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9.10 Maximize portfolio utility

Maximizing risk-averse log utility for economic and existence values

One option in the search procedure for optimum fishing patterns is to search for relative fleet sizes that would maximize a utility function of the form $w_1\log(NPV)+w_2Slog(B)-w_3V$, where the wi are utility weights chosen by the user and the utility components NPV, Slog(B), and V are defined as:

i.   NPV is net present economic value of harvests, calculated as discounted sum over all fleets and times of catches times prices minus costs of fishing, ie the discounted total profit from fishing the ecosystem.
ii. Slog(B) is an existence value index for all components of the ecosystem over time. It is calculated as the discounted sum over times and biomass pools of user-entered Structure weights times logs of biomasses, scaled to per-time and per-pool by dividing the sum by the number of simulation years and number of living biomass pools.
iii. V is a variance measure for the prediction of log(NPV)+Slog(B). It is assumed to be proportional to how severely the ecosystem is disturbed away from the Ecopath base state, where disturbance is measured at each time in the simulation by the multidimensional distance of the ecosystem biomass state from the Ecopath base state. This term is negative, implying that increased uncertainty about the predictions for more severe disturbances causes a decrease in the mean of log(NPV); this term represents both aversion to management portfolio choices that have high variance in predicted returns, and the observation that the mean of the log of a random variable (NPV*PB) is approximately equal to the log of the mean of that variable minus 1/2 the variance of the variable. Large w_3 can be used to represent both high uncertainty about predictions that involve large deviations of biomass from the Ecopath base state, and strong risk aversion to policy choices that have high uncertainty.

This utility function combines several basic concepts of utility.

First, the log scaling of value components represents the notion of "diminishing returns", that adding some amount to any value measure is less important when the value measure is already large than when the value measure is small.

Second, the log scaling also represents the notion of "balance", that no value component should be ignored entirely (unless it is assigned a zero wi); the overall utility measure approaches minus infinity if either net economic performance (NPV) or if any biomass component of the ecosystem (any biomass Bi in Slog(B)) approaches zero.

Third, it represents the notion that our predictions about the future of both economic performance and biodiversity (biomasses) become progressively more uncertain for policies that policies that result in more extreme departures from the Ecopath base state about which we presume to have at least some knowledge.

In the terminology of portfolio selection theory in economics, fishing policies result in a portfolio of value components with "expected total returns on investment" equal to NPV+SB. But policies that have higher expected total returns are most often also ones that would push the ecosystem into more extreme states, and hence represent portfolio choices with higher variance in total returns. For example, maximizing the deterministic prediction of NPV in Ecosim often involves a "farming policy", in which fishing is deployed so as to severely simplify the ecosystem to maximize production of one or a few species that appear at present to be the most valuable (price, potential total catch). This may even involve deploying some fleets just to remove predators and competitors for the most valued species, just like deploying pesticides and herbicides to remove "pests" in agricultural systems. But simplifying an ecosystem in such ways can make the behaviour of the system deeply unpredictable, by creating opportunities for ecological response (population growth) by a variety of species that are rare in the "normal" ecosystem and hence are not well researched or understood in terms of their potential impacts on valued species should they become abundant. Simplifying an ecosystem is hence much like investing in high-risk, high-return stock market options; such investments may make you rich, but they may also bankrupt you. Most people are risk-averse as investors, and seek to "spread risk" by investing in "balanced portfolios" with lower expected returns on investment but much lower probabilities of severe loss.

The prediction variance measure V is not meant to represent all components of variation or uncertainty about future biomasses and fishery values. V goes to zero for policies that hold or maintain the ecosystem at the Ecopath base state Bo for every biomass, for all simulation times. It is obviously not correct to suggest that we would expect no variance in future biomasses (and hence in the harvest components of NPV as well) if such a policy were implemented. Imagine running a very large number of simulations of future biomass changes under such a policy, while varying all possible uncertain quantities such as the Ecopath base biomasses and biomass accumulation rates, productivities, Ecosim vulnerability parameters, environmental forcing inputs representing oceanographic productivity regimes, future demand and price patterns, and changing vulnerabilities to fishing due to biophysical and technological factors.

Even for the baseline policy where Ecosim predicts stable ("flat line trajectory") expected or mean biomasses over time, these simulations would likely reveal high variances and complex covariance patterns for most biomasses over time, i.e. we would see wide probability distributions of possible future biomass states for the ecosystem. We should not be arrogant enough to suggest that we can describe all the uncertainties well enough to accurately calculate the variances of such distributions. But note that much of that variance in predictions of future biomasses (and hence variance in the value components) would be due to sources of uncertainty and variability that are the same no matter what the policy choice, i.e. would cause about the same amount of variance in predictions for any future harvest policy that we might simulate. When comparing policy choices using an optimization objective function, there is no point in including extra constant terms that do not change with the policy variables (e.g. a base variance Vo in predictions that does not change with fishing rate policy and just represents uncertainty about any prediction that Ecosim might make). Hence the V distance measure is meant to represent only extra variance or uncertainty in predictions for policy scenarios that would likely drive biomasses far from the Ecopath mean

state.

Note that Ecosim does not deliberately advocate or promote any particular risk-averse portfolio approach to public investment in ecosystem harvest and existence values. Rather, it provides the logarithmic utility function option so that users who do have highly risk-averse attitudes about ecosystem values can identify policy options that would better meet their objectives. Users should always construct a series of policy scenarios with varying utility weights w_1, w_2, and w_3 on the log utility components, to see how placing different emphases on these components would alter the predicted best policy choice.