MAS Project: Case Study 1 Overview

Scope

Here we propose to develop a new object-oriented population assessment system to support NOAA Fisheries ongoing modeling software needs. This system will support maintainable and extensible assessment models, and use state-of-the-art analytical approaches which support spatial modeling, parallelization, and high performance computing. The Analytics Template Library (ATL) is a new NMFS modern C++11 library for automatic differentiation and parameter estimation. ATL was designed to support NOAA Fisheries assessment modeling needs and performs higher order automatic differentiation computations for fixed and random effects with object-oriented data structures and operations that are readily parallelizable. Many NOAA Fisheries stock assessments use the Automatic Differentiation Model Builder (ADMB) open-source software application for model construction and parameter estimation. In particular, the Stock Synthesis 3 (SS3, available at http://nft.nefsc.noaa.gov/) application and other integrated modeling software used by NOAA Fisheries (e.g., ASAP, AMAK, BAM, and others) all depend on ADMB for model construction and parameter estimation. ATL has many features that are included in ADMB and new features that are not available in ADMB. ATL is NOAA developed and NOAA maintained, thus reducing the overall long-term cost of maintenance and support.

The Metapopulation Assessment System (MAS) is a prototype of a spatial assessment system for developing integrated movement-based single-population or metapopulation assessment models using ATL for function minimization and parameter estimation. MAS is being designed as an objected-oriented, open-source statistical catch-at-age population dynamics application for building integrated spatial assessment models, with similar functionality to SS3. MAS will be an integral part of a projection and simulation testing framework, which will include functionality for comparing and selecting among alternative models, producing stochastic population projections and forecasting quantities of interest, simulation testing, and management strategy evaluation.

The combination of ATL and MAS provides a path for NOAA Fisheries to maintain and improve assessment modeling software and processes. In this context, the use of ATL would provide a NOAA Fisheries-supported model estimation engine, noting that the expertise needed to do this is within NOAA Fisheries. Similarly, the modeling features of SS3 and other integrated models can be translated into a more modern and extensible system designed to incorporate spatial population dynamics, namely MAS. Here an excellent opportunity exists to build MAS incrementally by putting together a set of projects (i.e., Case Study 1) to construct and validate the components of MAS sequentially.

Project Goals

The overall goal of Case Study 1 is to implement an initial model construction layer for MAS. The goals of this case study as part of the MAS project are:

- To create the data structures and operations, along with model analysis layers needed for producing the maximum likelihood estimates of the parameters and their covariance matrix for an integrated metapopulation model.
- To estimate the parameters of the case study using ATL applied to simulated data with a known true state of nature for a two-area, two-population, two-fleet fishery, one-survey system in order to validate and verify MAS.
- To produce model diagnostics and output quantities of interest and their uncertainty.
- To provide a well-documented example of implementing a production-level software development process for NMFS.

Timeline

The timeline to complete the case study is the remainder of fiscal year 2017. The starting date is set to be the first week in March 2017. The time horizon extends through a total of 15 bi-weekly periods that correspond to federal pay periods.

Deliverables

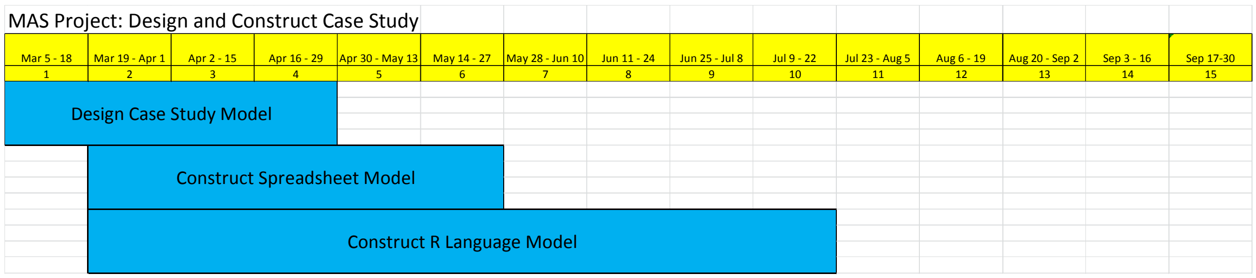
Given that the goal of implementing the model construction layer of MAS, the primary deliverables of the MAS project case study include:

- Working C++11 standard code for MAS that implements the case study using Github for version control of code and documentation.
- Well-documented case study that will serve as a test case for MAS development including a project overview document, the case study vignette, as well as the R language and spreadsheet implementations of the model.
- An example of implementing software design practices for quality control and assurance for the ongoing work of the NOAA Fisheries National Stock Assessment Program.

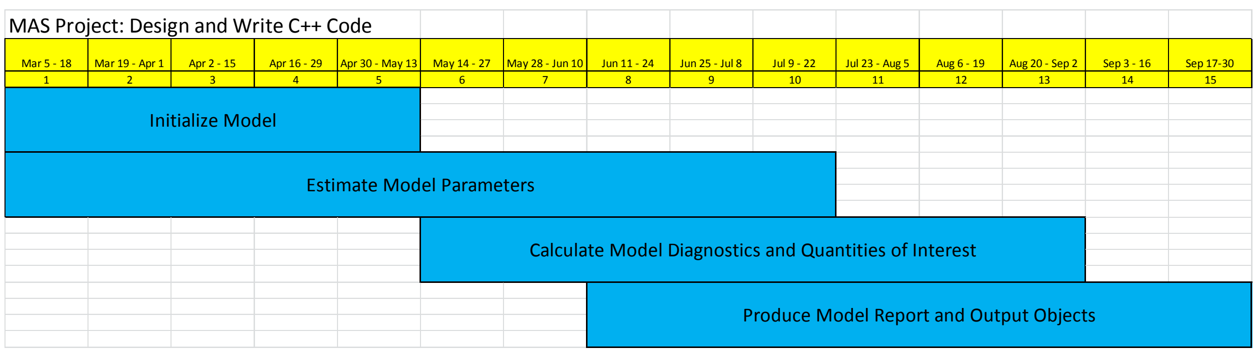
Summary Tasks

To achieve the goals of the Case Study, we can break down the development of the model construction layer with one good example into three summary tasks. These summary tasks are:

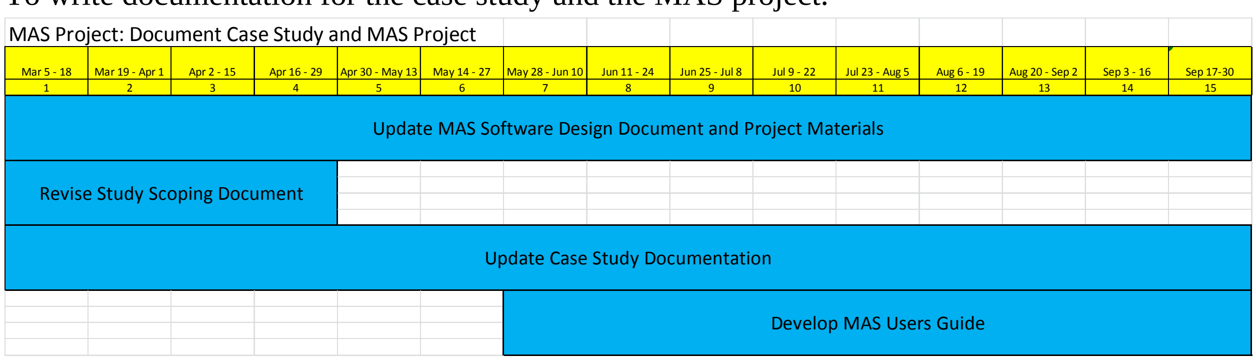
- To design and construct the case study model.



- To design and write MAS C++ code to implement the case study.



- To write documentation for the case study and the MAS project.



Stakeholders

The current MAS project stakeholders can be broken out into groups of people with similar roles. The project customers are the people in NOAA Fisheries who conduct stock assessments or use assessment information for domestic or international fisheries management. These are the people who have the stock assessment modeling problem to solve. The project sponsors are those who want the project to succeed. We consider the following NOAA Fisheries people to be sponsors: Rick Methot, Steve Brown, Clay Porch, Patrick Lynch, and Annie Yau. The project team is the set of people who will do the project work. We consider the current project team to be Matthew Supernaw (Matthew.Supernaw@NOAA.GOV), Teresa A'mar (Teresa.Amar@NOAA.GOV), and Jon Brodziak (Jon.Brodziak@NOAA.GOV), with Jon Brodziak serving as the project manager and also noting that we would like to add more team members.

Communication

Project tasks will be broken into time cycles to conduct work, complete tasks, and review progress. We will have regular teleconferences with the team members and interested sponsors and other stakeholders. The teleconference meeting schedule cycle is initially set at 2-weeks intervals to foster progress, with a suggested meeting time of 2PM EST Thursdays. We will also have face-to-face workshops where major issues can be addressed, and project plans, documents, and other materials can be updated and reported. The tentative workshop cycle is set for every 4 to 6 months with sites alternating between SERO in St. Petersburg, the AFSC in Seattle, and the PIFSC in Honolulu. Regular project communication will be conducted by phone and email noting that the current team members work at different duty stations.

Requirements

The project requirements consist of the staff time and resources needed to do the project work. For the recent past, the percent of staff time of team members allocated for the project has been roughly: Matthew Supernaw at 70-80%, Teresa A'mar at 10-20%, and Jon Brodziak at 50-60%. The current team members are all FTEs employed by NOAA Fisheries.

The computer resources needed for the project are partially funded. Each project team member needs a laptop or desktop computer that can compile C++11. At present, Matthew Supernaw, the NOAA Fisheries National Modeling and Assessment Team scientific software engineer, is the only team member with the necessary computer resources. We note that the lack of computer resources with comparable software development environments has severely hampered the development of MAS and the team needs the computer resources as soon as possible. As it is the goal of MAS to be platform-agnostic, project tasks, including development, will be performed on Mac OS X, Linux, or possibly Microsoft Windows 7/8 if a suitable C++11 compliant compiler were to become available for the Windows OS, with full administrative rights for the developers.

At present, requests for computer resources have been submitted by Teresa at NMFS S&T and Jon at PIFSC but these may be delayed under continuing resolution funding.

The project requirements also include travel costs for 2 team members to participate in a face-to-face workshop twice in fiscal year 2017 (FY17). The next workshop is tentatively scheduled for 26-30 June 2017 in Honolulu.

Case Study Vignette

Here is a brief description of the metapopulation model to be constructed and fit to data. Case Study 1 represents a simple two-population model with a hypothetical north-south latitudinal cline for the species characteristics between two areas. The two populations are loosely modeled as an abundant and migratory groundfish species with 9 true age classes comprised of ages 0 to 8 years and a plus group for ages 9 and older. The time horizon for assessment is 20 years and an annual time step with a single season is used for fishery dynamics modeling. Both populations are modeled as having two sexes but there is no difference between genders in either population. The two populations inhabit two areas and have distinct recruitment and demographic dynamics. Both populations spawn in both areas and engage in feeding migrations between area 1, which is more temperate (northerly), and area 2, which is more southerly (warmer). Both populations have life history characteristics that persist when individuals move among areas. That is, the demographic characteristics of individual fish are determined by their genetics and population of origin and not by the area which they occur. Further, the two populations are modeled as moving among areas, with population 2 exhibiting higher mixing rates for early life history stages, juveniles, and adults.

There is a mixed-population fishery in both areas. The two fishing fleets harvest both populations through time, one fleet in each area. Both fleets are stable in operating characteristics throughout the assessment time horizon and fishery selectivity at age is constant through time for each fleet. The fishing effort in both fleets changes through time. In the pre-assessment time period consisting of 10 years, both fleets have a low constant annual fishing mortality rate of F=0.1. In the first 10 years of the assessment time horizon, the fishing mortality increases in both areas as both fishing fleets expand in capacity. In area 1, the fully-selected fishing mortality increases 4-fold to F=0.4 while in area 2, F increases 2-fold to F=0.2. In the second 10 years of the assessment time horizon, the fishing mortality decreases in area 1 and does not change in area 2. That is, the fully-selected fishing mortality in area 1 decreases 50% during period 2, while the fishing mortality in area 2 remains the same in period 2. Overall, fishing mortality ramps up in the first period and then decreases or remains the same in period 2, leading to changes in the abundances of both populations. The fisheries produce observed fishery catch biomasses and fishery age compositions by year in each area.

There is one fishery-independent research survey information available in both areas. The survey has had stable operating characteristics throughout the entire assessment time horizon. The survey selectivity at age is constant through time for each population. Survey selectivity for population 1 is slightly higher and less variable at age than for population 2. The survey produces an observed biomass index and survey age composition by year for each area.