142	1.034	1.63E-06	0.78	0.899	0.126
1987	0.274	-0.026	0.299	1.034	1.63E-06	1.22	0.904	0.023
1988	0.065	0.059	0.006	1.034	1.63E-06	0.99	0.984	0.088
1989	0.065	0.242	-0.177	1.034	1.63E-06	0.99	1.182	0.136
1990	-0.031	0.296	-0.326	1.034	1.63E-06	0.9	1.247	0.174
1991	0.306	0.207	0.099	1.034	1.63E-06	1.26	1.142	0.065
1992	-0.124	0.114	-0.238	1.034	1.63E-06	0.82	1.04	0.151

Selectivities by age

Year	1	2	3	4	5
1980	0.165	0.935	1	0.249	0.186
1981	0.165	0.935	1	0.249	0.186
1982	0.165	0.935	1	0.249	0.186
1983	0.165	0.935	1	0.249	0.186

1985 0.165 0.935 1 0.249 0.186

1986 0.165 0.935 1 0.249 0.186

1987 0.165 0.935 1 0.249 0.186

1988 0.165 0.935 1 0.249 0.186

1989 0.165 0.935 1 0.249 0.186

1990 0.165 0.935 1 0.249 0.186

1991 0.165 0.935 1 0.249 0.186

1992 0.165 0.935 1 0.249 0.186

5.4 US_RR_66_114

Lognormal dist.

average numbers

Ages 2 - 3

log-likelihood = -5.03

deviance = 8.66

Chi-sq. discrepancy= 3.12

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1993 0.314 -0.238 0.553 1.034 2.11E-06 1.1 0.633 0

1994 -1.128 -0.255 -0.873 1.034 2.11E-06 0.26 0.622 0.298

1995 0.324 -0.27 0.594 1.034 2.11E-06 1.11 0.613 0.002

1996 0.708 -0.132 0.84 1.034 2.11E-06 1.63 0.704 0.067

1997 1.082 -0.104 1.186 1.034 2.11E-06 2.37 0.724 0.441

1998 0.548 -0.172 0.721 1.034 2.11E-06 1.39 0.676 0.022

1999 0.504 -0.18 0.684 1.034 2.11E-06 1.33 0.671 0.014

2000 0.168 -0.013 0.18 1.034 2.11E-06 0.95 0.793 0.047

2001 -0.557 -0.009 -0.548 1.034 2.11E-06 0.46 0.796 0.229

2002 0.611 -0.042 0.654 1.034 2.11E-06 1.48 0.77 0.008

2003 -0.672 0.133 -0.806 1.034 2.11E-06 0.41 0.918 0.285

2004 1.021 0.568 0.453 1.034 2.11E-06 2.23 1.418 0.003

2005 0.998 0.684 0.314 1.034 2.11E-06 2.18 1.593 0.02

2006 -0.326 0.15 -0.476 1.034 2.11E-06 0.58 0.933 0.211

2007 -0.579 -0.216 -0.363 1.034 2.11E-06 0.45 0.647 0.184

2008 -0.831 0.089 -0.92 1.034 2.11E-06 0.35 0.878 0.307

2009 -0.831 -0.005 -0.826 1.034 2.11E-06 0.35 0.799 0.289

2010 -0.275 -0.253 -0.022 1.034 2.11E-06 0.61 0.623 0.095

2011 -0.004 -0.148 0.144 1.034 2.11E-06 0.8 0.693 0.055

2012 -0.697 -0.016 -0.681 1.034 2.11E-06 0.4 0.79 0.259

2013 -0.379 0.43 -0.809 1.034 2.11E-06 0.55 1.235 0.286

Selectivities by age

Year 2 3

---- ----- -----

1993 0.364 1

1994 0.364 1

1995 0.364 1

1996 0.364 1

1997 0.364 1

1998 0.364 1

1999 0.364 1

2000 0.364 1

2001 0.364 1

2002 0.364 1

2003 0.364 1

2004 0.364 1

2005 0.364 1

2006 0.364 1

2007 0.364 1

2008 0.364 1

2009 0.364 1

2010 0.364 1

2011 0.364 1

2012 0.364 1

2013 0.364 1

5.5 US_RR_115_144

Lognormal dist.

average numbers

Ages 4 - 5

log-likelihood = -3.42

deviance = 5.44

Chi-sq. discrepancy= 2.5

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1993 0.136 -0.063 0.199 1.034 3.28E-06 0.99 0.812 0.043

1994 -1.201 -0.204 -0.997 1.034 3.28E-06 0.26 0.705 0.321

1995 -0.316 -0.202 -0.114 1.034 3.28E-06 0.63 0.706 0.119

1996 -0.169 -0.262 0.094 1.034 3.28E-06 0.73 0.665 0.066

1997 -1.281 -0.207 -1.074 1.034 3.28E-06 0.24 0.702 0.334

1998 0.041 -0.094 0.135 1.034 3.28E-06 0.9 0.786 0.057

1999 -0.115 -0.082 -0.033 1.034 3.28E-06 0.77 0.796 0.098

2000 0.385 -0.174 0.559 1.034 3.28E-06 1.27 0.726 0

2001 0.454 -0.089 0.542 1.034 3.28E-06 1.36 0.791 0

2002 1.102 0.018 1.083 1.034 3.28E-06 2.6 0.88 0.279

2003 -0.382 0.005 -0.386 1.034 3.28E-06 0.59 0.868 0.189

2004 -0.254 -0.023 -0.232 1.034 3.28E-06 0.67 0.845 0.15

2005 -0.316 0.252 -0.568 1.034 3.28E-06 0.63 1.111 0.233

2006 0.524 0.703 -0.178 1.034 3.28E-06 1.46 1.745 0.136

2007 0.538 0.636 -0.098 1.034 3.28E-06 1.48 1.632 0.115

2008 0.468 -0.003 0.471 1.034 3.28E-06 1.38 0.862 0.002

2009 -0.796 -0.074 -0.721 1.034 3.28E-06 0.39 0.802 0.267

2010 0.361 0.137 0.225 1.034 3.28E-06 1.24 0.991 0.037

2011 0.385 -0.025 0.41 1.034 3.28E-06 1.27 0.843 0.007

2012 0.25 -0.238 0.489 1.034 3.28E-06 1.11 0.681 0.001

2013 0.185 -0.01 0.195 1.034 3.28E-06 1.04 0.855 0.043

Selectivities by age

Year 4 5

---- ----- -----

1993 0.971 1

1994 0.971 1

1995 0.971 1

1996 0.971 1

1997 0.971 1

1998 0.971 1

1999 0.971 1

2000 0.971 1

2001 0.971 1

2002 0.971 1

2003 0.971 1

2004 0.971 1

2005 0.971 1

2006 0.971 1

2007 0.971 1

2008 0.971 1

2009 0.971 1

2010 0.971 1

2011 0.971 1

2012 0.971 1

2013 0.971 1

5.6 US_RR_145_177

Not used

5.7 US_RR>195

Lognormal dist.

average numbers

Ages 10 - 16

log-likelihood = -1.24

deviance = 1.81

Chi-sq. discrepancy= 1.31

Year	Observed	Predicted	Residuals (Obs-pred)	Standard Deviation	Q Catchabil.	Untransfrmd Observed	Untransfrmd Predicted	Chi-square Discrepancy
1983	1.165	0.12	1.044	1.034	2.08E-05	2.81	0.989	0.231
1984	0.355	0.107	0.248	1.034	2.08E-05	1.25	0.976	0.033
1985	-0.019	0.081	-0.1	1.034	2.08E-05	0.86	0.951	0.116
1986	-0.562	0.043	-0.605	1.034	2.08E-05	0.5	0.916	0.242
1987	-0.504	0.027	-0.53	1.034	2.08E-05	0.53	0.901	0.224
1988	0.069	0.001	0.068	1.034	2.08E-05	0.94	0.878	0.073
1989	-0.143	-0.033	-0.11	1.034	2.08E-05	0.76	0.848	0.118
1990	-0.331	-0.076	-0.255	1.034	2.08E-05	0.63	0.813	0.156
1991	-0.067	-0.114	0.047	1.034	2.08E-05	0.82	0.782	0.078
1992	0.037	-0.156	0.193	1.034	2.08E-05	0.91	0.75	0.044

Selectivities by age

Year	10	11	12	13	14	15	16
1983	0.224	0.274	0.433	0.553	0.773	1	0.903

1984 0.224 0.274 0.433 0.553 0.773 1 0.903

1985 0.224 0.274 0.433 0.553 0.773 1 0.903

1986 0.224 0.274 0.433 0.553 0.773 1 0.903

1987 0.224 0.274 0.433 0.553 0.773 1 0.903

1988 0.224 0.274 0.433 0.553 0.773 1 0.903

1989 0.224 0.274 0.433 0.553 0.773 1 0.903

1990 0.224 0.274 0.433 0.553 0.773 1 0.903

1991 0.224 0.274 0.433 0.553 0.773 1 0.903

1992 0.224 0.274 0.433 0.553 0.773 1 0.903

5.8 US_RR>195_COMB

Not used

5.9 US_RR>177

Lognormal dist.

average numbers

Ages 8 - 16

log-likelihood = -6.78

deviance = 12.16

Chi-sq. discrepancy= 5.3

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

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1993 -0.161 -0.392 0.231 1.034 1.17E-05 0.69 0.548 0.036

1994 0.148 -0.364 0.512 1.034 1.17E-05 0.94 0.563 0

1995 0.333 -0.287 0.62 1.034 1.17E-05 1.13 0.608 0.004

1996 1.413 -0.206 1.62 1.034 1.17E-05 3.33 0.659 2.007

1997 0.616 -0.18 0.796 1.034 1.17E-05 1.5 0.677 0.047

1998 0.693 -0.168 0.861 1.034 1.17E-05 1.62 0.685 0.078

1999 0.842 -0.149 0.991 1.034 1.17E-05 1.88 0.698 0.175

2000 -0.252 -0.14 -0.112 1.034 1.17E-05 0.63 0.704 0.118

2001 0.532 -0.103 0.635 1.034 1.17E-05 1.38 0.731 0.006

2002 0.873 -0.087 0.96 1.034 1.17E-05 1.94 0.743 0.147

2003 -0.588 -0.083 -0.505 1.034 1.17E-05 0.45 0.746 0.218

2004 -0.091 -0.064 -0.027 1.034 1.17E-05 0.74 0.76 0.097

2005 -0.22 -0.016 -0.205 1.034 1.17E-05 0.65 0.798 0.143

2006 -0.634 0.034 -0.668 1.034 1.17E-05 0.43 0.839 0.256

2007 -0.898 0.077 -0.976 1.034 1.17E-05 0.33 0.875 0.317

2008 -0.706 0.128 -0.834 1.034 1.17E-05 0.4 0.921 0.291

2009 -1.028 0.223 -1.251 1.034 1.17E-05 0.29 1.013 0.362

2010 0.148 0.396 -0.248 1.034 1.17E-05 0.94 1.204 0.154

2011 -0.317 0.464 -0.781 1.034 1.17E-05 0.59 1.288 0.28

2012 -0.22 0.442 -0.662 1.034 1.17E-05 0.65 1.261 0.255

2013 -0.483 0.476 -0.958 1.034 1.17E-05 0.5 1.304 0.314

Selectivities by age

Year 8 9 10 11 12 13 14 15 16

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1993 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1994 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1995 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1996 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1997 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1998 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

1999 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2000 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2001 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2002 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2003 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2004 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2005 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2006 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2007 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2008 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2009 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2010 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2011 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2012 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

2013 0.176 0.265 0.251 0.359 0.438 0.595 0.845 1 0.763

5.1 JLL_AREA_2_(WEST)

Lognormal dist.

month 0 numbers

Ages 2 - 16

log-likelihood = -8.14

deviance = 13.75

Chi-sq. discrepancy= 4.83

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

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1976 -0.454 0.149 -0.604 1.034 2.14E-06 0.61 1.116 0.241

1977 0.899 0.072 0.827 1.034 2.14E-06 2.36 1.032 0.06

1978 0.171 -0.001 0.172 1.034 2.14E-06 1.14 0.959 0.048

1979 -0.208 -0.068 -0.14 1.034 2.14E-06 0.78 0.897 0.126

1980 0.439 -0.159 0.598 1.034 2.14E-06 1.49 0.819 0.002

1981 0.698 -0.253 0.95 1.034 2.14E-06 1.93 0.746 0.139

1982 -0.302 -0.327 0.024 1.034 2.14E-06 0.71 0.693 0.084

1983 -0.804 -0.32 -0.484 1.034 2.14E-06 0.43 0.698 0.213

1984 0.06 -0.312 0.371 1.034 2.14E-06 1.02 0.704 0.012

1985 0.206 -0.289 0.495 1.034 2.14E-06 1.18 0.72 0.001

1986 -2.368 -0.294 -2.074 1.034 2.14E-06 0.09 0.716 0.449

1987 -0.208 -0.271 0.063 1.034 2.14E-06 0.78 0.733 0.074

1988 0.206 -0.27 0.476 1.034 2.14E-06 1.18 0.733 0.002

1989 0.03 -0.242 0.272 1.034 2.14E-06 0.99 0.754 0.028

1990 -0.158 -0.159 0 1.034 2.14E-06 0.82 0.82 0.09

1991 -0.158 -0.103 -0.056 1.034 2.14E-06 0.82 0.867 0.104

1992 0.263 -0.087 0.35 1.034 2.14E-06 1.25 0.881 0.015

1993 0.247 -0.065 0.312 1.034 2.14E-06 1.23 0.9 0.021

1994 0.171 -0.057 0.228 1.034 2.14E-06 1.14 0.908 0.036

1995 -0.134 -0.067 -0.067 1.034 2.14E-06 0.84 0.899 0.107

1996 0.787 -0.056 0.843 1.034 2.14E-06 2.11 0.908 0.068

1997 0.302 -0.045 0.347 1.034 2.14E-06 1.3 0.919 0.015

1998 -0.454 -0.04 -0.415 1.034 2.14E-06 0.61 0.923 0.196

1999 -0.376 -0.038 -0.338 1.034 2.14E-06 0.66 0.925 0.177

2000 -0.158 0.004 -0.162 1.034 2.14E-06 0.82 0.965 0.132

2001 -0.614 0.035 -0.649 1.034 2.14E-06 0.52 0.995 0.252

2002 -0.454 0.054 -0.508 1.034 2.14E-06 0.61 1.014 0.219

2003 -0.471 0.08 -0.551 1.034 2.14E-06 0.6 1.041 0.229

2004 -0.595 0.201 -0.796 1.034 2.14E-06 0.53 1.174 0.283

2005 -0.406 0.364 -0.77 1.034 2.14E-06 0.64 1.383 0.278

2006 0.135 0.402 -0.267 1.034 2.14E-06 1.1 1.436 0.159

2007 0.565 0.378 0.186 1.034 2.14E-06 1.69 1.403 0.045

2008 -0.275 0.394 -0.669 1.034 2.14E-06 0.73 1.425 0.256

2009 0.559 0.362 0.197 1.034 2.14E-06 1.68 1.38 0.043

2010 -0.454 0.303 -0.757 1.034 2.14E-06 0.61 1.3 0.275

2011 0.992 0.258 0.734 1.034 2.14E-06 2.59 1.243 0.026

2012 1.324 0.236 1.088 1.034 2.14E-06 3.61 1.216 0.286

2013 1.003 0.229 0.774 1.034 2.14E-06 2.62 1.209 0.038

Selectivities by age

Year 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

---- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----

1976 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1977 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1978 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1979 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1980 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1981 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1982 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1983 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1984 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1985 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

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1987 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1988 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

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1990 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

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1994 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1995 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1996 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1997 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1998 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

1999 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2000 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2001 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2002 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2003 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2004 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2005 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2006 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2007 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2008 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2009 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2010 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2011 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2012 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

2013 0.029 0.279 0.367 0.535 0.73 0.745 0.791 0.776 0.624 0.441 0.553 0.757 0.888 1 0.846

5.11 JLL_AREA_3_(31+32)

Not used

5.12 JLL_AREAS_17+18

Not used

5.13 LARVAL_ZERO_INFLATED

Lognormal dist.

average biomass

Ages 9 - 16

log-likelihood = -1966.91

deviance = 3931.54

Chi-sq. discrepancy= #NAME?

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1977 1.512 0.963 0.549 1.034 5.40E-08 2.25 1.299 0

1978 2.181 0.797 1.384 1.034 5.40E-08 4.39 1.1 0.936

1981 0.491 0.179 0.311 1.034 5.40E-08 0.81 0.593 0.021

1982 0.867 #NAME? #NAME? 1.034 5.40E-08 1.18 #NAME? #NAME?

1983 0.527 #NAME? #NAME? 1.034 5.40E-08 0.84 #NAME? #NAME?

1984 -0.47 #NAME? #NAME? 1.034 5.40E-08 0.31 #NAME? #NAME?

1986 -0.348 #NAME? #NAME? 1.034 5.40E-08 0.35 #NAME? #NAME?

1987 -0.47 #NAME? #NAME? 1.034 5.40E-08 0.31 #NAME? #NAME?

1988 0.806 #NAME? #NAME? 1.034 5.40E-08 1.11 #NAME? #NAME?

1989 0.223 #NAME? #NAME? 1.034 5.40E-08 0.62 #NAME? #NAME?

1990 -0.407 #NAME? #NAME? 1.034 5.40E-08 0.33 #NAME? #NAME?

1991 -0.502 #NAME? #NAME? 1.034 5.40E-08 0.3 #NAME? #NAME?

1992 -0.166 #NAME? #NAME? 1.034 5.40E-08 0.42 #NAME? #NAME?

1993 -0.119 #NAME? #NAME? 1.034 5.40E-08 0.44 #NAME? #NAME?

1994 0.085 #NAME? #NAME? 1.034 5.40E-08 0.54 #NAME? #NAME?

1995 -0.813 #NAME? #NAME? 1.034 5.40E-08 0.22 #NAME? #NAME?

1996 0.466 #NAME? #NAME? 1.034 5.40E-08 0.79 #NAME? #NAME?

1997 -0.407 #NAME? #NAME? 1.034 5.40E-08 0.33 #NAME? #NAME?

1998 -1.506 #NAME? #NAME? 1.034 5.40E-08 0.11 #NAME? #NAME?

1999 -0.075 #NAME? #NAME? 1.034 5.40E-08 0.46 #NAME? #NAME?

2000 -0.685 #NAME? #NAME? 1.034 5.40E-08 0.25 #NAME? #NAME?

2001 -0.075 #NAME? #NAME? 1.034 5.40E-08 0.46 #NAME? #NAME?

2002 -0.726 #NAME? #NAME? 1.034 5.40E-08 0.24 #NAME? #NAME?

2003 0.466 #NAME? #NAME? 1.034 5.40E-08 0.79 #NAME? #NAME?

2004 0.104 -0.032 0.136 1.034 5.40E-08 0.55 0.48 0.057

2005 -1.013 #NAME? #NAME? 1.034 5.40E-08 0.18 #NAME? #NAME?

2006 -0.054 0.061 -0.114 1.034 5.40E-08 0.47 0.527 0.119

2007 -0.24 0.138 -0.378 1.034 5.40E-08 0.39 0.569 0.187

2008 -0.47 0.215 -0.685 1.034 5.40E-08 0.31 0.615 0.26

2009 0.157 0.264 -0.107 1.034 5.40E-08 0.58 0.645 0.117

2010 -0.24 0.335 -0.575 1.034 5.40E-08 0.39 0.693 0.235

2011 0.721 0.383 0.338 1.034 5.40E-08 1.02 0.728 0.017

2012 -0.502 0.467 -0.969 1.034 5.40E-08 0.3 0.791 0.316

2013 0.681 0.57 0.111 1.034 5.40E-08 0.98 0.877 0.062

Selectivities by age

Year	9	10	11	12	13	14	15	16
1977	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1978	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1981	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1982	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1983	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1984	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1986	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1987	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1988	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1989	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1990	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1991	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1992	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1993	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1994	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1995	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1996	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1997	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1998	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
1999	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2000	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2001	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2002	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2003	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2004	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2005	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2006	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2007	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2008	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2009	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733
2010	0.014	0.05	0.121	0.223	0.411	0.435	1	0.733

2011 0.014 0.05 0.121 0.223 0.411 0.435 1 0.733

2012 0.014 0.05 0.121 0.223 0.411 0.435 1 0.733

2013 0.014 0.05 0.121 0.223 0.411 0.435 1 0.733

5.14 GOM_PLL_1-6

Lognormal dist.

month 0 numbers

Ages 9 - 16

log-likelihood = -2.53

deviance = 3.59

Chi-sq. discrepancy= 2.23

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1992 0.335 -0.291 0.627 1.034 1.89E-05 0.8 0.428 0.005

1993 -0.24 -0.356 0.116 1.034 1.89E-05 0.45 0.401 0.061

1994 -0.55 -0.354 -0.196 1.034 1.89E-05 0.33 0.401 0.14

1995 -0.613 -0.334 -0.279 1.034 1.89E-05 0.31 0.41 0.162

1996 -1.156 -0.302 -0.854 1.034 1.89E-05 0.18 0.423 0.295

1997 -0.55 -0.2 -0.351 1.034 1.89E-05 0.33 0.469 0.18

1998 -0.463 -0.142 -0.321 1.034 1.89E-05 0.36 0.496 0.173

1999 0.064 -0.112 0.176 1.034 1.89E-05 0.61 0.511 0.047

2000 0.442 -0.131 0.573 1.034 1.89E-05 0.89 0.502 0.001

2001 -0.115 -0.047 -0.068 1.034 1.89E-05 0.51 0.546 0.107

2002 -0.176 -0.002 -0.173 1.034 1.89E-05 0.48 0.571 0.135

2003 0.408 -0.027 0.434 1.034 1.89E-05 0.86 0.557 0.005

2004 0.31 -0.037 0.347 1.034 1.89E-05 0.78 0.551 0.015

2005 0.031 0.017 0.014 1.034 1.89E-05 0.59 0.582 0.086

2006 -0.333 0.079 -0.412 1.034 1.89E-05 0.41 0.619 0.196

2007	-0.039	0.07	-0.109	1.034	1.89E-05	0.55	0.614	0.118
2008	0.789	0.175	0.614	1.034	1.89E-05	1.26	0.682	0.004
2009	0.607	0.217	0.39	1.034	1.89E-05	1.05	0.711	0.009
2010	0.442	0.293	0.149	1.034	1.89E-05	0.89	0.767	0.054
2011	0.244	0.359	-0.115	1.034	1.89E-05	0.73	0.819	0.119
2012	0.851	0.516	0.335	1.034	1.89E-05	1.34	0.958	0.017
2013	-0.286	0.61	-0.896	1.034	1.89E-05	0.43	1.053	0.303

Selectivities by age

Year	9	10	11	12	13	14	15	16
1992	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1993	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1994	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1995	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1996	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1997	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1998	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
1999	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2000	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2001	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2002	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2003	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2004	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2005	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2006	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2007	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2008	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2009	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2010	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2011	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2012	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403
2013	0.029	0.074	0.232	0.118	0.299	0.286	1	0.403

5.15 JLL_GOM

Lognormal dist.

month 0 numbers

Ages 9 - 16

log-likelihood = -1.3

deviance = 2.07

Chi-sq. discrepancy= 0.95

	Residuals	Standard	Q	Untransfrmd	Untransfrmd	Chi-square		
Year	Observed	Predicted	(Obs-pred)	Deviation	Catchabil.	Observed	Predicted	Discrepancy
1974	0.153	0.484	-0.331	1.034	8.70E-06	0.968	1.348	0.175
1975	-0.442	0.402	-0.844	1.034	8.70E-06	0.534	1.242	0.293
1976	-0.221	0.314	-0.535	1.034	8.70E-06	0.666	1.138	0.226
1977	0.094	0.155	-0.061	1.034	8.70E-06	0.913	0.97	0.105
1978	0.053	-0.04	0.093	1.034	8.70E-06	0.876	0.798	0.067
1979	0.438	-0.226	0.664	1.034	8.70E-06	1.287	0.663	0.01
1980	0.332	-0.44	0.772	1.034	8.70E-06	1.158	0.535	0.037
1981	-0.407	-0.65	0.243	1.034	8.70E-06	0.553	0.434	0.033

Selectivities by age

Year	9	10	11	12	13	14	15	16
1974	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857
1975	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857
1976	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857
1977	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857
1978	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857
1979	0.026	0.058	0.094	0.284	0.589	0.632	1	0.857

1980 0.026 0.058 0.094 0.284 0.589 0.632 1 0.857

1981 0.026 0.058 0.094 0.284 0.589 0.632 1 0.857

5.16 TAGGING

Lognormal dist.

average numbers

Ages 1 - 3

log-likelihood = -2.45

deviance = 4.09

Chi-sq. discrepancy= 1.82

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1970 1.232 0.169 1.063 1.034 2.74E-01 1065132 367931.421 0.253

1971 1.17 0.235 0.935 1.034 2.74E-01 1001624 393366.673 0.127

1972 0.329 0.263 0.066 1.034 2.74E-01 431955 404468.606 0.073

1973 -0.526 0.176 -0.703 1.034 2.74E-01 183616 370683.694 0.263

1974 0.094 0.407 -0.312 1.034 2.74E-01 341589 466751.94 0.171

1975 0.579 0.141 0.438 1.034 2.74E-01 554596 357885.98 0.004

1976 -0.205 -0.054 -0.151 1.034 2.74E-01 253265 294523.364 0.129

1977 -0.189 -0.128 -0.06 1.034 2.74E-01 257385 273377.205 0.105

1978 -0.943 -0.194 -0.749 1.034 2.74E-01 121110 256035.617 0.273

1979 -1.146 -0.275 -0.871 1.034 2.74E-01 98815 235995.896 0.298

1980 -0.479 -0.349 -0.13 1.034 2.74E-01 192541 219225.757 0.123

1981 0.084 -0.39 0.474 1.034 2.74E-01 337995 210508.946 0.002

Selectivities by age

Year 1 2 3

---- ----- ----- -----

1970 1 1 1

1971 1 1 1

1972 1 1 1

1973 1 1 1

1974 1 1 1

1975 1 1 1

1976 1 1 1

1977 1 1 1

1978 1 1 1

1979 1 1 1

1980 1 1 1

1981 1 1 1

===

TOTAL NUMBER OF FUNCTION EVALUATIONS = 9815

Appendix B. VPA of eastern Atlantic Bluefin tuna used to condition the operating model.

****

VPA-2BOX

SUMMARY STATISTICS AND DIAGNOSTIC OUTPUT

****

BFT East 1950-2013 ReRun

6/7/2017 0:00 2:03:00 PM

===

Total objective function = -39.32

(with constants) = 125.17

Number of parameters (P) = 30

Number of data points (D)= 179

AIC : 2*objective+2P = 310.33

AICc: 2*objective+2P(...)= 322.9

BIC : 2*objective+Plog(D)= 405.95

Chi-square discrepancy = 105.85

Loglikelihoods (deviance)= 32.17 (178.98)

effort data = 32.17 (178.98)

Log-posteriors = 2.43

catchability = 0

f-ratio = 2.43

natural mortality = 0

mixing coeff. = 0

Constraints = 4.73

terminal F = 0

stock-rec./sex ratio = 4.73

Out of bounds penalty = 0

==

TABLE 1 FISHING MORTALITY RATE FOR BFTE

===

	1	2	3	4	5	6	7	8	9	10
1950	0.042	0.11	0.002	0.006	0.032	0.048	0.053	0.076	0.174	0.122
1951	0.008	0.015	0.017	0.014	0.044	0.08	0.079	0.063	0.154	0.108
1952	0.001	0.003	0.006	0.01	0.032	0.076	0.128	0.124	0.161	0.113
1953	0.002	0.005	0.009	0.012	0.068	0.057	0.119	0.168	0.141	0.099
1954	0.002	0.004	0.001	0.005	0.049	0.089	0.057	0.068	0.187	0.131
1955	0.002	0.013	0.036	0.021	0.048	0.061	0.106	0.076	0.175	0.143
1956	0.001	0.01	0.017	0.012	0.017	0.048	0.059	0.108	0.114	0.094
1957	0.002	0.02	0.029	0.015	0.018	0.044	0.145	0.107	0.132	0.108
1958	0.006	0.03	0.045	0.019	0.038	0.048	0.049	0.142	0.116	0.095
1959	0.003	0.023	0.081	0.031	0.015	0.015	0.018	0.025	0.132	0.108
1960	0.002	0.013	0.024	0.037	0.051	0.031	0.02	0.038	0.066	0.099
1961	0.002	0.026	0.046	0.035	0.089	0.067	0.02	0.021	0.063	0.095
1962	0.002	0.016	0.042	0.03	0.042	0.1	0.038	0.049	0.057	0.086
1963	0.002	0.017	0.033	0.038	0.042	0.036	0.05	0.028	0.025	0.038
1964	0.005	0.027	0.057	0.048	0.06	0.039	0.036	0.037	0.026	0.039
1965	0.003	0.032	0.043	0.041	0.029	0.041	0.044	0.021	0.029	0.044
1966	0.015	0.044	0.15	0.059	0.037	0.044	0.032	0.021	0.018	0.026
1967	0.025	0.05	0.071	0.084	0.033	0.041	0.057	0.022	0.032	0.048
1968	0.01	0.032	0.066	0.042	0.049	0.018	0.041	0.029	0.018	0.027
1969	0.021	0.103	0.088	0.063	0.023	0.027	0.015	0.036	0.026	0.039
1970	0.024	0.072	0.054	0.038	0.029	0.016	0.03	0.021	0.038	0.034
1971	0.001	0.107	0.082	0.039	0.034	0.018	0.014	0.044	0.034	0.03
1972	0.003	0.076	0.177	0.046	0.036	0.029	0.024	0.01	0.027	0.024
1973	0.002	0.078	0.068	0.044	0.017	0.02	0.034	0.05	0.032	0.028
1974	0.014	0.087	0.113	0.075	0.067	0.032	0.023	0.031	0.074	0.065
1975	0.032	0.216	0.087	0.06	0.023	0.059	0.031	0.027	0.038	0.092

1976 0.004 0.148 0.304 0.08 0.067 0.017 0.04 0.019 0.03 0.075

1977 0.034 0.133 0.111 0.104 0.016 0.024 0.015 0.039 0.031 0.075

1978 0.06 0.188 0.116 0.058 0.029 0.008 0.019 0.008 0.025 0.06

1979 0.008 0.054 0.163 0.066 0.028 0.018 0.014 0.042 0.024 0.058

1980 0.061 0.131 0.239 0.114 0.023 0.027 0.024 0.014 0.032 0.057

1981 0.039 0.266 0.203 0.062 0.055 0.017 0.026 0.04 0.025 0.045

1982 0.111 0.227 0.309 0.11 0.043 0.027 0.019 0.069 0.051 0.092

1983 0.129 0.1 0.204 0.088 0.053 0.04 0.08 0.032 0.056 0.101

1984 0.05 0.252 0.071 0.088 0.089 0.065 0.06 0.083 0.065 0.117

1985 0.043 0.204 0.234 0.074 0.05 0.049 0.026 0.04 0.057 0.083

1986 0.149 0.166 0.131 0.09 0.022 0.034 0.031 0.025 0.057 0.084

1987 0.065 0.226 0.167 0.067 0.029 0.021 0.065 0.05 0.055 0.08

1988 0.187 0.11 0.238 0.097 0.034 0.027 0.038 0.063 0.086 0.126

1989 0.093 0.213 0.101 0.096 0.085 0.02 0.036 0.031 0.07 0.103

1990 0.089 0.135 0.201 0.085 0.107 0.034 0.035 0.055 0.083 0.125

1991 0.034 0.166 0.14 0.092 0.093 0.031 0.032 0.042 0.107 0.161

1992 0.038 0.143 0.224 0.062 0.05 0.043 0.073 0.089 0.117 0.176

1993 0.043 0.255 0.185 0.089 0.045 0.049 0.053 0.071 0.108 0.163

1994 0.052 0.15 0.114 0.048 0.083 0.071 0.142 0.158 0.267 0.403

1995 0.076 0.108 0.166 0.07 0.066 0.12 0.078 0.134 0.159 0.511

1996 0.084 0.239 0.193 0.165 0.08 0.039 0.079 0.074 0.194 0.622

1997 0.101 0.183 0.131 0.114 0.102 0.097 0.06 0.171 0.218 0.7

1998 0.059 0.347 0.215 0.162 0.073 0.18 0.03 0.034 0.12 0.387

1999 0.069 0.09 0.215 0.121 0.068 0.031 0.035 0.051 0.118 0.379

2000 0.208 0.189 0.115 0.141 0.115 0.092 0.037 0.064 0.084 0.176

2001 0.005 0.248 0.122 0.086 0.107 0.062 0.117 0.087 0.111 0.233

2002 0.01 0.309 0.221 0.098 0.044 0.102 0.044 0.079 0.097 0.204

2003 0.007 0.064 0.088 0.062 0.097 0.046 0.162 0.082 0.113 0.239

2004 0.027 0.095 0.085 0.065 0.034 0.073 0.074 0.107 0.115 0.242

2005 0.041 0.137 0.09 0.052 0.072 0.069 0.08 0.052 0.253 0.3

2006 0.057 0.039 0.155 0.051 0.015 0.115 0.053 0.071 0.196 0.233

2007 0 0.046 0.017 0.144 0.105 0.043 0.125 0.094 0.244 0.29

2008 0 0.026 0.033 0.04 0.083 0.066 0.045 0.154 0.161 0.192

2009 0 0.008 0.014 0.064 0.021 0.071 0.114 0.06 0.138 0.144

2010 0 0.006 0.008 0.031 0.044 0.021 0.047 0.056 0.051 0.054

2011 0 0.026 0.012 0.014 0.038 0.027 0.015 0.03 0.045 0.047

2012 0 0 0.003 0.008 0.003 0.012 0.048 0.061 0.043 0.045

2013 0 0 0.001 0.007 0.007 0.026 0.04 0.087 0.05 0.052

==

TABLE 2 ABUNDANCE AT THE BEGINNING OF THE YEAR [BY AREA] FOR BFTE

===
==

1 2 3 4 5 6 7 8 9 10

1950 7568965 3218125 3144460 1802760 1233510 1440428 831155 348903 232426 262963

1951 5991037 3790391 1730654 2062891 1275607 885041 1047812 613804 254394 349021

1952 11663260 3103106 2242989 1118123 1447851 904733 623669 754157 453204 433307

1953 11783041 6085615 1857511 1464365 788128 1039186 640363 427418 523983 629745

1954 13360387 6139628 3637840 1209102 1029926 545678 749701 442967 284230 836146

1955 9196710 6964209 3671575 2388128 856062 726340 380911 551281 325475 791497

1956 5231553 4791665 4126361 2326167 1664608 604193 521543 266941 401864 783276

1957 3425841 2727250 2850052 2666725 1636572 1212953 439624 382818 188460 874517

1958 5005061 1784125 1605285 1819399 1869876 1190987 885718 296216 270654 776438

1959 4207764 2597857 1039931 1008440 1270170 1334048 866985 657137 202233 773476

1960 3503032 2191115 1525150 629983 696179 927099 1003442 663261 504096 712012

1961 4699328 1825354 1298273 977915 431988 489877 685848 766147 502166 910363

1962 4406191 2447714 1068486 815061 672238 292897 349739 523567 590188 1059936

1963 4837706 2295311 1447094 673263 562866 477583 202404 262349 392283 1248111

1964 3772354 2521213 1355426 920231 461475 399803 351834 149926 200654 1294419

1965 6404213 1959775 1473083 841324 624327 321913 293508 264295 113601 1178135

1966 3631290 3333765 1139356 926832 574815 449289 235954 218835 203628 1012519

1967 3627387 1867720 1916013 644449 622050 410331 328233 177974 168591 969750

1968 2940015 1847144 1066934 1172355 421858 445973 300653 241369 136949 889535

1969 2762254 1519426 1073839 656205 799970 297539 334488 224686 184491 817574

1970 2194026 1411457 823273 646018 438338 579372 221144 256581 170489 789799

1971 5030255 1117737 788784 512273 442553 315536 435309 167171 197697 758138

1972 2850398 2623577 603179 477459 350658 316789 236625 334197 125860 757426

1973 4233991 1484080 1460218 332091 324634 250487 234837 179965 260366 704689

1974 4456506 2204835 824561 896280 226109 236405 187429 176780 134727 765194

1975 3600516 2294600 1213796 483969 591678 156634 174760 142654 134825 688215

1976 5419280 1820255 1110492 731353 324311 428159 112671 132000 109173 619214

1977 2756708 2816692 943059 538558 480760 224687 321194 84321 101900 556388

1978 2276891 1391343 1480654 554659 345597 350432 167396 246306 63763 502617

1979 2777903 1118884 692387 866587 372366 248708 265274 127952 192114 437774

1980 3523117 1438855 636432 386535 577277 268312 186548 203817 96495 490337

1981 3241603 1730773 757614 329193 245503 417853 199298 141830 158120 455002

1982 5616230 1627496 796260 406388 220290 172167 313571 151222 107201 481337

1983 7440468 2624823 778703 384205 259126 156342 127954 239550 110970 441982

1984 4525188 3414205 1425853 417020 250309 182084 114702 91970 182491 412196

1985 4062634 2247076 1592957 872212 271800 169585 130276 84146 66564 438667

1986 5909344 2031398 1100681 828553 576466 191556 123308 98807 63576 381401

1987 5002722 2658411 1033131 634696 539092 417771 141323 93080 75802 335803

1988 6225918 2446236 1273210 574514 422318 387784 312147 103087 69620 311852

1989 6945479 2696781 1315738 659489 371078 302359 288089 234074 76132 276846

1990 6973950 3302881 1308445 781220 426310 252513 226164 216325 178543 262029

1991 9949730 3331947 1732806 703516 510955 283840 186279 170034 161009 322587

1992 8347510 5021814 1694839 989533 456908 344941 210094 140554 128305 342108

1993 9131131 4195298 2613334 889939 662076 322137 252301 152107 101128 327469

1994 8095929 4568164 1951758 1427596 579740 469095 234249 186276 111423 301395

1995 8233758 4010637 2360548 1144589 968568 395143 333531 158225 125094 234133

1996 7465870 3985091 2162053 1313723 759760 671590 267482 240332 108846 201498

1997 4317610 3583429 1884639 1170897 792489 519490 493185 192437 175530 161211

1998 8155154 2037492 1791111 1086642 743368 530250 359889 361705 127523 179934

1999 5885641 4012719 865023 948738 657559 511869 338102 271953 274992 191712

2000 6376679 2867162 2201380 458629 598320 455277 378941 254250 203322 305543

2001 4480856 2704309 1425127 1289802 283411 395261 317011 284318 187593 361337

2002 7885820 2327871 1267402 828663 842609 188611 283488 219530 204985 370444

2003 6316067 4074325 1026148 667671 535019 597201 129999 211183 159494 398136

2004 8150344 3275258 2294917 617612 446615 359654 435494 86087 153114 372050

2005 10793518 4142348 1788181 1385262 411859 319791 255255 314835 60870 349819

2006 5559625 5411038 2168111 1074158 936276 283907 227948 183578 235196 250459

2007 6088216 2740354 3124954 1220015 726859 683360 193244 168332 134574 319253

2008 7231059 3177269 1571357 2019417 751705 484842 499603 132770 120559 281022

2009 7349489 3774404 1859606 998895 1381131 512723 346483 372040 89522 273143

2010 6488269 3836044 2249256 1205396 666736 1002125 364636 240807 275684 256843

2011 5934655 3386989 2289545 1466061 831463 472701 748939 271028 179028 411631

2012 5895704 3097258 1981671 1487132 1029061 593060 351334 574368 206794 460416

2013 5896244 3077804 1859590 1297806 1050341 759787 447434 260865 424877 520756

2014 3078079 1848047 1220343 917312 772921 565149 334961 188040 732238

==
==

TABLE 3 CATCH OF BFTE

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==

1 2 3 4 5 6 7 8 9 10

1950 227221 264498 3926 8984 33578 59513 38101 22709 33515 27330

1951 34493 43234 23622 24377 47004 59748 70418 33534 32856 32403

1952 4421 7682 11665 9197 38989 57831 66408 78472 60929 41914

1953 16403 21593 14130 14728 44604 50110 63493 58955 62224 53658

1954 14798 19900 2612 5405 42788 41008 37064 26001 43927 93313

1955 13292 72607 107287 41942 35018 37857 33831 35982 47166 95779

1956 5455 35668 55304 22788 23589 24829 26572 24377 39251 63567

1957 6090 42315 66203 33614 24986 46228 52604 34525 21086 81420

1958 21161 41049 57634 29588 59760 48488 37140 34886 26780 63842

1959 7803 45504 66430 25744 16179 17160 13577 14502 22619 71987

1960 4765 22822 30071 19572 30203 25135 17431 22141 29166 61076

1961 7810 36086 47258 28390 31705 27849 12017 14114 27817 74816

1962 6947 29693 35821 20586 23845 24378 11403 22140 29668 79161

1963 6052 29894 38038 21146 20055 14641 8764 6465 8772 41784

1964 13483 53407 61334 36574 23306 13436 11044 4904 4604 44458

1965 13433 48963 51094 28637 15434 11246 11086 4832 2980 45956

1966 39435 112262 130124 44909 18096 16945 6580 4015 3189 23646

1967 65607 71403 107837 43983 17335 14462 16219 3449 4776 40828

1968 21693 46196 55828 41113 17492 6842 10761 6080 2258 21866

1969 43105 116781 74227 34278 15471 6882 4455 7075 4268 28148

1970 38988 76924 35680 20582 10730 8007 5747 4676 5799 23883

1971 3451 89131 50860 16650 12913 4879 5481 6382 5947 20270

1972 5572 150796 80312 18136 10840 8034 4908 2851 3067 16399

1973 7760 87196 78669 12238 4771 4351 6947 7737 7455 17932

1974 44979 144277 72124 55221 12699 6556 3768 4789 8696 43995

1975 83784 352022 82482 24055 11863 7932 4665 3441 4480 54950

1976 17501 196886 239993 47506 18187 6492 3897 2187 2948 40376

1977 67420 276479 81061 45074 6677 4738 4363 2903 2778 36620

1978 98571 188169 132603 26750 8539 2569 2746 1850 1398 26717

1979 15968 46352 85484 47174 8803 3802 3159 4700 4051 22395

1980 153268 139588 111494 35392 11439 6346 3925 2495 2715 24603

1981 91413 320656 114393 16726 11334 6214 4537 4938 3506 18038

1982 435146 261565 174574 35996 8002 3991 5295 9038 4835 38429

1983 666700 196954 118435 27650 11539 5339 8741 6724 5468 38481

1984 162819 602875 80533 29876 18523 10029 5897 6546 10421 41447

1985 126331 327195 273250 52930 11441 7068 3014 2958 3330 31802

1986 605591 245280 110492 60475 10837 5638 3356 2173 3201 27826

1987 233816 425594 130379 35130 13521 7777 7936 4072 3661 23513

1988 787367 200806 221887 45198 12256 9116 10263 5612 5200 33541

1989 457214 409308 103865 51467 26165 5341 9140 6317 4674 24559

1990 436998 328719 195471 53837 37392 7450 6938 10362 12813 27930

1991 243244 401950 186084 52344 39257 7563 5140 6163 14736 43604

1992 229346 527897 280117 50401 19089 12662 13102 10683 12770 50171

1993 280527 748302 362085 64110 24965 13406 11620 9313 9357 44736

1994 304847 502294 171942 56713 40131 28247 27583 24303 23658 91142

1995 443085 322789 296576 65549 53665 39323 22101 17700 16645 85605

1996 444407 669904 312383 170612 50658 22396 18070 15305 17362 85496

1997 306608 474221 189334 107589 66458 42200 25467 27051 31144 74423

1998 345669 474503 285614 138652 45367 76859 9470 10785 13079 52632

1999 290410 272684 137390 91981 37213 13567 10306 11996 27670 55146

2000 889625 389997 195408 51453 56122 35131 12280 14041 14718 44863

2001 15982 469971 134430 90060 24959 20977 31157 21135 17744 68379

2002 59816 491266 206724 65445 31542 16089 10914 14936 17076 62174

2003 31034 198423 70575 34139 42902 23442 17278 14727 15451 77055

2004 158681 233925 152823 33096 12919 22190 27681 7757 14995 72745

2005 315743 419028 125613 59295 24776 18596 17314 14100 12307 82640

2006 228908 162488 255561 44960 11960 27030 10456 11129 37839 47307

2007 1510 96996 42049 139516 62706 25349 20195 13425 26398 73223

2008 755 63119 41758 67049 51597 27174 19392 16913 16230 44548

2009 1025 22513 20458 52792 24551 30777 33063 19205 10417 33298

2010 244 18233 14681 31594 24787 18450 14728 11765 12418 12144

2011 1287 68174 21397 17206 26735 10930 10119 7243 7044 17003

2012 13 390 5275 9709 2986 6082 14506 30483 7939 18557

2013 43 209 1858 7658 6055 17066 15351 19433 18707 24068

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TABLE 4 SPAWNING STOCK FECUNDITY AND RECRUITMENT OF BFTE

==

spawning recruits

year biomass from VPA

1950 367723 7568965

1951 394551 5991037

1952 405482 11663260

1953 398614 11783041

1954 397696 13360387

1955 398981 9196710

1956 438333 5231553

1957 450353 3425841

1958 486421 5005061

1959 471421 4207764

1960 448315 3503032

1961 439487 4699328

1962 425850 4406191

1963 387339 4837706

1964 378485 3772354

1965 371572 6404213

1966 353195 3631290

1967 351094 3627387

1968 342142 2940015

1969 325188 2762254

1970 302651 2194026

1971 296893 5030255

1972 280739 2850398

1973 274150 4233991

1974 262464 4456506

1975 247345 3600516

1976 234698 5419280

1977 217487 2756708

1978 216402 2276891

1979 200031 2777903

1980 205916 3523117

1981 188627 3241603

1982 188074 5616230

1983 167387 7440468

1984 156185 4525188

1985 156727 4062634

1986 162301 5909344

1987 157924 5002722

1988 162281 6225918

1989 161512 6945479

1990 162200 6973950

1991 171715 9949730

1992 174562 8347510

1993 186838 9131131

1994 182539 8095929

1995 189344 8233758

1996 190410 7465870

1997 193213 4317610

1998 199321 8155154

1999 200404 5885641

2000 205064 6376679

2001 196920 4480856

2002 201621 7885820

2003 198097 6316067

2004 185472 8150344

2005 182872 10793518

2006 188624 5559625

2007 203242 6088216

2008 216986 7231059

2009 240783 7349489

2010 260362 6488269

2011 283620 5934655

2012 310834 5895704

2013 337231 5896244

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TABLE 5 FITS TO INDEX DATA FOR BFTE

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5.1 ESPMarTrap

Lognormal dist.

average numbers

Ages 6 - 10

log-likelihood = 10.36

deviance = 22.78

Chi-sq. discrepancy= 16.34

	Residuals	Standard	Q	Untransfrmd	Untransfrmd	Chi-square		
Year	Observed	Predicted	(Obs-pred)	Deviation	Catchabil.	Observed	Predicted	Discrepancy
----	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------
1981	0.118	0.268	-0.151	0.507	1.67E-03	768.36	893.264	0.202
1982	0.418	0.259	0.16	0.507	1.67E-03	1038.12	884.758	0.003
1983	0.469	0.183	0.286	0.507	1.67E-03	1092.05	820.44	0.099
1984	0.564	0.113	0.45	0.507	1.67E-03	1200.27	764.959	0.493
1985	0.176	0.088	0.088	0.507	1.67E-03	814.46	745.795	0.005
1986	-0.55	-0.025	-0.525	0.507	1.67E-03	394.33	666.469	0.786
1987	-0.455	-0.079	-0.375	0.507	1.67E-03	433.53	630.978	0.535
1988	0.395	-0.107	0.503	0.507	1.67E-03	1014.56	613.758	0.703
1989	-0.251	-0.124	-0.127	0.507	1.67E-03	531.45	603.408	0.173
1990	-0.106	-0.107	0	0.507	1.67E-03	614.37	614.079	0.049
1991	0.063	-0.031	0.094	0.507	1.67E-03	727.86	662.62	0.004
1992	-0.777	-0.025	-0.752	0.507	1.67E-03	313.95	666.287	1.171
1993	-0.742	-0.06	-0.682	0.507	1.67E-03	325.36	643.309	1.053
1994	-0.692	-0.162	-0.531	0.507	1.67E-03	341.9	581.264	0.796
1995	-1.118	-0.319	-0.799	0.507	1.67E-03	223.43	496.675	1.247
1996	-0.599	-0.352	-0.247	0.507	1.67E-03	375.22	480.374	0.335
1997	0.373	-0.372	0.745	0.507	1.67E-03	992.41	471.019	2.485
1998	0.303	-0.247	0.55	0.507	1.67E-03	925.14	533.667	0.94
1999	0.51	-0.129	0.638	0.507	1.67E-03	1137.45	600.731	1.511

2000 0.079 0.078 0.001 0.507 1.67E-03 739.23 738.615 0.049

2001 0.631 0.136 0.495 0.507 1.67E-03 1284.62 782.755 0.671

2002 0.504 0.117 0.387 0.507 1.67E-03 1130.42 767.818 0.297

2003 -0.03 0.13 -0.16 0.507 1.67E-03 662.66 778.006 0.215

2004 -0.72 0.067 -0.787 0.507 1.67E-03 332.36 730.371 1.228

2005 -0.008 -0.016 0.008 0.507 1.67E-03 677.39 672.122 0.044

2006 -0.075 -0.136 0.061 0.507 1.67E-03 633.94 596.577 0.015

2007 0.382 -0.052 0.434 0.507 1.67E-03 1000.6 648.249 0.436

2008 -0.074 -0.073 -0.002 0.507 1.67E-03 634.18 635.141 0.051

2009 0.249 -0.022 0.271 0.507 1.67E-03 876.71 668.273 0.081

2010 0.422 0.138 0.284 0.507 1.67E-03 1042.24 784.443 0.097

2011 -0.012 0.371 -0.383 0.507 1.67E-03 674.97 989.922 0.547

2012 0.553 0.489 0.064 0.507 1.67E-03 1187.75 1113.79 0.013

Selectivities by age

Year 6 7 8 9 10

---- ----- ----- ----- ----- -----

1981 0.067 0.126 0.225 0.399 1

1982 0.067 0.126 0.225 0.399 1

1983 0.067 0.126 0.225 0.399 1

1984 0.067 0.126 0.225 0.399 1

1985 0.067 0.126 0.225 0.399 1

1986 0.067 0.126 0.225 0.399 1

1987 0.067 0.126 0.225 0.399 1

1988 0.067 0.126 0.225 0.399 1

1989 0.067 0.126 0.225 0.399 1

1990 0.067 0.126 0.225 0.399 1

1991 0.067 0.126 0.225 0.399 1

1992 0.067 0.126 0.225 0.399 1

1993 0.067 0.126 0.225 0.399 1

1994 0.067 0.126 0.225 0.399 1

1995 0.067 0.126 0.225 0.399 1

1996 0.067 0.126 0.225 0.399 1

1997 0.067 0.126 0.225 0.399 1

1998 0.067 0.126 0.225 0.399 1

1999 0.067 0.126 0.225 0.399 1

2000 0.067 0.126 0.225 0.399 1

2001 0.067 0.126 0.225 0.399 1

2002 0.067 0.126 0.225 0.399 1

2003 0.067 0.126 0.225 0.399 1

2004 0.067 0.126 0.225 0.399 1

2005 0.067 0.126 0.225 0.399 1

2006 0.067 0.126 0.225 0.399 1

2007 0.067 0.126 0.225 0.399 1

2008 0.067 0.126 0.225 0.399 1

2009 0.067 0.126 0.225 0.399 1

2010 0.067 0.126 0.225 0.399 1

2011 0.067 0.126 0.225 0.399 1

2012 0.067 0.126 0.225 0.399 1

5.2 JLL EastMed

Lognormal dist.

average numbers

Ages 6 - 10

log-likelihood = 14.34

deviance = 18.9

Chi-sq. discrepancy= 15.71

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1975 0.361 0.485 -0.124 0.507 3.01E-06 1.9 2.15 0.169

1976 0.485 0.398 0.087 0.507 3.01E-06 2.15 1.97 0.006

1977 0.981 0.305 0.676 0.507 3.01E-06 3.53 1.796 1.814

1978 0.125 0.271 -0.147 0.507 3.01E-06 1.5 1.737 0.198

1979 0.713 0.194 0.518 0.507 3.01E-06 2.7 1.608 0.777

1980 0.244 0.246 -0.002 0.507 3.01E-06 1.69 1.694 0.051

1981 0.208 0.215 -0.007 0.507 3.01E-06 1.63 1.642 0.055

1982 0.919 0.213 0.706 0.507 3.01E-06 3.32 1.638 2.091

1983 0.471 0.154 0.317 0.507 3.01E-06 2.12 1.544 0.147

1984 0.202 0.053 0.149 0.507 3.01E-06 1.62 1.396 0.001

1985 0.279 0.031 0.248 0.507 3.01E-06 1.75 1.366 0.055

1986 -0.003 -0.076 0.073 0.507 3.01E-06 1.32 1.227 0.01

1987 0.489 -0.134 0.624 0.507 3.01E-06 2.16 1.158 1.402

1988 0.019 -0.155 0.174 0.507 3.01E-06 1.35 1.134 0.007

1989 -0.232 -0.136 -0.095 0.507 3.01E-06 1.05 1.155 0.137

1990 0.063 -0.13 0.193 0.507 3.01E-06 1.41 1.163 0.015

1991 -0.09 -0.068 -0.022 0.507 3.01E-06 1.21 1.236 0.066

1992 -0.251 -0.07 -0.181 0.507 3.01E-06 1.03 1.235 0.242

1993 -0.241 -0.099 -0.143 0.507 3.01E-06 1.04 1.2 0.193

1994 -0.167 -0.192 0.025 0.507 3.01E-06 1.12 1.093 0.033

1995 0.07 -0.347 0.417 0.507 3.01E-06 1.42 0.936 0.382

1996 -0.974 -0.357 -0.617 0.507 3.01E-06 0.5 0.926 0.942

1997 -0.916 -0.388 -0.527 0.507 3.01E-06 0.53 0.898 0.79

1998 -0.623 -0.219 -0.404 0.507 3.01E-06 0.71 1.063 0.582

1999 -0.727 -0.142 -0.585 0.507 3.01E-06 0.64 1.149 0.889

2000 -0.582 0.054 -0.636 0.507 3.01E-06 0.74 1.397 0.975

2001 -0.322 0.115 -0.436 0.507 3.01E-06 0.96 1.485 0.635

2002 0.437 0.085 0.352 0.507 3.01E-06 2.05 1.441 0.215

2003 0.25 0.09 0.16 0.507 3.01E-06 1.7 1.449 0.003

2004 -0.479 0.011 -0.49 0.507 3.01E-06 0.82 1.338 0.726

2005 -0.409 -0.017 -0.392 0.507 3.01E-06 0.88 1.302 0.562

2006 0.366 -0.169 0.535 0.507 3.01E-06 1.91 1.119 0.86

2007 -0.343 -0.094 -0.248 0.507 3.01E-06 0.94 1.205 0.336

2008 -0.082 -0.115 0.033 0.507 3.01E-06 1.22 1.181 0.028

2009 -0.241 -0.012 -0.23 0.507 3.01E-06 1.04 1.309 0.31

Selectivities by age

Year	6	7	8	9	10
1975	0.062	0.135	0.337	0.38	1
1976	0.062	0.135	0.337	0.38	1
1977	0.062	0.135	0.337	0.38	1
1978	0.062	0.135	0.337	0.38	1
1979	0.062	0.135	0.337	0.38	1
1980	0.062	0.135	0.337	0.38	1
1981	0.062	0.135	0.337	0.38	1
1982	0.062	0.135	0.337	0.38	1
1983	0.062	0.135	0.337	0.38	1
1984	0.062	0.135	0.337	0.38	1
1985	0.062	0.135	0.337	0.38	1
1986	0.062	0.135	0.337	0.38	1
1987	0.062	0.135	0.337	0.38	1
1988	0.062	0.135	0.337	0.38	1
1989	0.062	0.135	0.337	0.38	1
1990	0.062	0.135	0.337	0.38	1
1991	0.062	0.135	0.337	0.38	1
1992	0.062	0.135	0.337	0.38	1
1993	0.062	0.135	0.337	0.38	1
1994	0.062	0.135	0.337	0.38	1
1995	0.062	0.135	0.337	0.38	1
1996	0.062	0.135	0.337	0.38	1
1997	0.062	0.135	0.337	0.38	1
1998	0.062	0.135	0.337	0.38	1
1999	0.062	0.135	0.337	0.38	1
2000	0.062	0.135	0.337	0.38	1
2001	0.062	0.135	0.337	0.38	1
2002	0.062	0.135	0.337	0.38	1
2003	0.062	0.135	0.337	0.38	1

2004 0.062 0.135 0.337 0.38 1

2005 0.062 0.135 0.337 0.38 1

2006 0.062 0.135 0.337 0.38 1

2007 0.062 0.135 0.337 0.38 1

2008 0.062 0.135 0.337 0.38 1

2009 0.062 0.135 0.337 0.38 1

5.3 Nor PS

Lognormal dist.

average biomass

Ages 10 - 10

log-likelihood = -13.51

deviance = 62.36

Chi-sq. discrepancy= 17.34

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1955 0.235 -0.168 0.402 0.507 1.76E-07 36.199 24.205 0.339

1956 -0.298 -0.08 -0.218 0.507 1.76E-07 21.254 26.426 0.292

1957 -0.001 -0.075 0.074 0.507 1.76E-07 28.607 26.556 0.009

1958 -0.171 -0.052 -0.119 0.507 1.76E-07 24.126 27.172 0.164

1959 0.124 -0.125 0.25 0.507 1.76E-07 32.408 25.249 0.057

1960 0.492 -0.223 0.715 0.507 1.76E-07 46.831 22.913 2.172

1961 0.594 0.059 0.535 0.507 1.76E-07 51.836 30.365 0.858

1962 0.815 0.242 0.573 0.507 1.76E-07 64.669 36.48 1.067

1963 -2.841 0.328 -3.169 0.507 1.76E-07 1.671 39.722 3.167

1964 0.171 0.417 -0.246 0.507 1.76E-07 33.978 43.437 0.332

1965 0.889 0.395 0.493 0.507 1.76E-07 69.604 42.498 0.662

1966 0.221 0.285 -0.064 0.507 1.76E-07 35.705 38.082 0.105

1967 0.758 0.285 0.473 0.507 1.76E-07 61.057 38.065 0.576

1968 -0.196 0.235 -0.431 0.507 1.76E-07 23.532 36.215 0.627

1969 -0.02 0.113 -0.133 0.507 1.76E-07 28.056 32.036 0.18

1970 0.401 0.031 0.37 0.507 1.76E-07 42.755 29.538 0.255

1971 0.419 0.039 0.38 0.507 1.76E-07 43.519 29.756 0.28

1972 0.408 0.023 0.385 0.507 1.76E-07 43.047 29.29 0.292

1973 0.387 -0.01 0.397 0.507 1.76E-07 42.148 28.328 0.325

1974 0.468 0.048 0.42 0.507 1.76E-07 45.719 30.047 0.391

1975 0.283 -0.055 0.338 0.507 1.76E-07 38 27.106 0.185

1976 -0.302 -0.124 -0.178 0.507 1.76E-07 21.16 25.277 0.238

1977 0.394 -0.281 0.675 0.507 1.76E-07 42.444 21.616 1.805

1978 -0.846 -0.33 -0.516 0.507 1.76E-07 12.278 20.571 0.771

1979 -2.033 -0.553 -1.479 0.507 1.76E-07 3.75 16.459 2.183

1980 -0.351 -0.425 0.073 0.507 1.76E-07 20.143 18.723 0.01

Selectivities by age

Year 10

---- -----

1955 1

1956 1

1957 1

1958 1

1959 1

1960 1

1961 1

1962 1

1963 1

1964 1

1965 1

1966 1

1967 1

1968 1

1969 1

1970 1

1971 1

1972 1

1973 1

1974 1

1975 1

1976 1

1977 1

1978 1

1979 1

1980 1

5.4 JP LL NEA

Lognormal dist.

month 1 numbers

Ages 4 - 10

log-likelihood = 5.38

deviance = 16.43

Chi-sq. discrepancy= 13.58

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1990 -1.342 -0.102 -1.24 0.507 3.58E-07 0.076 0.262 1.897

1991 -1.034 -0.105 -0.929 0.507 3.58E-07 0.103 0.261 1.455

1992 -0.287 -0.118 -0.168 0.507 3.58E-07 0.218 0.258 0.225

1993 -0.244 -0.128 -0.116 0.507 3.58E-07 0.227 0.255 0.16

1994 -0.116 -0.083 -0.033 0.507 3.58E-07 0.258 0.267 0.076

1995 -0.003 -0.107 0.104 0.507 3.58E-07 0.289 0.261 0.002

1996 0.978 -0.07 1.048 0.507 3.58E-07 0.772 0.271 7.763

1997 0.541 -0.001 0.541 0.507 3.58E-07 0.498 0.29 0.891

1998 -0.17 0.036 -0.206 0.507 3.58E-07 0.245 0.301 0.276

1999 0.196 0.12 0.076 0.507 3.58E-07 0.353 0.327 0.009

2000 0.275 0.126 0.15 0.507 3.58E-07 0.382 0.329 0.002

2001 0.436 0.142 0.294 0.507 3.58E-07 0.449 0.334 0.111

2002 0.164 0.095 0.069 0.507 3.58E-07 0.342 0.319 0.011

2003 0.161 0.055 0.106 0.507 3.58E-07 0.341 0.307 0.002

2004 0.104 0.001 0.102 0.507 3.58E-07 0.322 0.291 0.002

2005 -0.22 -0.022 -0.198 0.507 3.58E-07 0.233 0.284 0.264

2006 -0.051 -0.009 -0.041 0.507 3.58E-07 0.276 0.287 0.083

2007 -0.029 -0.007 -0.022 0.507 3.58E-07 0.282 0.288 0.067

2008 0.126 0.042 0.083 0.507 3.58E-07 0.329 0.303 0.007

2009 0.514 0.135 0.379 0.507 3.58E-07 0.485 0.332 0.277

Selectivities by age

Year 4 5 6 7 8 9 10

---- ----- ----- ----- ----- ----- ----- -----

1990 0.03 0.073 0.2 0.402 0.673 1 0.884

1991 0.03 0.073 0.2 0.402 0.673 1 0.884

1992 0.03 0.073 0.2 0.402 0.673 1 0.884

1993 0.03 0.073 0.2 0.402 0.673 1 0.884

1994 0.03 0.073 0.2 0.402 0.673 1 0.884

1995 0.03 0.073 0.2 0.402 0.673 1 0.884

1996 0.03 0.073 0.2 0.402 0.673 1 0.884

1997 0.03 0.073 0.2 0.402 0.673 1 0.884

1998 0.03 0.073 0.2 0.402 0.673 1 0.884

1999 0.03 0.073 0.2 0.402 0.673 1 0.884

2000 0.03 0.073 0.2 0.402 0.673 1 0.884

2001 0.03 0.073 0.2 0.402 0.673 1 0.884

2002 0.03 0.073 0.2 0.402 0.673 1 0.884

2003 0.03 0.073 0.2 0.402 0.673 1 0.884

2004 0.03 0.073 0.2 0.402 0.673 1 0.884

2005 0.03 0.073 0.2 0.402 0.673 1 0.884

2006 0.03 0.073 0.2 0.402 0.673 1 0.884

2007 0.03 0.073 0.2 0.402 0.673 1 0.884

2008 0.03 0.073 0.2 0.402 0.673 1 0.884

2009 0.03 0.073 0.2 0.402 0.673 1 0.884

5.5 SP BB1

Lognormal dist.

average biomass

Ages 5 - 6

log-likelihood = 2.38

deviance = 10.19

Chi-sq. discrepancy= 9.34

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1952 -0.438 0.251 -0.689 0.507 2.89E-06 179.22 357.014 1.065

1953 -0.408 0.035 -0.443 0.507 2.89E-06 184.74 287.648 0.647

1954 -0.204 -0.165 -0.039 0.507 2.89E-06 226.46 235.582 0.082

1955 -0.396 -0.14 -0.256 0.507 2.89E-06 187.01 241.475 0.347

1956 0.527 0.184 0.343 0.507 2.89E-06 470.53 333.81 0.196

1957 0.126 0.447 -0.321 0.507 2.89E-06 315.05 434.467 0.448

1958 -0.096 0.513 -0.609 0.507 2.89E-06 252.25 463.753 0.929

1959 0.601 0.404 0.197 0.507 2.89E-06 506.79 416.034 0.017

1960 0.558 -0.088 0.646 0.507 2.89E-06 485.16 254.369 1.567

1961 0.164 -0.691 0.855 0.507 2.89E-06 327.29 139.184 3.896

1962 -0.433 -0.749 0.316 0.507 2.89E-06 180.12 131.318 0.145

Selectivities by age

Year 5 6

---- ----- -----

1952 0.958 1

1953 0.958 1

1954 0.958 1

1955 0.958 1

1956 0.958 1

1957 0.958 1

1958 0.958 1

1959 0.958 1

1960 0.958 1

1961 0.958 1

1962 0.958 1

5.6 SP BB2

Lognormal dist.

average biomass

Ages 2 - 3

log-likelihood = 7.12

deviance = 45.56

Chi-sq. discrepancy= 31.59

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year Observed Predicted (Obs-pred) Deviation Catchabil. Observed Predicted Discrepancy

---- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------

1963 -0.796 -0.037 -0.759 0.507 2.05E-05 312.09 666.632 1.182

1964 -0.414 -0.016 -0.398 0.507 2.05E-05 457.4 680.778 0.571

1965 -1.106 -0.095 -1.011 0.507 2.05E-05 228.91 629.394 1.58

1966 -0.684 0.079 -0.764 0.507 2.05E-05 349.1 749.149 1.189

1967 -0.693 0.03 -0.723 0.507 2.05E-05 345.89 712.67 1.122

1968 -0.437 -0.219 -0.218 0.507 2.05E-05 447 555.812 0.293

1969 -0.125 -0.477 0.352 0.507 2.05E-05 610.62 429.514 0.214

1970 -0.152 -0.536 0.384 0.507 2.05E-05 594.66 405.019 0.29

1971 0.074 -0.64 0.714 0.507 2.05E-05 744.71 364.737 2.162

1972 -0.275 -0.265 -0.01 0.507 2.05E-05 525.63 530.699 0.057

1973 -0.256 -0.231 -0.025 0.507 2.05E-05 535.63 549.222 0.069

1974 -1.037 -0.244 -0.793 0.507 2.05E-05 245.39 542.207 1.237

1975 -0.357 -0.129 -0.228 0.507 2.05E-05 484.22 608.454 0.308

1976 -0.357 -0.324 -0.033 0.507 2.05E-05 483.96 500.245 0.076

1977 -0.234 -0.091 -0.143 0.507 2.05E-05 547.56 631.534 0.193

1978 0.019 -0.298 0.317 0.507 2.05E-05 705.26 513.639 0.147

1979 -0.105 -0.689 0.585 0.507 2.05E-05 623.01 347.233 1.141

1980 -0.086 -0.664 0.578 0.507 2.05E-05 634.81 356.223 1.099

1981 -0.304 -0.482 0.179 0.507 2.05E-05 510.66 427.156 0.009

1982 -0.317 -0.466 0.149 0.507 2.05E-05 503.78 433.981 0.001

1983 -0.102 -0.061 -0.04 0.507 2.05E-05 625.14 650.692 0.082

1984 -0.735 0.283 -1.019 0.507 2.05E-05 331.71 918.655 1.59

1985 0.487 0.027 0.459 0.507 2.05E-05 1125.74 711.191 0.525

1986 0.082 -0.152 0.234 0.507 2.05E-05 751.21 594.411 0.042

1987 0.377 -0.056 0.433 0.507 2.05E-05 1008.43 654.194 0.432

1988 0.701 0.003 0.698 0.507 2.05E-05 1394.68 694.001 2.011

1989 0.619 0.04 0.579 0.507 2.05E-05 1285.6 720.471 1.107

1990 0.355 0.144 0.211 0.507 2.05E-05 986.51 799.178 0.025

1991 0.264 0.284 -0.019 0.507 2.05E-05 901.2 918.819 0.064

1992 0.005 0.547 -0.542 0.507 2.05E-05 695.16 1195.731 0.816

1993 1.107 0.558 0.55 0.507 2.05E-05 2093.55 1208.362 0.937

1994 0.375 0.575 -0.199 0.507 2.05E-05 1007.03 1229.235 0.267

1995 0.58 0.57 0.01 0.507 2.05E-05 1235.91 1223.616 0.043

1996 0.922 0.406 0.516 0.507 2.05E-05 1739.29 1038.069 0.766

1997 1.178 0.404 0.774 0.507 2.05E-05 2246.41 1036.325 2.806

1998 0.24 -0.046 0.286 0.507 2.05E-05 879.51 660.578 0.1

1999 -0.711 0.285 -0.997 0.507 2.05E-05 339.77 920.403 1.557

2000 0.328 0.258 0.07 0.507 2.05E-05 960.44 895.767 0.011

2001 0.018 0.024 -0.006 0.507 2.05E-05 704.49 709.047 0.054

2002 -0.007 -0.12 0.114 0.507 2.05E-05 687.42 613.534 0.001

2003 -0.442 0.307 -0.749 0.507 2.05E-05 444.91 940.865 1.165

2004 0.559 0.396 0.163 0.507 2.05E-05 1210.46 1028.459 0.004

2005 1.237 0.41 0.827 0.507 2.05E-05 2383.57 1042.306 3.492

2006 0.206 0.71 -0.504 0.507 2.05E-05 850.09 1406.994 0.75

Selectivities by age

Year 2 3

---- ----- -----

1963 1 0.632

1964 1 0.632

1965 1 0.632

1966 1 0.632

1967 1 0.632

1968 1 0.632

1969 1 0.632

1970 1 0.632

1971 1 0.632

1972 1 0.632

1973 1 0.632

1974 1 0.632

1975 1 0.632

1976 1 0.632

1977 1 0.632

1978 1 0.632

1979 1 0.632

1980 1 0.632

1981 1 0.632

1982 1 0.632

1983 1 0.632

1984 1 0.632

1985 1 0.632

1986 1 0.632

1987 1 0.632

1988 1 0.632

1989 1 0.632

1990 1 0.632

1991 1 0.632

1992 1 0.632

1993 1 0.632

1994 1 0.632

1995 1 0.632

1996 1 0.632

1997 1 0.632

1998 1 0.632

1999 1 0.632

2000 1 0.632

2001 1 0.632

2002 1 0.632

2003 1 0.632

2004 1 0.632

2005 1 0.632

2006 1 0.632

5.7 SP BB3

Lognormal dist.

average biomass

Ages 3 - 6

log-likelihood = 3.62

deviance = 2.28

Chi-sq. discrepancy= 1.49

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year	Observed	Predicted	(Obs-pred)	Deviation	Catchabil.	Observed	Predicted	Discrepancy
2007	0.134	0.03	0.104	0.507	1.65E-05	2176.44	1961.738	0.002
2008	0.119	0.009	0.11	0.507	1.65E-05	2144.54	1921.273	0.001
2009	-0.689	-0.093	-0.597	0.507	1.65E-05	955.29	1734.609	0.908
2010	0.103	0.023	0.079	0.507	1.65E-05	2109.08	1948.268	0.008
2011	0.373	-0.019	0.392	0.507	1.65E-05	2762.62	1867.345	0.31
2012	0.152	0.048	0.104	0.507	1.65E-05	2216.18	1996.305	0.002
2013	-0.191	0.001	-0.193	0.507	1.65E-05	1571.64	1905.709	0.258

Selectivities by age

Year	3	4	5	6
2007	1	0.964	0.534	0.327
2008	1	0.964	0.534	0.327
2009	1	0.964	0.534	0.327
2010	1	0.964	0.534	0.327
2011	1	0.964	0.534	0.327
2012	1	0.964	0.534	0.327
2013	1	0.964	0.534	0.327

5.8 JP LL NEA2

Lognormal dist.

month 1 numbers

Ages 4 - 10

log-likelihood = 2.48

deviance = 0.48

Chi-sq. discrepancy= 0.47

Residuals Standard Q Untransfrmd Untransfrmd Chi-square

Year	Observed	Predicted	(Obs-pred)	Deviation	Catchabil.	Observed	Predicted	Discrepancy
2010	-0.494	-0.234	-0.26	0.507	3.76E-06	2.043	2.65	0.354
2011	-0.153	-0.102	-0.051	0.507	3.76E-06	2.875	3.025	0.092
2012	0.361	0.157	0.204	0.507	3.76E-06	4.806	3.92	0.021
2013	0.287	0.18	0.107	0.507	3.76E-06	4.463	4.01	0.002

Selectivities by age

Year	4	5	6	7	8	9	10
2010	0	0	0.004	0.163	0.81	1	0.726
2011	0	0	0.004	0.163	0.81	1	0.726
2012	0	0	0.004	0.163	0.81	1	0.726
2013	0	0	0.004	0.163	0.81	1	0.726

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TOTAL NUMBER OF FUNCTION EVALUATIONS = 22333