Age based assessment in the sea scallop *Placopecten magellanicus*: a pilot study.

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1.0 EXECUTIVE SUMMARY

Project Title: Age-based assessment in the sea scallop *Placopecten magellanicus*

Year Awarded: 04/01/2018 - 03/31/2020

RSA Priorities Addressed By This Research: This project focuses on **development of an age based assessment for sea scallops** to supplement the Catch at Size Analysis (CASA) currently employed by NEFSC scientists.

Industry Partners: F/V Alaska, F/V Cove, F/V Frank and Maria

Summary:

This project employs continuing RSA funded dredge based assessment sampling to support development of age at length keys for scallops collected from the Mid Atlantic Bight and Nantucket Lightship areas. The **overall objective** of the project is to support a pilot study that extends the current CASA, length-based stock assessment model to include an age based assessment module for presentation and comparative evaluation prior to the next benchmark. **In doing so, the project will calibrate the length based approach against age – a fundamental element of any fishery assessment.** Early age at length data, mostly from historical archive shell collections dating back to the 1980's, was reported at the 2018 benchmark. The current effort focuses on a complete product for 2021 benchmark. Depending on the utility of the age based module as an additional tool, something to be evaluated by the NEFSC, an expanded program can be set in place to support the future efforts.

To date the project has examined and estimated age for over 1500 scallops, expanded details are given in the following section. We have employed three methods of examination: external growth rings or signatures, resilium signatures within the hinge structure, and isotopic oxygen within the shell carbonate. There is good agreement between the methods.

2.0 PRELIMINARY RESULTS AND DISCUSSION

Why bother with an age based assessment when the CASA length-based model has a proven track record in scallop management? An age based model calibrates a length based model and includes a description as to whether or not the age-length relationship is constant throughout the exploited range of the fishery and/or constant over time. It also improves description of recruitment in species where age estimation for small/young individuals is difficult, and a description of mortality where age estimation of large/old individuals is difficult - both are the current case for sea scallops. Indeed, fishery assessments generally include and are dependent on rate based (i.e., time based) reference points for recruitment, mortality, growth and more. Finfish fishery assessment and management plans reflect this focus by significant annual investment in age at length determinations based on otolith or scale reading from survey collections. There is an ongoing examination of age structure in scallop surveys, but it is modest. An additional consideration for inclusion of age data in scallop management is the annual update cycle that is central to current scallop management action - age assessments approaches for finfishes do not typically require this very quick turnaround time in data acquisition to management action. Thus any proposal to include age based data in scallop management must employ methods and analysis that are time responsive.

Age determination in scallops has been described in the literature(1,2,3,4). Shell external signatures or growth rings provide a basis for estimation of von Bertalanffy growth parameters from growth increments (2,3). In practical application this is optimized by examining a modest number of scallops from a large number of stations on a regular basis. More information (more increments measured) come from larger scallops, so there is a relative lack of information on the smaller scallops. Also, there is a learning curve to reading external growth lines, especially where additional lines result from disturbance rather than annual events. For the current study we have built on an earlier award examining age at length in archived scallops shell from NEFSC collections dating back to 1979. We employed three methods to estimate age at length (where length is the measurement from the hinge to the growing edge, in classical morphological descriptions this is actually the height but we adopt the commonly used terminology for this report). The first approach is that of growth increments based on external rings or signatures as described above. The second method uses oxygen isotopes in the shell calcium carbonate to verify that the external rings are annual. Oxygen in sea water exists as two isotopes, O16 and O18 with the latter being in much lower relative abundance. Incorporation of O16 relative to O18 into shell carbonate (as CaCO3) is temperature dependent, thus a seasonal cycle of the O16/O18 ratio in the carbonate oxygen is expected in concert with varying water temperature. The annual cycle should thus be evident in carbonate formation between the presumed annual growth rings. The third method of age estimation is based on signatures in the hinge of the scallop as first described in practical application by Merrill and co-authors over 50 years ago (1). These signatures exist in the resilium structure and, as we will described below, are distinctly annual in nature, relatively easy to read in large numbers in modest periods of time and, importantly, provide comparable results to the two methods described earlier.

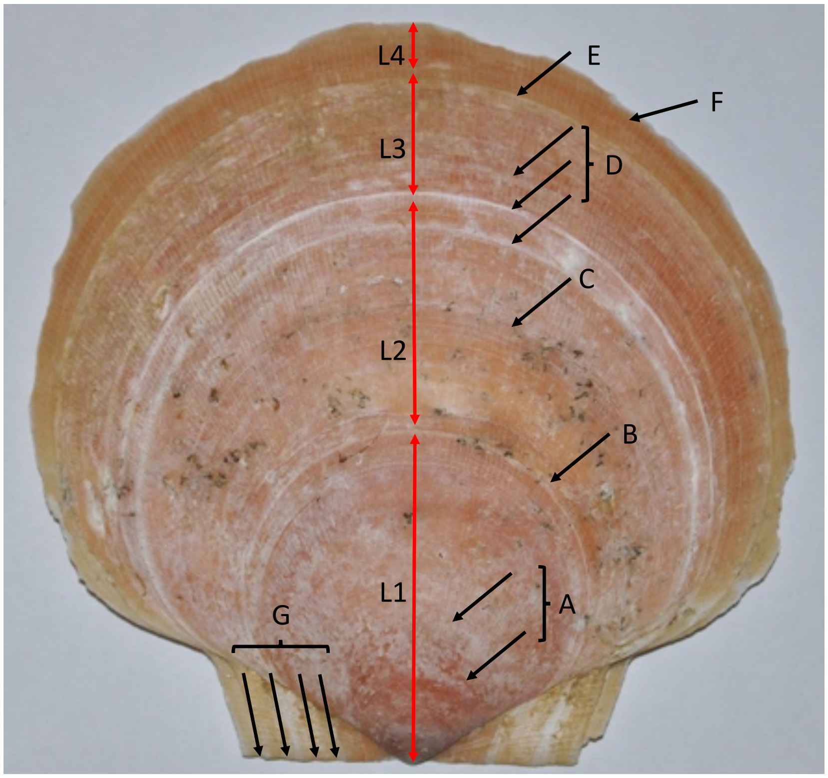

Figure 1. Valve external view

Consider the information available in external rings. Figure 1 illustrates a single shell. Where are the critical rings? A indicates a region where two rings are evident, but they are probably from the year of spawning and recruitment. So they are “partial year’ rings, less than one year. Do we count them? Our protocol is not to count them. B is a single distinct ring and we count this as year one – depending on recruitment date and sampling date the included period is actually more than one year. C is notable, but probably a disturbance ring – it is less distinct than B. The next significant ring is within region D, but which one of the three identified rings is it? We consider the central ring of the three to be the annual ring, this is year 2. E is the next ring and we consider this year 3. F is a fourth ring, but is it annual or a sub-annual ring? Given that we have identified B, D and E as annual then the growth increment between E and F is probably sub-annual. If so then the growth increments to be recorded are L1, L2 and L3 for annual and L4 as part year to the growing edge. Can we support this conclusion by additional external signatures? The hinge region, G has arguably 4 distinct signatures, and if these are followed onto the larger shell surface they correspond to A, B, D and E. In general annual growth increments decrease in size moving away from the hinge (that is L1>L2>L3 and so on), but there are occasions where many shells from the same location show a single unusually large or small relative growth increment in the sequence of measurements corresponding to arguably good or bad food and/or environment years. The example illustrates how data is collected, but also possible errors. These are minimized by multiple reader recording, including repeat samples, plus subsequent comparison with other methods. The increment data for a substantial sample size were examined using a generalized linear mixed effect models (GLMM) following the procedure in Hart and Chute (2). Estimates of von Bertalanffy growth parameters and growth curves were generated. Figure 2 is an example for the Mid Atlantic Bight and Georges Bank regions respectively for historical data.

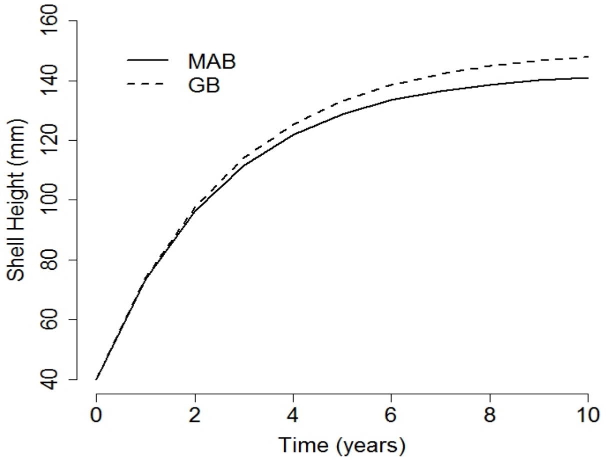

Figure 2. Predicted growth of 40 mm scallop by area from estimated von Bertalanffy growth parameters for NEFSC archived scallops.

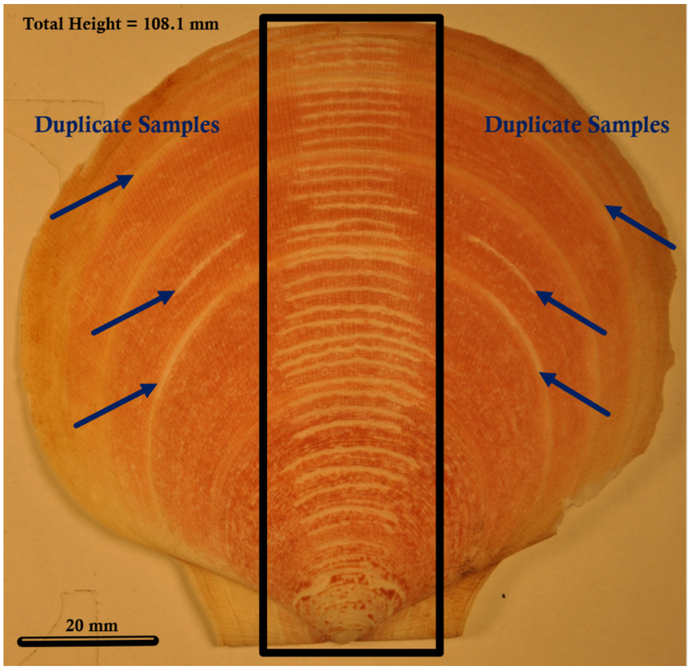

Figure 3: Isotope sample collections from archived 1989 scallop shell.

Figure 3 illustrates the external surface of a second shell, this from the NEFSC archive, which has been sampled for shell carbonate, as dust, using a diamond tipped Dremel tool to capture single samples (~0.005 g – 0.015 g material) along an identified growth ring and at regular intervals between the rings. The samples were collected from the region within the rectangle. Additional samples, analytical duplicates or replicates, were collected from outside the rectangle region as noted. The sequence from hinge to growing edge thus represents the growth history of the scallop. Isotope analysis was completed at Boston University.

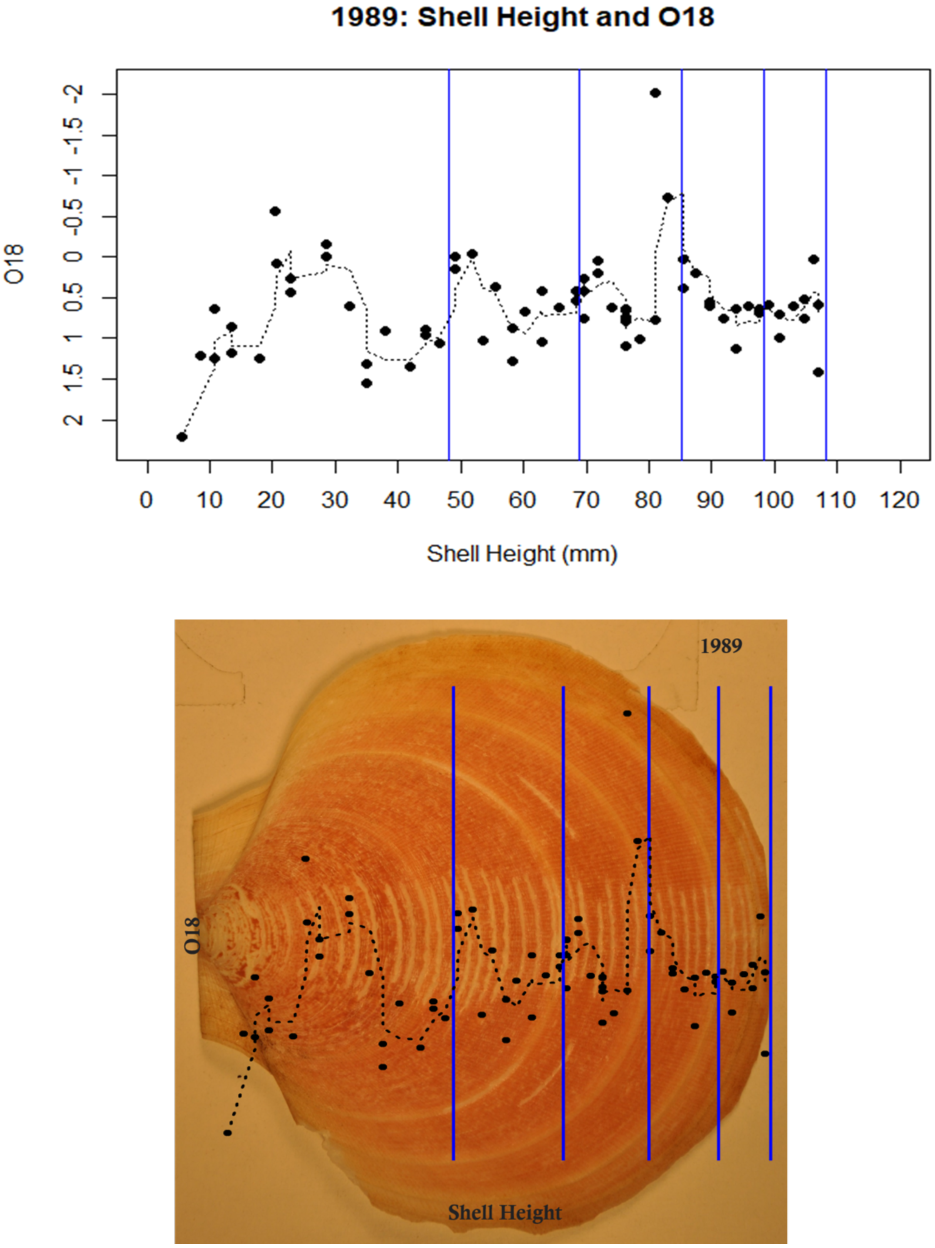

Figure 4. Isotopic O18 shell carbonate analysis from sequential sampling in Figure 3 (upper image), and with data overlaid on Figure 3 in lower image.

Figure 4 provides, in the upper graphic, the O18 sequence over the growing life of the scallop illustrated in Figure 3. The sequence is then overlaid on the image of Figure 3 (after the image is rotated) to illustrate the concordance of the O18 trace with the major growth rings on the shell surface – the rings correspond to the annual temperature cycle with one major ring per year. Lower O18 values (-ve) correspond to higher temperatures, higher values (+ve) correspond to lower temperatures. External rings are laid down in the summer as also noted by Chute et al (4).

The third method of age estimation uses the resilium in the hinge structure. Figure 5 illustrates the position of the resilium. To view the resilium plate the hinge resilium ligament was removed by soaking the shell in water for 24 hours. This is adequate even for specimens that have been sitting in dry boxes for over 20 years. The exposed resilium plate can then be examined for age signatures. The resilium plate is protected by the resilium ligament and arguably less exposed to disturbances than external shell signatures. Note the presence of distinct bands on the resilium plate, the spacing of the bands along the resilium (and how these spaces may be proportional to the spacing of the external growth rings) and the periphery of the resilium moving from the position adjacent to the external hinge (top of the right image in Figure 5) to the inner edge of the resilium (bottom of the right image in Figure 5). The left and right borders of the resilium are not straight but show a general out then in curvature between each band. These curvatures are important in that they aid definition of the bands.

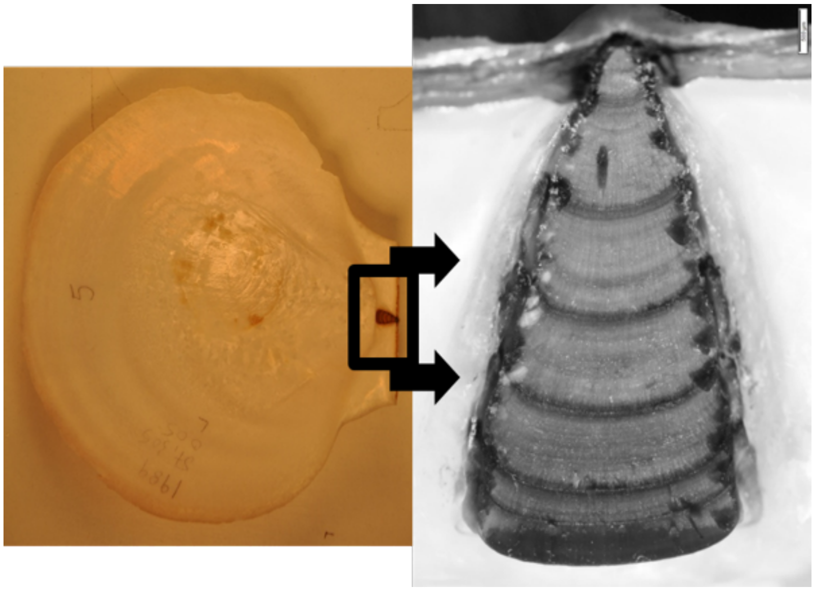

Figure 5. Position of the resilium on the internal shell surface hinge region.

The question now arises of the concordance of the external annual rings and the bands on the resilium. Figure 6 provides a comparison for the shell illustrated earlier in Figures 3 and 4. As with those figures the first age signature was ignored because it only counts as a partial year of growth (spring spawning/fall spawning). There is good agreement between the observed signatures in the resilium and the external shell, as indeed suggested by Merrill and co-authors (1) over half a century ago! In a practical sense resilia based age estimates are simple to collect.

They can be used to generate single age at length estimates per shell (much like an otolith with a fish length), and this is the manner in which we have used them. The option exists, but we have not yet examined this in detail, to measure growth increments in the resilium and compare them with external growth ring increments (it is on the to do list!)

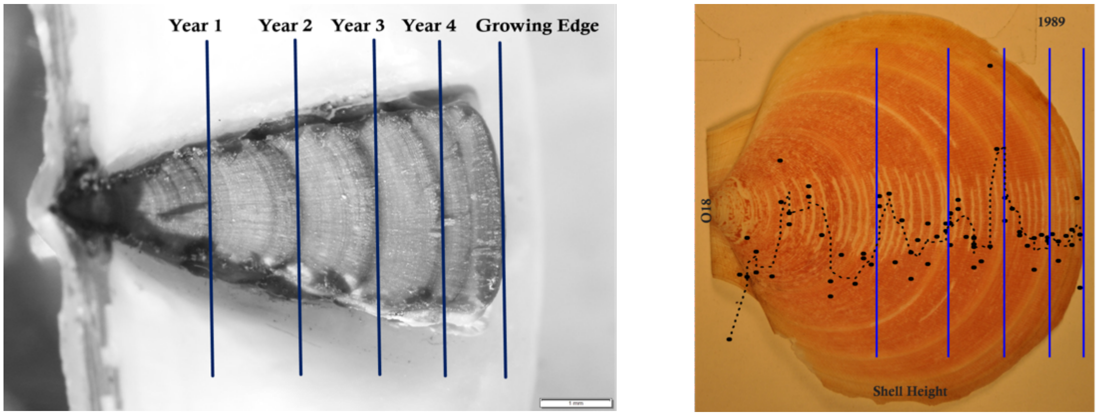

Figure 6. Annual signatures on resilium (left image) and corresponding annual rings (blue lines) and O18 values superimposed on external view of a scallop.

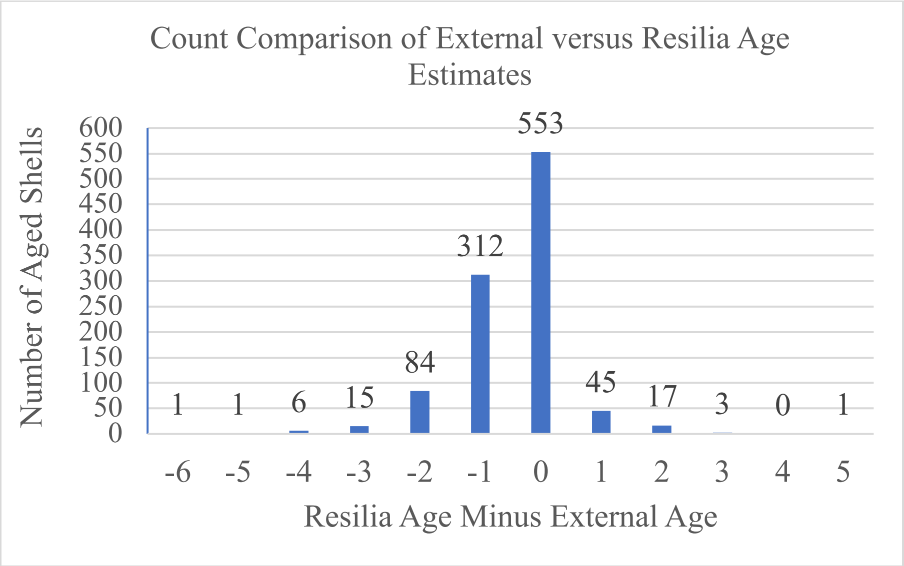

Figure 7. A comparison of age estimates from 1038 scallop employing both external and resilium methods.

So how have these approaches worked in application in the current project? To date the project has measured and aged scallops from 18 research cruises and 411 stations from the years 2012, and 2016 through 2018. A total of 1527 scallops from the years 2012, and 2016 through 2018 have been aged by external ring counts. A total of 1250 scallops, from years 2012 and 2018, have been aged using the resilium method. A total of 1038 scallops were aged by both methods – again note that the resilium signature is protected from external erosion and abrasion so it is possible to assign an age estimate by the resilium method when external signatures are problematic.

The data summarized in Figure 7 shows that 553 individuals (53.3%) gave the same age estimate. Estimates of age from external rings exceeds resilium base estimates by one year for 312 individuals (30%) and by two years for 84 individuals (8.1%). Resilium based estimates exceeded external ring based estimates in comparatively smaller numbers (45 individuals (4.3%) where the difference was one year, 17 (1.6%) where the difference was 2 years). Only 27 individuals from ten total of 1038 fell outside of the difference in age estimates of 2 years. We consider the slight bias towards rings based estimates exceeding resilium based estimates is driven by inclusion of growth rings near the growing edge. These are generally closely spaced and difficult to distinguish from sub-annual and disturbance signatures. In a very limited number of instances these differences can be large – see Figure 7 where resilium age minus external age values are between -6 and -4. By contrast scallop shells with highly abraded external surfaces (not generally recommended for age estimation) give resilium age estimates larger than external ring estimates. We will continue to update this data set as the project progresses.

What's next?

We are in discussions with NEFSC and other stock assessment experts as we move to the first computational examination and analysis of the age based data in a stock assessment protocol. CASA software is not suitable, but the most recent version of Stock Synthesis (SS3) is promising. SS3 is, to quote the manual appendices prepared by Richard Methot Jr. and Chantell Wetzel (SEDAR39-RD-08), "an assessment program that provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. SS3 is designed to deal with both age- and size-structure with multiple stock sub-areas and multiple growth patterns." There is a growing base of experience using SS3 among stock assessment scientists in the northeast and our focus remains on this option at the current time.

As noted earlier both the ring count and resilium methods can be used to process large numbers of scallops in a modest time period and are thus responsive to the short time frames that are central to scallop management. Present at sea data collection includes length using measuring boards connected to computers. Can we collect resilium information at sea? This is a question we are beginning to explore given the promise of rapid imaging of the hinge region and machine learning to discriminate and count annual signatures.

Literature cited.

1. Merrill, A. S., J. A. Posgay & F. E. Nichy. 1966.Fish Bull. 65:299–311.
2. Hart, D. R. & A. S. Chute. 2009a. ICES J. Mar. Sci. 66:2165–2175.
3. Hart, D. R. & A. S. Chute. 2009b. Can. J. Fish. Aquat. Sci. 66:751–758
4. Chute A.C., S. C. Wainright & D. R. Hart. 2012. J. Shellfish Research, 31(3): 649-662.

3.0 SPECIAL COMMENTS

This project has piggy backed on existing RSA funded surveys with, we consider, great success from modest additional funding. The progression from an earlier study on archived material to rapid lab based processing of material returned from recent assessment cruises in the present study has been a smooth transition. We have an experienced project staff who can now train new personnel in age techniques in modest time periods, and are sharing these techniques by video recordings – see an example at https://www.youtube.com/watch?v=nRN8OtpvtLU&t=22s. This video is predominantly for lab instruction within our VIMS lab, but it can be customized for other uses as required. Indeed, a poster presentation by Co-PI Rudders at the recent scallop 2019 International Pectinid Workshop in Spain has elicited much interest and both PI's have expressed interest in participation is a scallop age workshop provisionally planned for Spring 2020 in Aberdeen, Scotland.