Scientific Report for Formulation Step

SSA 7.6, Søndeledfjorden, Norway

Jakob Gjøsæter[1], Eirik Mikkelsen[2], Erlend Moksness[1],
Håkan T. Sandersen[4] and Jon Helge Vølstad[3]

1) Institute of Marine Research, Flødevigen Marine Research Station, 4817 His, Norway
2) Norut AS, Postboks 6434 Forskningsparken, 9294 Tromsø, Norway
3) Institute of Marine Research, 5817 Bergen, Norway
4) Bodø University College, Dep. of Social Science, 8049 Bodø, Norway

23 December 2008

1 Input Approximations and Transformations

In this study the status of the local cod (*Gadus morhua*) population is used as a proxy for the status of the ecosystem. Cod is an important component of the fjord ecosystem, and has historically been highly valued by commercial and recreational fishers. Coastal cod is of particular concern since the stock south of 92º N has been included in the Red List which is essentially a forecast of the risk of species becoming extinct in Norway. The abundance and population structure of the cod population is projected over a 20-year time period (default), using a demographic model implemented in Extend, where abundance and biomass of cod by age-class (0-10) is projected in yearly time-steps. Annual recruitment (number of age 0) is simulated by random selections from log-normal distributions of age 0 abundance indices based on empirical data from beach seine surveys, and is a function of habitat. Age groups 1-10 are projected based on estimated yearly growth and mortality. The baseline ecosystem model reflects the 2008 situation without any regulations, and is parameterized using empirical data and information from the literature. The economic model component estimates (net) local economic benefits from tourism in the Søndeledfjord area under different policy options. For more details see System Formulation Report, Document Report and the two documents "**System Formulation, Part 1: ExtendSim Model description"** and "**System Formulation, Part 2: Running the model**".

2 Description of Policy Issue Scenarios and Interface

In study site SSA 7.6 we evaluate how increased local economic benefits from tourism can be achieved while sustaining a healthy local coastal cod stock, and at the same time minimizing conflicts with local users of the fjord system. The goal is to develop a user-friendly modeling tool that can help policy-makers and regulators by revealing connections between policy and the

environmental and the socio-economic components, and how policy changes are likely to affect these components. Tourist fishers represent an interface between the status of the cod population (a proxy for the ecosystem) and socio-economic factors. Policy instruments that influence the dynamics of the cod population in the model includes TAC (total allowable catch on each year-class per year), amount of bottom habitat occupied by marinas, and the number of predators (birds and mammals) which can be controlled by hunting.

3 Scope and Methods for the interpretive Analyses

The ecosystem component of the model is parameterized to account for mortality from top predators (birds and seals), change in recruitment as a function of available habitat (influenced by 2nd homes and marinas) and predation by 1-year old cod, fishing (eel-fishers, commercial fishers and tourist fishers) and stock enhancement. The effect from each of the above drivers can be regulated in accordance with policy choices, and the expected change in the cod population and economical output is calculated for each policy scenario. The output includes yearly abundance and biomass of cod for each age-class projected forward over 20-years. Monte-Carlo simulations are used to account for uncertainty in model projections by taking into account uncertainty in input parameters. The economic benefits/costs related to tourism that we consider include expenditures from tourists visiting the area and associated effects of those expenditures (multiplier effects of expenditures evaluated from a regional input-output model), building and maintenance of 2nd homes and associated effects, changed income in the commercial fishery due to changes in the coastal cod stock, which is also affected by tourism (fishing + habitat changes). To estimate the economic value of these goods and services we will use the expenditure/regional multiplier method above, and the market price method for changed harvests in the commercial fishery. Although surveys to estimate importance of fish abundance on tourists numbers would have been useful for our model's calibration, the available resources in the project prohibits this. The Social aspect of the total model will mainly be evaluated through a relationship estimating the conflict level (a conflict indicator), assumed to depend on total tourist numbers and economic returns from tourism to the local economic system.

4 Representation of System Function

The virtual system described in the design step has been greatly simplified by using the population of cod, which is a key species in the fjord fish community, as an indicator for the ecosystem. The revised concept diagram is described in the Documentation report.

5 Description of ESE Linkages

The Ecological, Social and Economic sectors (ESE) are linked in the Extend model through feed-back loops between the cod population (which is an indicator for the ecosystem), and main ecosystem goods and services. The abundance of the 0-group cod in the population is modeled as a function of the area of suitable habitats (eelgrass etc) for recruitment and the strength of the 1-group cod. The total population size and the strength of the different year-classes of cod is a

function of natural predators (as birds and mammals) and fishing mortality (caused by tourists, recreational fishers, and commercial fishers) and other human activities (Eco-tourists etc). Ecosystem goods include the availability of market-sized cod (age 2+) for tourists and local residents mainly, but to some extent also for commercial fishermen. Ecosystem services include natural habitat and scenic landscape that is for tourism, and for recreation by local residents, both for boating and rambling.

The level of conflict between tourists and local residents is assumed to depend on tourists numbers (+), as well as the economic benefits to the local system from tourism (-). Other aspects linking ESE could also be added into the conflict level indicator estimation (state of the cod stock and landscape quality (which may depends on the number of cabins, boat marinas and constructed beaches). The conflict level is also assumed to impact on tourist numbers, with higher conflict level reducing tourist numbers.

6 Description of Hindcast Results

Monte-Carlo model projections (100) were run to produce time-series (20-years) of cod abundance and population characteristics as a baseline for comparison to assess effects of policy changes and for model calibration. Population trajectories where compared to historic data, and estimated natural and fishing mortality were compared to published data to ground-truth the parameterization of the model. Baseline abundance trajectories and the age-structure of the population match expectations. Social and economic model components are being calibrated separately by comparing model output variables under baseline conditions to available data from the literature and official statistics.

7 Assessment Plans for ESE Components

The baseline model for the local cod population is run with a starting population for cod that is affected by predation (natural mortality) and fishing (fishing mortality) driven by different components (predators and users) in the study area. The baseline model will apply 2008 policy and regulations, and the number in each category of users will be based on 2008 figures. The assessment of ESE components will be based on model outputs under different policy scenarios. Reduction or increase in any of the user categories, and in the number of predators by category, will affect the local cod population, as well as socio-economic components of the fjord system. Policy actions will regulate the:

(1) Development of 2nd homes, which will affect available habitat for 0-group cod,
(2) Factors that influence the number of tourists in the different categories
(3) fishing by different tourist categories, and the commercial fishers, thus affecting the fishing mortality, and
(4) Number of predators in the fjord system by category, which will affect natural mortality of cod,

(5) Stock enhancement, which will affect the recruitment (age 0) and abundance of age 1 cod each year.

In the present version of the model, affect on the cod populations by other predators (as other fish species in the ecosystem feeding on 0-group cod), food availability or habitat availability for age groups 1-10 of cod, are not included.

Model output for the ecological model component under each policy scenario will include tables with summary statistics (mean, Standard deviation, lower and upper 90% confidence limits) for number and biomass of cod by year class for all years (20). We will also present figures of 20-year trajectories of abundance and biomass of age 2+ cod for each policy scenario. Socio-economic assessments will be based on the associated economic value of the goods and services, and conflict levels related to tourism.