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SEDAR65-DW02

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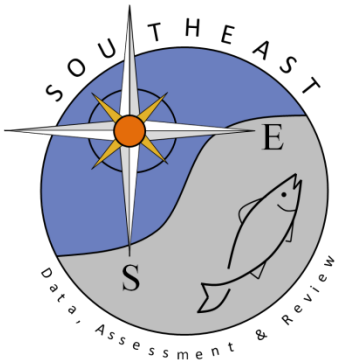

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Age and growth parameters for blacktip sharks, *Carcharhinus limbatus*, in the western North Atlantic Ocean

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Introduction

Through fishery-dependent and –independent sources, a total of 547 blacktip sharks, *Carcharhinus limbatus*, were collected in the western North Atlantic Ocean between 2006 and 2018, which were used to update age and growth parameters for this species. Four different growth models were applied to the length-at-age data for females (n=269), males (n=278), and both sexes combined, with the three parameter von Bertalanffy growth curving resulting in the best fit.

Methods

Samples used in this analysis were collected from 2006 to 2018 in both fishery-dependent commercial fisheries and –independent NMFS research surveys. Upon capture, specimens were measured to fork length (FL, cm) and a section of vertebrae was collected for age estimation. Vertebra were collected from either below the first dorsal fin or above the branchial chamber, closer to head, dependent on the source.

Preparation of vertebrae followed protocols outlined in Carlson et al. (2003). An individual centrum from each specimen was sectioned along the longitudinal axis using an isomet low-speed saw at a thickness of 0.6 mm and one half of the section was stained with crystal violet to enhance visibility of band pairs. Digital images of mounted sections were captured using a Lumenera Infinity 2 camera attached to a Meiji Techno dissecting microscope and band pairs were counted and marked using editing software (Adobe© Photoshop© Elements 6, Adobe Systems, San Jose, CA, USA). Band counts were completed by two independent readers on the vertebrae sections of 480 blacktip sharks, following the methods of Carlson et al. (2006). Where readers disagreed on band counts by more than two, images were re-evaluated by both readers simultaneously, until an agreement was reached. When a final count was determined, 1.5 was subtracted from all band counts to provide a final given age, except those with 1 band which were given an age of 0. APE was calculated based on the recommended equation in Beamish and Fournier (1981):

$$APE = \frac{\sum_{j=1}^{n} APE_j}{n} \quad where\ APE_j = 100 * \frac{\sum_{i=1}^{R} \frac{|x_{ij} - \bar{x}_j|}{\bar{x}_j}}{R}$$

where APE_j is the average percent error for the *j*th fish, x_{ij} is the *i*th age estimate on the *j*th fish, x_j is the mean age estimate for the jth fish, *R* is the number of times that each fish was aged (assumed to be the same for all fish), and *n* is the number of aged fish in the sample. Percent agreement (PA = (# agreed / # read)*100) and PA ± 1 year (PA ± 1) were calculated to estimated

reader precision (Cailliet and Goldman 2004; Goldman 2004). And the Bowker's test of symmetry was applied to determine bias between the readers (Bowker 1948):

$$x^2 = \sum_{i=1}^{m} \sum_{j=i+1}^{m} \frac{(n_{ij-} n_{ji})^2}{(n_{ij+} n_{ji})^2}$$

where n_{ij} is the number of specimens aged *i* by the tester and *j* by the reader, n_{ji} is the number of specimens aged *j* by the tester and *i* by the reader, and *m* is the maximum age.

An additional 67 vertebrae sections associated with reproduction data presented in SEDAR 65-DW-01 were processed using techniques outlined in Natanson et al. (2006), independently read by the first reader and included in the age and growth analysis. One additional vertebra was read but not included in age and growth analysis. This sample was obtained from a fishery independent survey in South Carolina. The sample was tagged as a known age individual, based on size (71 cm FL;1^+ yr), and recaptured with a returned vertebral sample after 12 years and 11 months at 127.5 cm FL, making it approximately 14 years of age. Band pair count of this individual was compared to time at liberty to validate the periodicity of band pair formation.

Four different growth models were applied to age-at-length data for females, males, and both sexes combined using packages in R (R Core Team 2017). The first model was the three-parameter von Bertalanffy growth curve (von Bertalanffy 1938; Beverton and Holt 1957):

$$L_t = L_\infty(1 - e^{-k(t-t_0)})$$

where L_t = mean fork length at time t; L_∞ = theoretical asymptotic length; k = growth coefficient; and t_0 = theoretical age at zero length. The second model was a modified von Bertalanffy growth curve which used the length at birth intercept rather than a theoretical age at zero intercept:

$$L_t = L_\infty - (L_\infty - L_0)e^{-kt}$$

The third model was a modified version of the Gompertz model (Ricker 1975):

$$L_t = L_0(e^{G(1-e(kt))})$$

where $G=ln(L / L0)$ (von Bertalanffy 1938) where L_0 = mean length-at-birth (45 cm PCL), Lt = length at time t, L = theoretical asymptotic length, and k= coefficient of growth. And the last model was the logistic model (Ricker 1975):

$$L_t = L_\infty/(1 + e^{-k(t-t_0)})$$

Akaike information criterion (AIC) values generated in these models were then used to determine which of the four models were the best fit to the age-at-length data (Akaike 1974):

$$AIC = -2logL(\hat{\theta}) + 2k$$

Where θ = the set(vector) of model parameters, $L(\hat{\theta}) =$ the likelihood of the candidate model given the data when evaluated at the maximum likelihood estimate of θ, and k = the number of estimated parameters in the candidate model. Models with a delta (Δ) AIC value of less than 2 where considered to be the best fit to this data, while models with a Δ AIC value of greater than 10 were not considered a candidate model.

Results and Discussion

Specimens ranged from 41 cm FL – 178 cm FL (Figure 1) and the maximum age observed was 17.5 years for females, and 13.5 years for males (Figure 2). APE was calculated as 4.36%, and reader PA and PA ± 1 were 45.2% and 78.5%, respectively. Some bias between readers was indicated with Bowker's test of symmetry (χ^2 = 78.53, df = 46, p<0.002). Based on Δ AIC values, the three parameter von Bertalanffy growth model was the best fit of the four models that were applied to the length-at-age data (Table 2). The von Bertalanffy growth parameters were L_∞ = 145.03 cm FL, k = 0.23 yr^{-1}, t_0 = -1.97 yr for males and L_∞ = 166.23 cm FL, k = 0.16 yr^{-1}, t_0 = -2.59 yr for females (Table 1; Figure 3). L_∞ values presented here are higher for females and both sexes combined than those reported by Carlson et al. (2006).

Based on band pair count, the age of the long-term recapture was determined to be 13 years as compared to 14 years based on the tag/recapture data. This suggests annual deposition of growth band pairs up to at least an age of 13 years, though more recaptures are needed to validate this.

Literature Cited

Akaike, H. 1974. A New Look at the Statistical Model Identification. I.E.E.E. Transactions on Automatic Control, AC 19, (1974): 716–723.

Beamish, R.J. and D.A. Fournier. 1981. A method for comparing the precision of a set of age determinations. Canadian Journal of Fisheries and Aquatic Sciences 38:982–983.

Beverton, R.J.H. & S.J. Holt. 1957. On the dynamic s of exploited fish populations. Ministry of Agriculture. Fisheries and Food Fishery Investigation Series II XIX, 533 pp.

Bowker, A.H. (1948) A Test for Symmetry in Contingency Tables. Journal of the American Statistical Association, 43, 572-574.

Cailliet, G. and K. Goldman. 2004. Age determination and validation in chondrichthyan fishes. *In*: Biology of sharks and their relatives. (J. Carrier, J. Musick and M. Heithaus, eds.). CRC Press, San Diego. P. 399-447.

Carlson, J.K., E. Cortés & D. Bethea. 2003. Life history and population dynamics of the finetooth shark, Carcharhinus isodon, in the northeast Gulf of Mexico. Fishery Bulletin 101:281-292.

Carlson, J.K., J.A. Sulikowski, and I.E. Baremore. 2006. Do differences in life history exist for blacktip sharks, *Carcharhinus limbatus,* from the United States South Atlantic Bight and Eastern Gulf of Mexico? Environ. Biol. Fishes 77:279-292.

Goldman, K. 2004. Age and Growth. *In*: Elasmobranch fisheries management techniques (J. Musick and R. Bonfil eds.), APEC Fisheries Working Group. p. 97-132.

Natanson, L.J., N.E. Kohler, D. Andizzone, G.M. Cailliet, S.P. Wintner, H.F. Mollet. 2006. Validated age and growth estimates for the shortfin mako, *Isurus oxyrinchus,* in the North Atlantic Ocean. Enviornmental Biology of Fishes 77:367-383.

R Core Team 2017. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of fish Populations. Bulletin of the Fisheries Research Board Canada 191: 1-382.

von Bertalanffy, L. 1938. A quantitative theory of organic growth (inquiries on growth laws II). Human Biology 10:181-213.

Table 1. Comparison of von Bertalanffy growth curve values from Carlson et al. (2006) and the current update.

Study	Sex	Sample Size	$L\infty$ (± SE)	k (± SE)	t_0 (± SE)
Carlson et al. 2006	F	78	158.5 ± 5.71	0.16 ± 0.02	-3.43 ± 0.50
Carlson et al. 2006	M	162	147.4 ± 2.60	0.21 ± 0.02	-2.58 ± 0.24
Carlson et al. 2006	Combined	240	150.9 ± 2.51	0.19 ± 0.10	-2.89 ± .23
Current Update	F	269	166.23 ± 2.47	0.16 ± 0.01	-2.59 ± 0.16
Current Update	M	278	145.03 ± 1.82	0.23 ± 0.02	-1.97 ± 0.16
Current Update	Combined	547	159.30 ± 1.87	0.17 ± .01	-2.51 ± 0.13

Table 2. Best fit model selection results based on Δ AIC for the length-at-age data for female, male, and combined sexes. Listed in order of best fit.

Model	Δ AIC (female)	Δ AIC (male)	Δ AIC (combined)
VB3	0.00	0.00	0.00
Gompertz	14.08	15.98	30.18
Logisitic	30.14	31.17	61.31
VB2	126.64	61.52	186.70

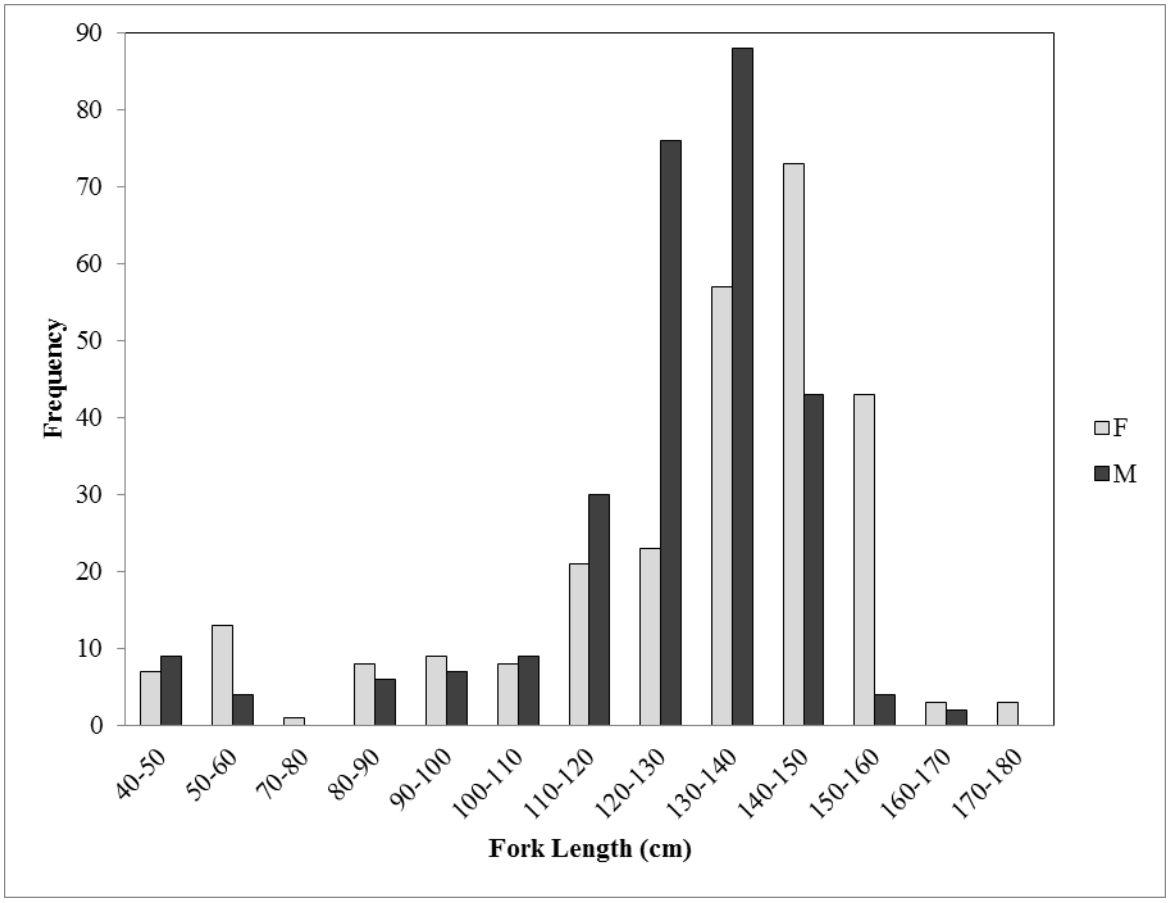


Figure 1. Frequency of fork length (measured in centimeters) of all individuals, N=547. Gray bars represent females (n=269) and black bars represent males (n=278).

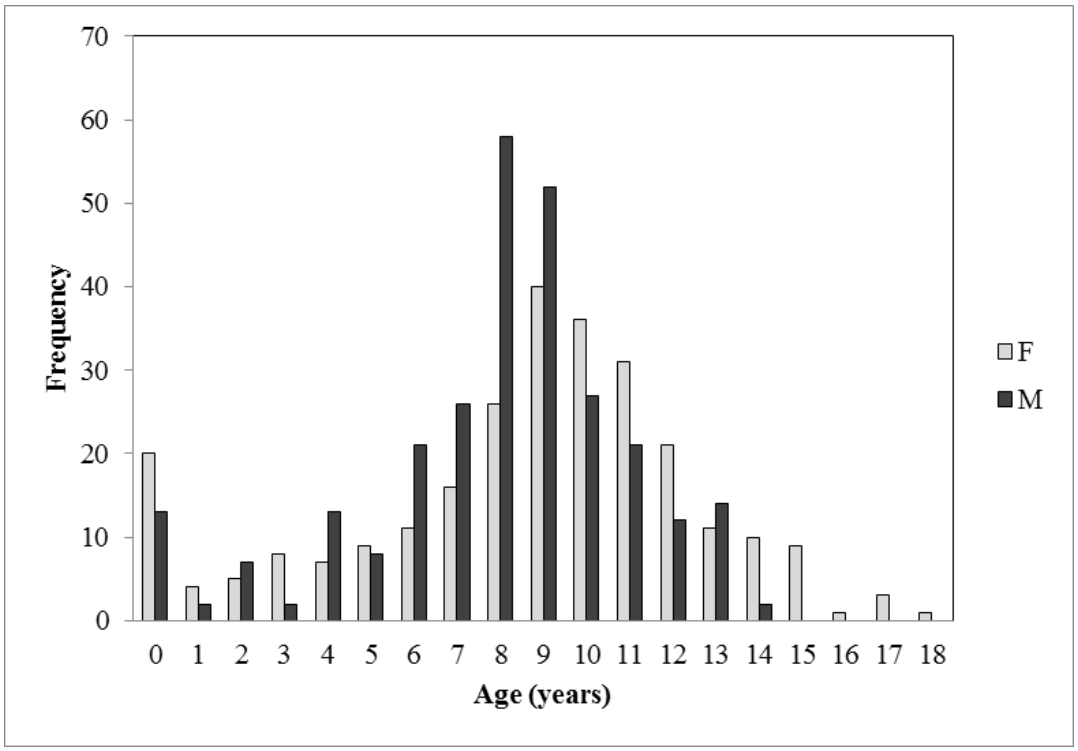
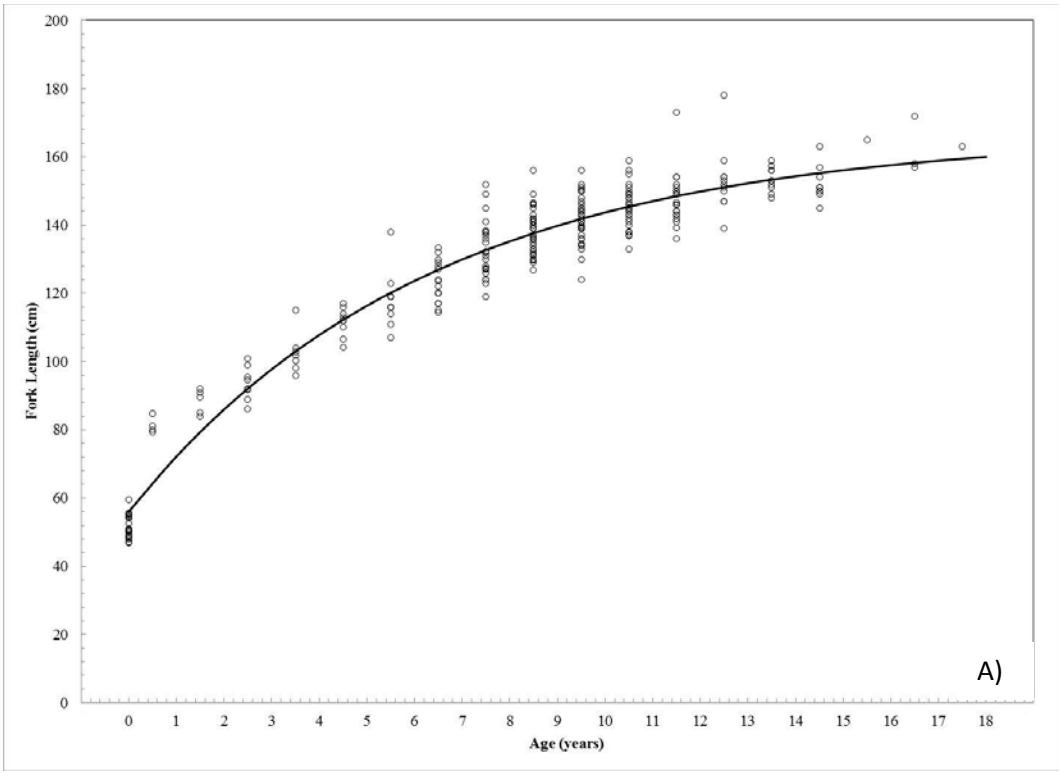
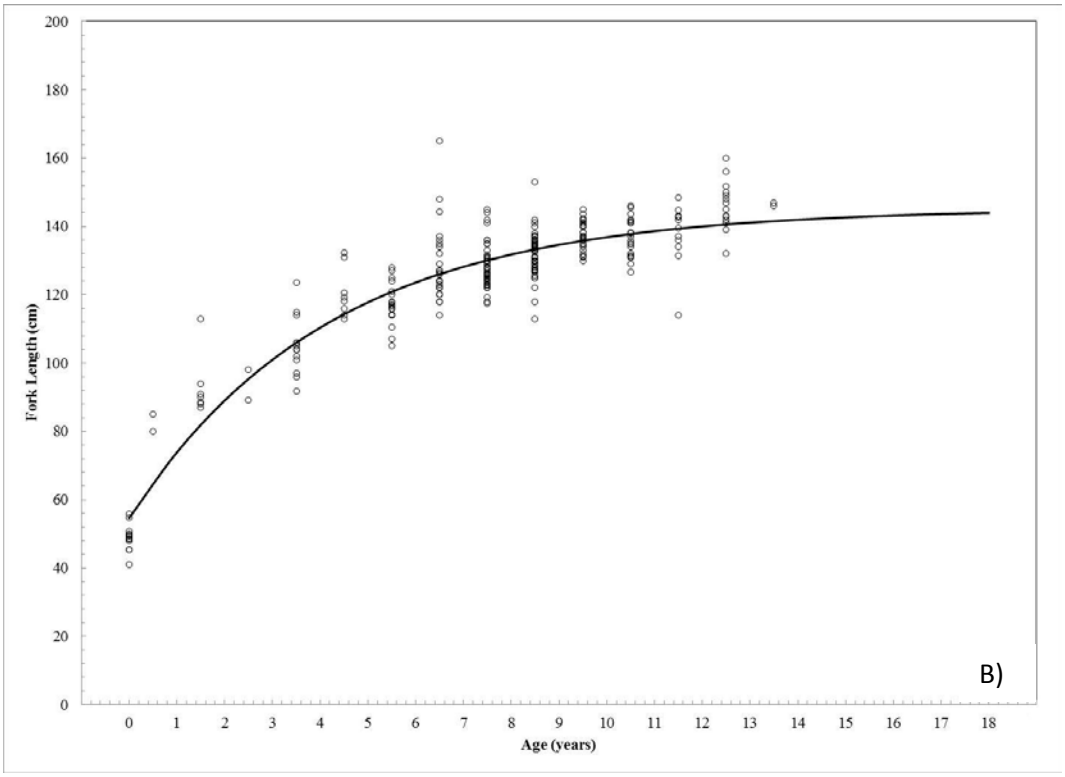


Figure 2. Frequency of age in years of all individuals, N=547. Gray bars represent females (n=269) and black bars represent males (n=278).


Fork Length (cm)
Age (years)
A)


Fork Length (cm)
Age (years)
B)

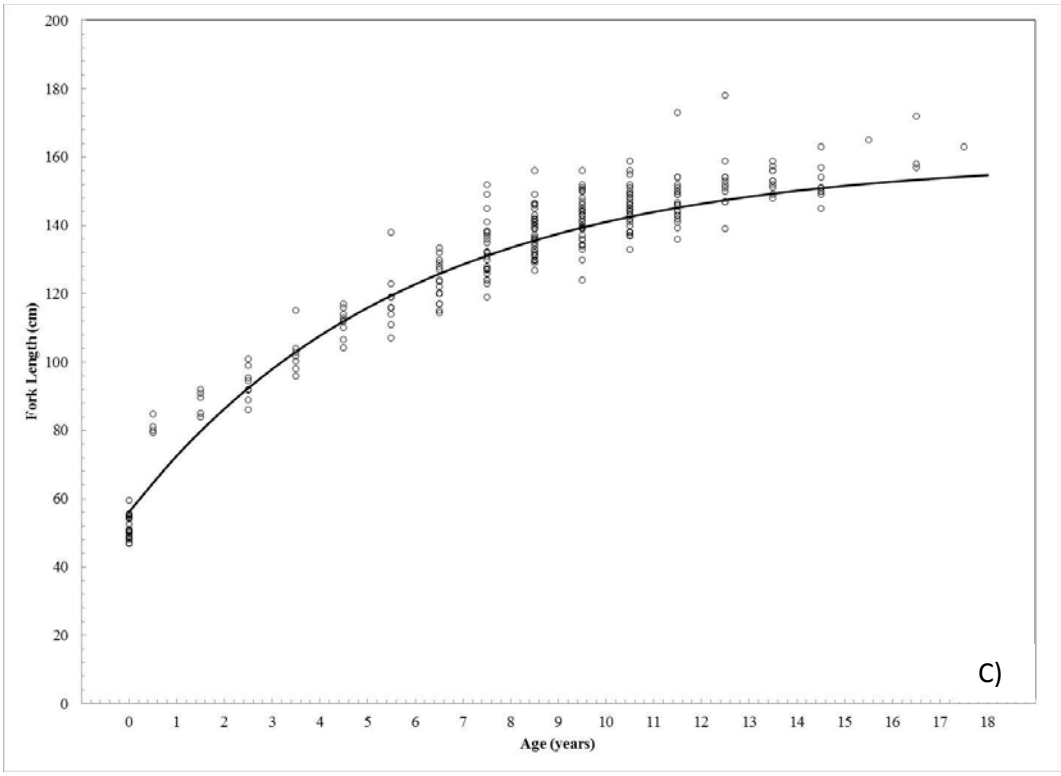


Figure 3. Western North Atlantic blacktip shark von Bertalanffy growth curves for female (A, n=269), male (B, n=278), and both sexes combined (C, n=547).