Larvamap – Prince William Sound Final Report

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Abstract

The aim of the LarvaMap project was to develop a viable web-based larval transport modeling package, and to test the program by running model simulations of larval transport for Pacific herring and Dungeness crab in Prince William Sound (PWS). The program was developed by Applied Science Associates, and works as intended. Behavior and development of simulated larvae can be designed and modified based on data for existing species using a "larva library". The program includes the ability to specify growth and development rates that vary dependent on water temperature, swimming abilities that vary depending on larval size and stage of larval development, and common larval behaviors such as diel vertical migrations. Once behavior for the species of interest has been designed, larval transport models can be specified and run using a straightforward interface. The LarvaMap application is available at the web address: http://services.asascience.com/MapApp/larvamap/.

Larval models were developed and run for both Pacific herring and Dungeness crab in the PWS area. A detailed literature review of larval development and behavior was carried out for each species, and this was used to design the simulated larvae used in the models. Larval transport models were run for Pacific herring in PWS for the years 2009-2012. Larvae originated at points based on data from aerial surveys of herring spawning carried out annually by Alaska Department of Fish and Game. Simulations ran for the entire larval phase, which is approximately 68 days in PWS. The results of the Pacific herring models showed that there was a substantial and unexpected amount of variation in the predicted final settlement locations for the larvae between years. Results for 2009 showed that a large proportion of the larvae settled in the eastern part of the sound, whereas in 2010 and 2012 the majority settled in the west. 2011 was also different in that many of the larvae were advected out of the sound, where they would presumably not survive. These results are an interesting first attempt to model larval transport, and could be compared with known distributions of juvenile herring in overwintering areas to verify the models.

Models were also run for Dungeness crabs in the PWS area for 2011 and 2012. The results also showed great interannual variation, of a similar magnitude to that seen for herring. The 2011 run showed that the majority of the larvae were retained near to their start point in the southeastern part of PWS, although in

2012 the majority were advected to the western part of the Sound. These results do not appear to implicate larval transport issues as a reason for the decline of Dungeness crab in PWS.

Objectives

The original objectives defined in the proposal were:

Objective 1: Develop and verify LarvaMap 2 as a successful web-based community larval transport model that allows users to 1) run larval trajectories for Pacific herring and Dungeness crab in PWS, 2) create other larval organisms through customizing the provided behavior suite, and 3) run larval trajectories in other regions where circulation model output is available using oceanographic community standards (NetCDF and THREDDS catalogs).

Objective 2: Extend the Regional Ocean Modeling System (ROMS) model time series for PWS from two individual years (2004 and 2009) to a complete time series from 2004 to 2010. This time series will allow statistical evaluation of larval settlement probability maps in PWS and analysis of interannual environmental factors that affect larval transport.

Objective 3: Develop probability maps for Pacific herring and Dungeness crab for the individual years from 2004 to 2010, and a statistical map for each species that covers the seven years from 2004-2010.

All three objectives were met fully or partially. For objective 1, the program was developed as specified, and can be used to run larval trajectories in PWS. The web address for LarvaMap is http://services.asascience.com/MapApp/larvamap/. The larval behavior library is at http://larva-library.herokuapp.com/ and can be used to modify existing organisms or develop new ones. As yet, no other forcing models have been connected to the LarvaMap program, but work is continuing on this.

For Objective 2, the time series was completed, running from 2004 through 2013.

For Objective 3, larval trajectories were run for herring in Prince William Sound for 2009-2012. These trajectories used data from the aerial survey of spawning herring to define start points and data collected from a comprehensive literature survey to define the behavior of the modeled larvae. Probability maps were developed from these runs and showed substantial inter-annual variation in the final distributions of larvae. Issues with the output format of the model time series in 2004-2008 prevented us from running trajectories for those years.

For Dungeness crab, a literature survey was completed and used to develop a behavior scheme for modeled larvae. However, few data were found to define where the larval hatching was likely to happen in the PWS area. Trajectories were run for two potential hatching areas, one within PWS and one off the Copper River delta. The PWS trajectories showed similar results to the herring runs, in that the larvae were mostly retained within PWS. The Copper River delta runs showed larvae moving mostly offshore, and ultimately leaving the range of the L1 ROMS model. This was not an unexpected result. Work on Dungeness crab off the west coast of the lower 48 states has shown that the larvae are advected offshore during the early stages and subsequently return to suitable settlement areas due to onshore transport in the late larval phase

Problems in project implementation

Work on this project was substantially delayed by staff issues. Dr. C.J. Beegle-Krause developed the proposal and was the primary Research 4D staff member assigned to coordinate and work on the project, starting in early 2010. However, she was recalled by NOAA to work on modeling of the Deepwater Horizon oil spill in April 2010. Consequently, work on the project did not start until the middle of 2011. Dr. Beegle-Krause subsequently moved to Norway in August 2012, at which point Dr. Nick Lowry took over management of the project.

Accomplishments

We succeeded in developing the LarvaMap package of the transport model and larval library, which allows non specialists to develop models of larval transport for organisms in Prince William Sound. Behavior models were developed for Pacific herring from hatching through metamorphosis and for Dungeness crab up to the megalops stage. Larval transport models were run for Pacific herring in Prince William Sound for the years 2009-2012 and probability maps of distribution of post-metamorphosis larvae were developed for each year. Behavior and transport models were also developed and run for Dungeness crab for 2011-2012.

Conclusions

The primary research conclusion arising from this project is that it appears that there is much greater inter-annual variability in the distribution of post-metamorphosis herring larvae within Prince William Sound than had been expected. This may be one of the factors leading to the observed high variability in year class strength for herring in PWS.

Questions arising from this project may be used to guide future work. The results achieved in this project are somewhat preliminary, as the times and places at which simulated larvae were released were limited. The precision of these results would be improved by better matching the time and place of larval hatching with the release times and locations for simulated larvae in the model. Extending the time series to include the full range of the circulation model from 2004 thru 2013 and comparing the results with observed distributions of juvenile herring in PWS has the potential to verify the transport model results and if a correlation was found, there would be potential to use the transport model to forecast herring year class sizes up to three years in the future.

The larval growth and behavior model used in the simulations is based on published data drawn from a wide range of areas and races of herring. The model would be improved by collecting and using specific data from PWS herring. This is especially true of the vertical migration component, which is likely to be key in determining the fate of the larvae. Collecting data which could be used to link growth and temperature would potentially improve estimates of the length of the larval phase. Data on whether hatching of larvae from each spawning event is synchronous or spread out could be used to improve model inputs, as could specific knowledge of the incubation time for herring eggs in PWS. One issue that was obvious in analysis of hatch timing data was that the date of hatching appears to have advanced by approximately 12 days from 1973 through 2012 (see appendix4c). A thorough investigation of whether this change is a real effect or an artifact of changes in spawning locations is necessary, and the impacts of any change on fate of larvae should be studied.

Appendices

1. Technical description of LarvaMap package
2. Pacific Herring Larval Transport modeling in Prince William Sound
3. Dungeness Crab Larval transport modeling
4. Published reports resulting from project work:
    a. LarvaMap poster presentation at AMSS 2012
    b. PWS circulation model poster presentation at AMSS 2012
    c. Herring synthesis report chapter