APPENDIX B2: Verification of annual shell growth increments

This appendix will examine the question of whether the growth increments obtained from shell rings are truly annual, and whether the growth matrices obtained from shell growth increment data gives appropriate predictions of growth. Early work examining monthly shell samples (Stevenson and Dickie 1954), or comparing growth from shell rings to tagging (Merrill et al. 1966) concluded that shell growth rings are laid down annually. Kranz et al. (1984) used stable isotope analysis to age two shells in the Mid-Atlantic Bight, and suggested that sea scallops lay down two shell rings a year. However, this conclusion is only really supported by one of their two shells. Stable isotope analysis of two shells from Brown's Bank was supportive of the 1 ring per year hypothesis (Tan et al. 1988).

Here, we followed the growth of large cohorts found in sites in the closed areas, to test whether the shell increments collected from these cohorts matched the observed growth. Four stations where large sets of small scallops were observed were selected for this study, two in Closed Area II, one in Nantucket Lightship Closed Area, and one in the Elephant Trunk Closed Area (Figure 1). These stations were revisited in subsequent years to obtain size-frequency frequency information. Starting in 2003 (2004 for sites #2 and #4) between 60-100 shells were saved at each station for growth analysis, as described in Appendix B3. Growth increment matrices were constructed for each site based on shells collected there. Growth from one year could then be projected to the next year and compared to the observed size frequency for that year to evaluate whether the growth matrix gave accurate predictions. In some cases, size-frequencies were not available for some years, in which case a multiyear projection was made by applying the matrix to the original size frequency the appropriate number of times.

Site #1 (Closed Area II)

This site was repeatedly sampled after a large set of small scallops (1998 year class) was observed there in 2000. In 2004 and 2006, the number of scallops caught at this site was small (141 in 2004, 81 in 2006), either because the dredge missed the main bed, or (in 2006), because of heavy fishing after the area was reopened. These years were therefore dropped from the analysis. The growth of scallops at this site during the remaining years is shown in Figure 2. Figure 3 compares the observed (normalized) size-frequency with that predicted from the previous observation and the site-specific growth matrix. In all cases the fit was very good.

Site #2 (Closed Area II)

This site, which is close to Station #1, was also selected because a large set of small scallops was observed there in 2000. The site was resampled in 2002, 2004, 2005, and 2006 (Figure 4). Comparison of the observed size-frequencies to that projected using the growth matrix matrix were good with the exception of the projection from 2002-2004, where the projected sizes were somewhat greater than that observed (Figure 5).

Site #3 (Nantucket Lightship Area)

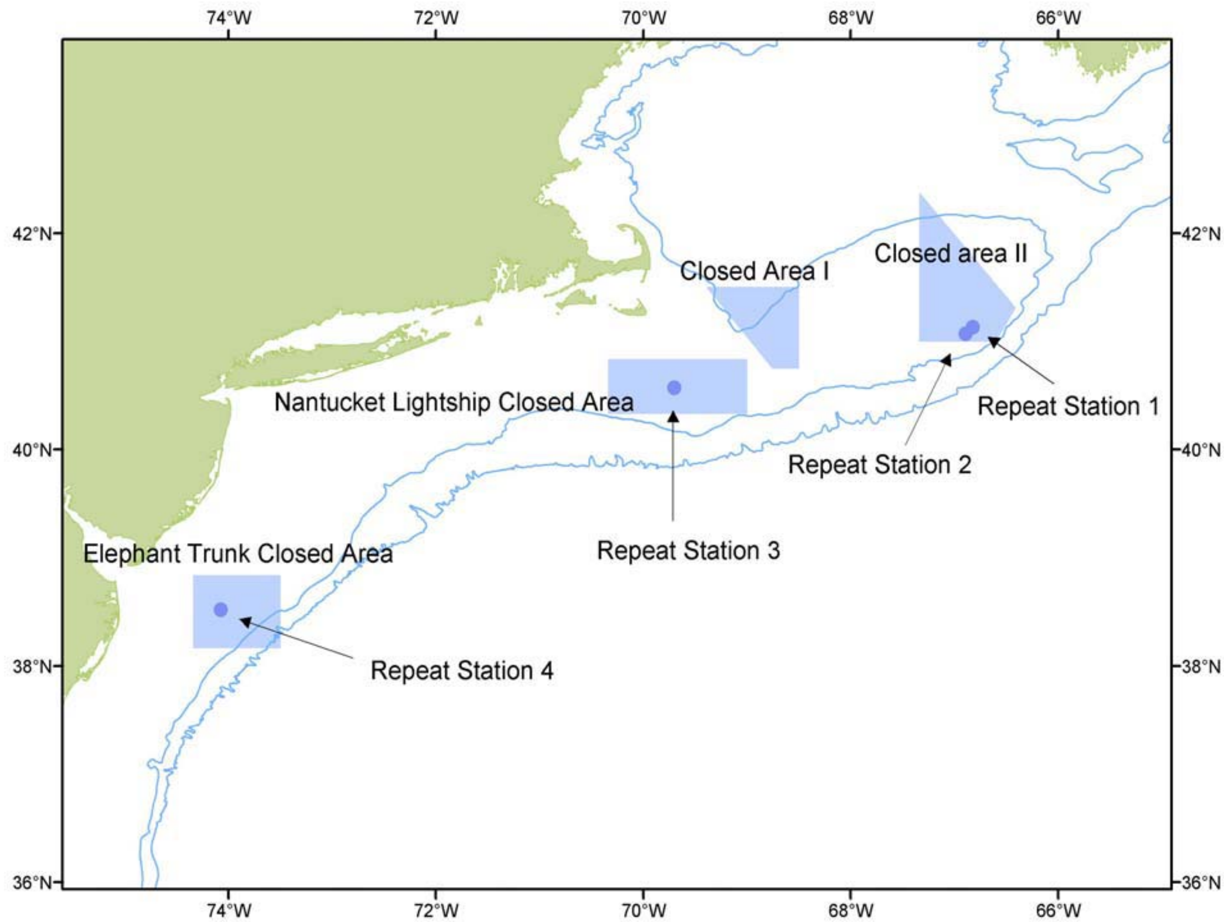
This site was originally sampled in 1999, and was revisited in 2000, 2003, 2004, 2005, and 2006 (Figure 6). In 2000, a second strong cohort was observed in addition to the one observed in 1999. Comparisons between predicted and observed growth was always quite good (Figure 7).

Site #4 (Elephant Trunk Closed Area)

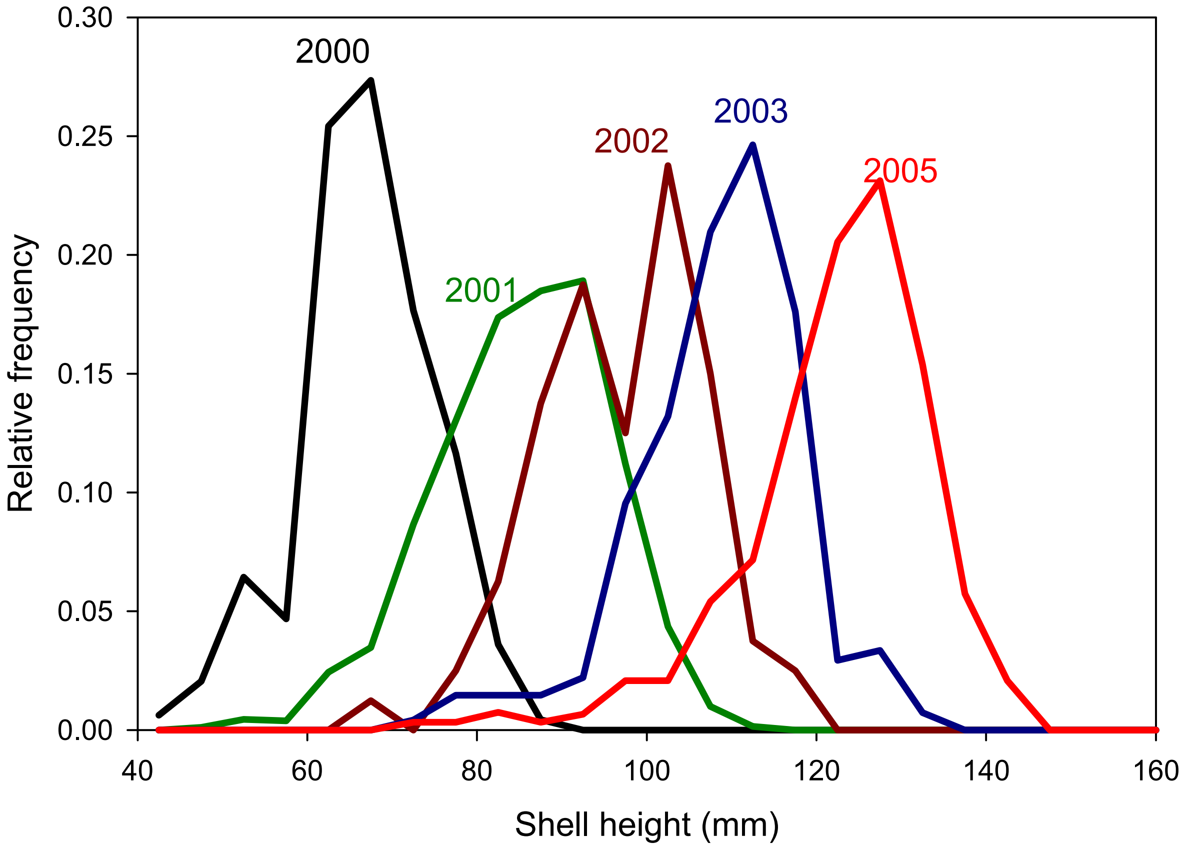
This site was first sampled in 2003, a year before this area was closed. However, nearly all of the scallops observed in 2003 were well below commercial size, so that the fishing that occurred in this area until it was closed in July 2004 should not have affected growth or mortality at this site. It was resampled each year thereafter (2004, 2005, 2006, Figure 8). There was little growth between 2005 and 2006, which was also observed in the Elephant Trunk as a whole. The growth between these years was inconsistent with that observed between 2004 and 2005. Comparisons between observed and projected size-frequencies showed good agreement in 2004 and 2005, but the projection from 2005 to 2006 predicted considerably greater growth than actually occurred (Figure 9). Projections were also made based on the Kranz et al. (1984) hypothesis that two growth rings are laid down each year, so that the growth matrix was applied twice to obtain the predicted shell heights in the next year (Figure 10). The observations do not support Kranz et al.'s hypothesis of semi-annual rings.

Discussion and Conclusions

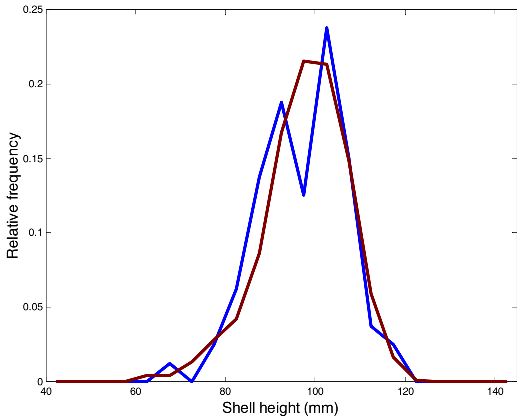
In all but two of the 16 comparisons made here, size-frequencies predicted from growth matrices were in good agreement with observations. One case was a modest deviation at site #2 for a two-year projection between 2002 and 2004. The other was a stronger deviation in site #4 between 2005 and 2006. None of the shells collected at this site would have reflected any growth since the last shell ring (probably in the fall of 2005) was laid down, since the partial increment from the last ring to the edge of the shell was not used. Thus, the projected sizes reflect what would have occurred if growth during 2005-6 was the same as in previous years. The deviation between observed and predicted growth does not imply that the shell rings are not annual. Rather, they indicate a change in growth between 2005 and 2006, probably related to environmental conditions (e.g., food supply). None of the data are consistent with the Kranz et al. hypothesis of semi-annual rings, since that would predict much faster growth than was observed. It can be concluded that growth matrices derived from shell ring data, under the assumption that the growth lines are laid down annually, generally give good predictions for growth, and are appropriate for use in this assessment.



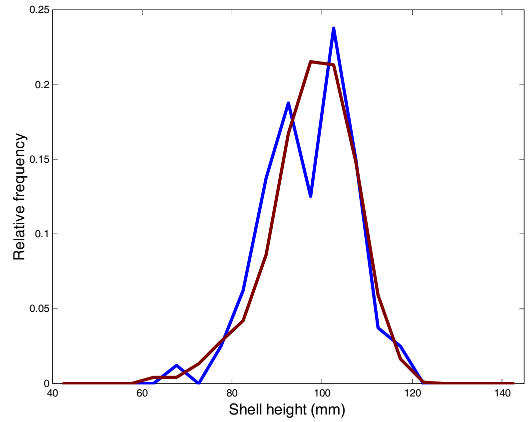
APPENDIX B2 Figure 1. Locations of the four repeat sites in this study.



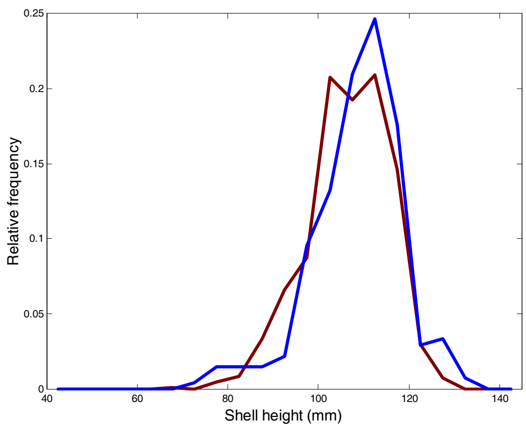
APPENDIX B2 Figure 2. Normalized size-frequences by year at site #1 (Closed Area II).



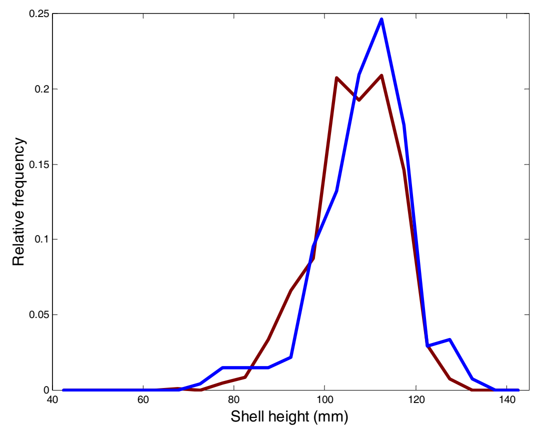
2000 to 2001



2001 to 2002

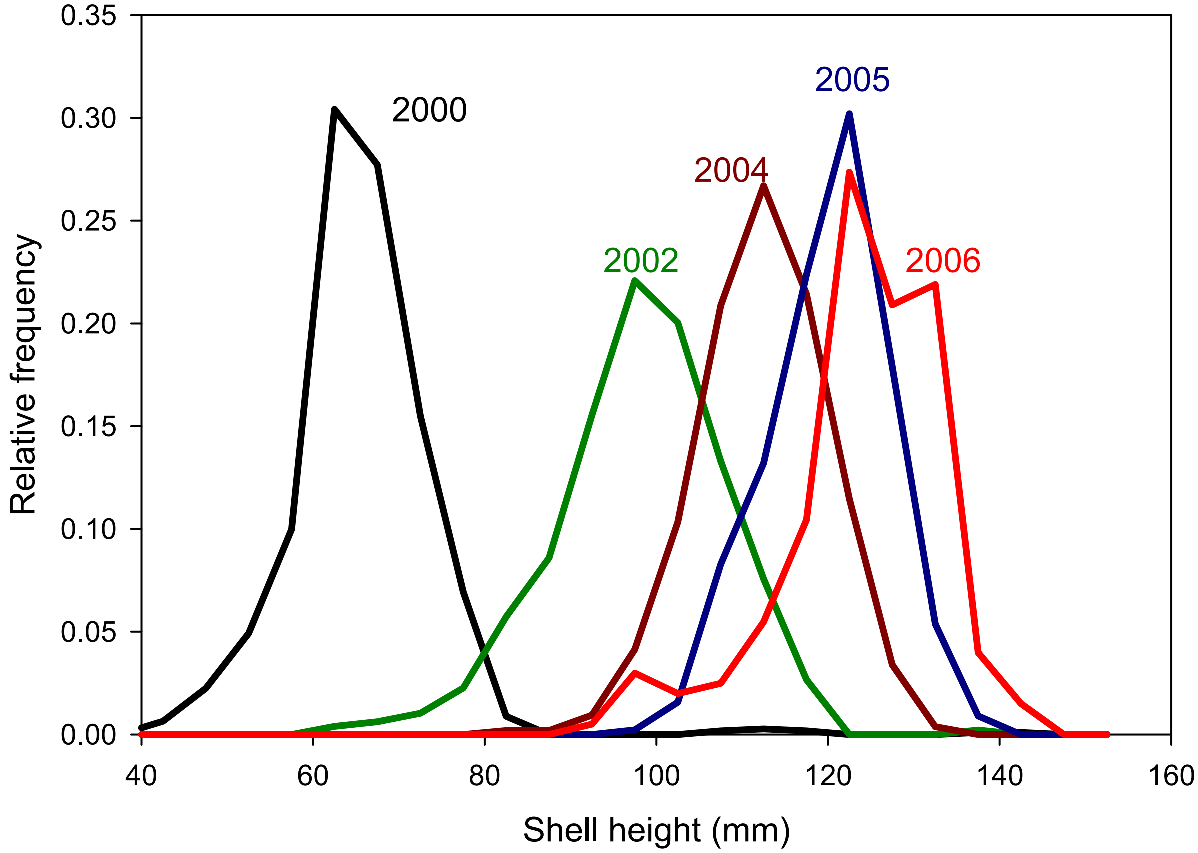


2002 to 2003

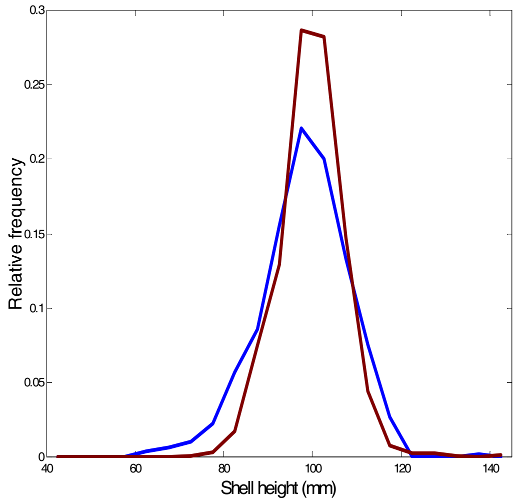


2003 to 2005

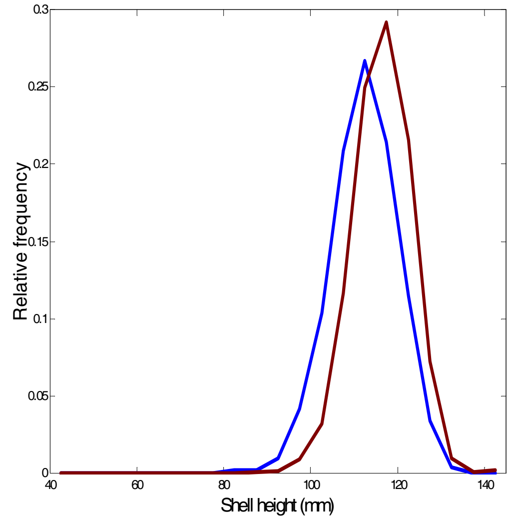
APPENDIX B2 Figure 3. Comparison between observed (solid blue line) and projected (dashed-dotted brown line) normalized size-frequencies at site #1 (Closed Area II).



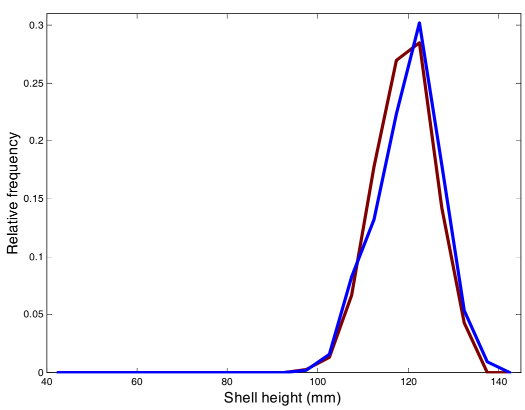
APPENDIX B2 Figure 4. Normalized size-frequencies at site #2 (Closed Area II).



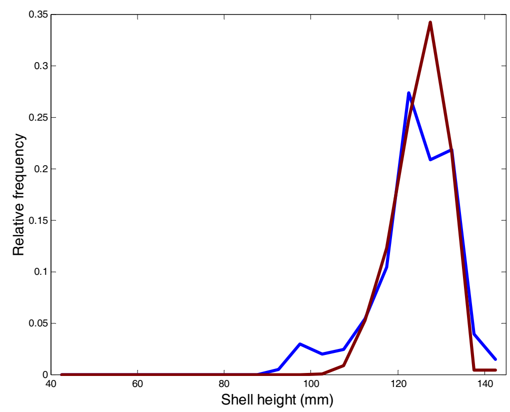
2000 to 2002



2002 to 2004

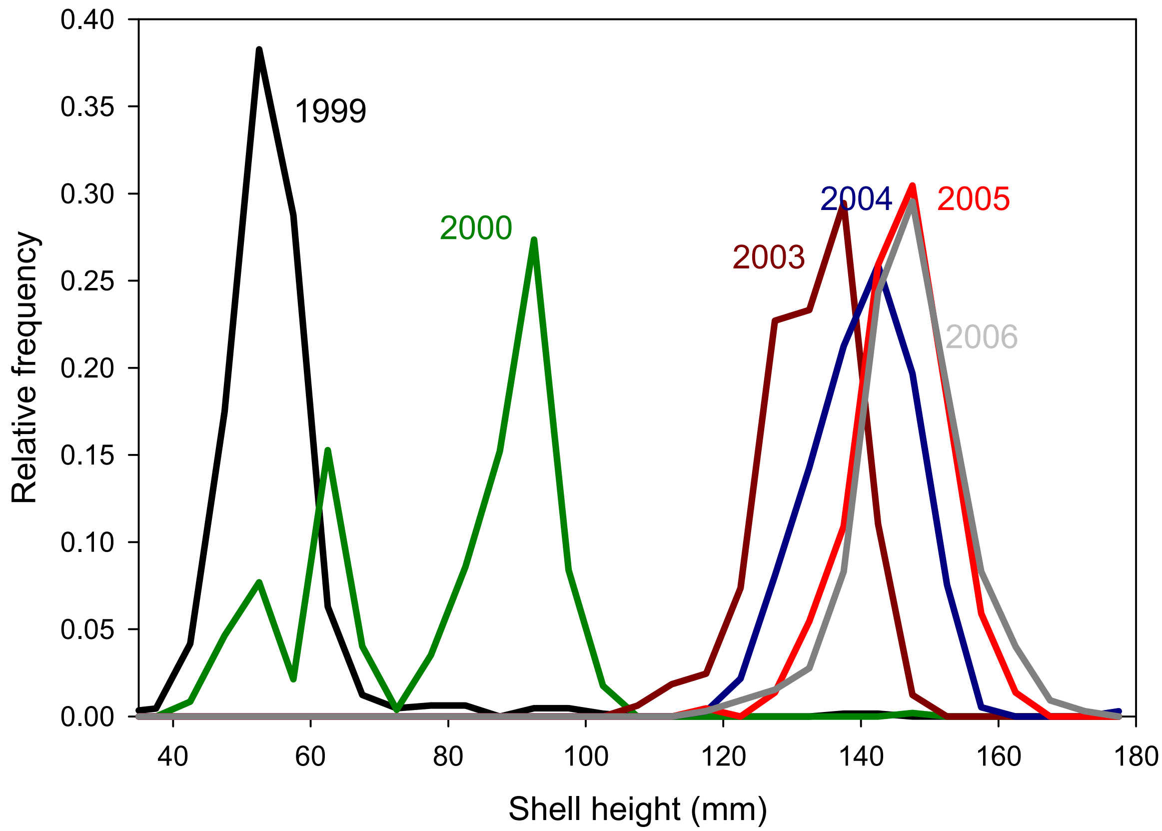


2004 to 2005

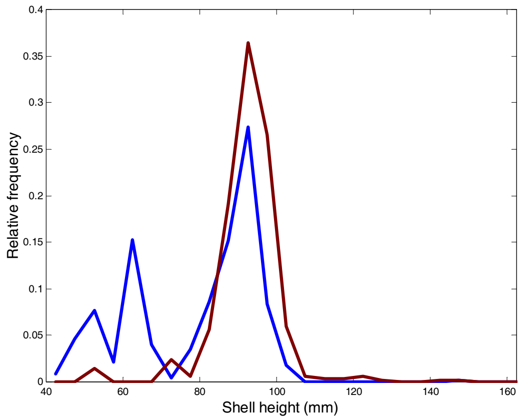


2005 to 2006

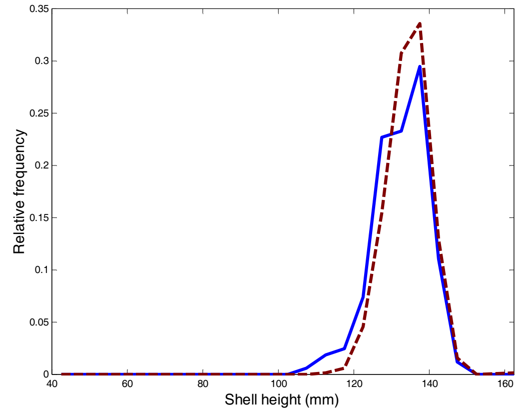
APPENDIX B2 Figure 5. Comparison between observed (solid blue line) and projected (dashed-dotted brown line) normalized size-frequencies at site #2 (Closed Area II).



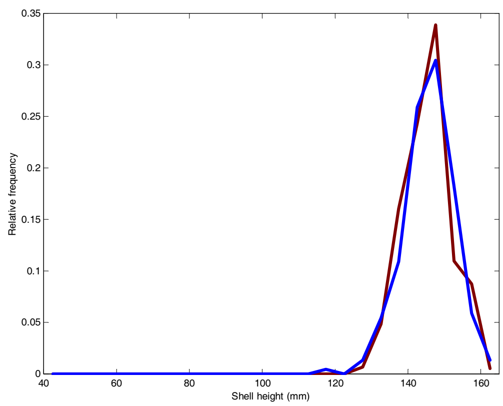
APPENDIX B2 Figure 6. Normalized size-frequencies at site #3 (Nantucket Lightship Closed Area).



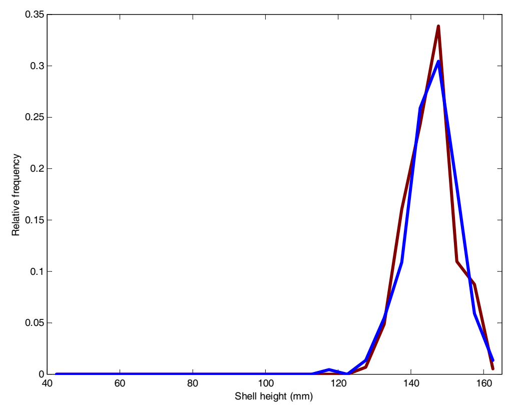
1999 to 2000



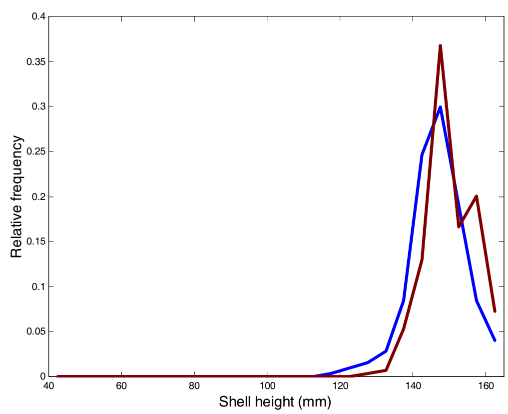
2000 to 2003



2003 to 2004

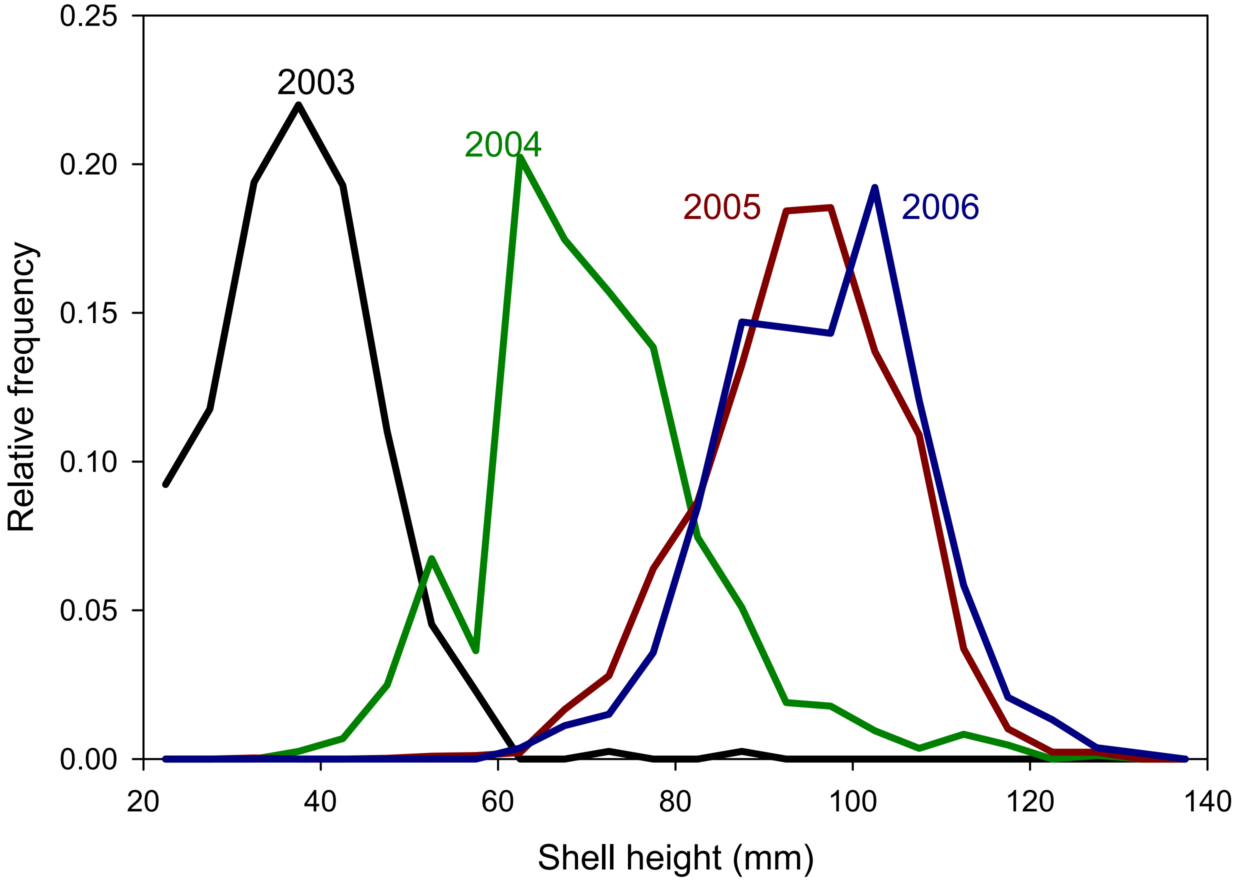


2004 to 2005

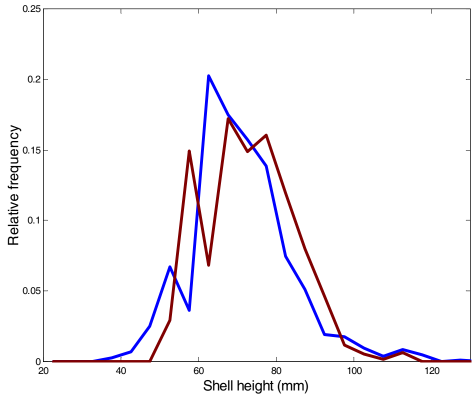


2005 to 2006

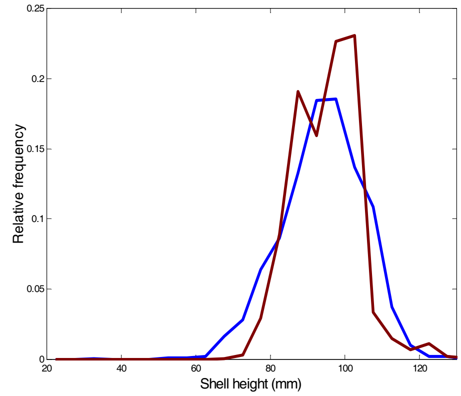
APPENDIX B2 Figure 7. Comparison between observed (solid blue line) and projected (dashed-dotted brown line) normalized size-frequencies at site #3 (Nantucket Lightship Closed Area).



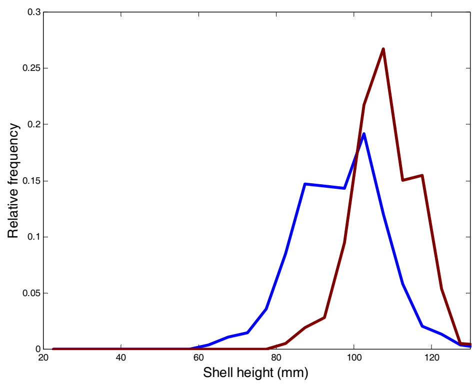
APPENDIX B2 Figure 8. Normalized size-frequencies at site #4 (Elephant Trunk Closed Area).



2003 to 2004

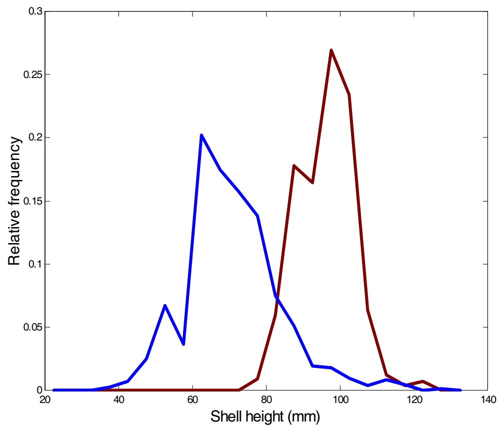


2004 to 2005

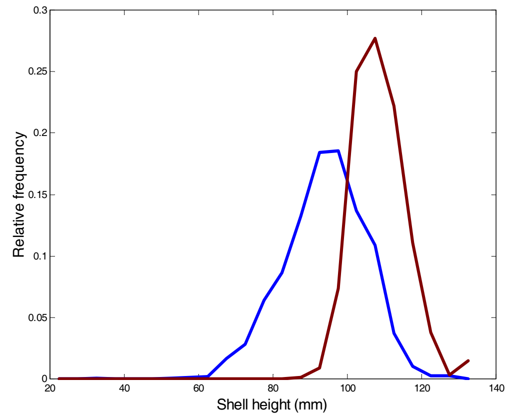


2005 to 2006

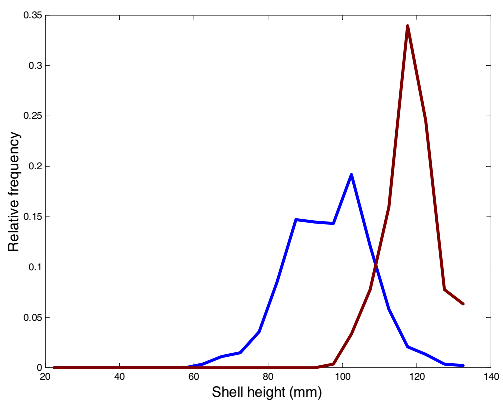
APPENDIX B2 Figure 9. Comparison between observed (solid blue line) and projected (dashed-dotted brown line) normalized size-frequencies at site #4 (Elephant Trunk Closed Area).



2003 to 2004



2004 to 2005



2005 to 2006

APPENDIX B2 Figure 10. Comparison between observed (solid blue line) and projected (dashed-dotted brown line) normalized size-frequencies at site #4, under the assumption that two shell growth lines are laid down annually, as suggested in Kranz et al. (1984).