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Assessment, Prediction and Risk Analysis of Stock Development: Shrimp off West Greenland, 2002

by

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Abstract

This document presents the results of applying a new assessment framework to generate an assessment of, and management advice for, the West Greenland shrimp stock in 2002.

Introduction

The "West Greenland shrimp stock" occurs off West Greenland in NAFO Divisions 0A and 1A–1F. The stock is assessed as a single population (Anon. 2002) and managed by catch control. A trawl fishery for shrimp started in inshore areas in 1935. After 1970 an offshore fishery developed and landings increased reaching close to 100000 tons in 2002 (Hvingel, 2002).

Management advice for this stock is basically formulated by qualitative assessment of trends in various indices of stock condition in response to the catch history (Anon., 2001). Biomass estimates and length compositions from research surveys, and commercial catch rate series, constitute the main data source, but additional observations may also be considered, such as predator abundance, temperature etc. Advice is given as an annual Total Allowable Catch (TAC) or as a statement about the sustainability of the current fishing practice as consented by the assessment board. The method of deriving the advice is not explicitly stated and the uncertainty associated with the process is not quantified. Such methods lack predictive rigour, including formal statements of uncertainty, and are therefore not suited for quantitative comparisons between alternative management options.

This paper presents results of applying an alternative assessment framework (Hvingel and Kingsley, 2002) based on a biological model of shrimp stock dynamics. Ten-year projections of stock development are made for five levels of annual catch: 80, 90, 100, 110 and 120 thousand tons and associated risk of transgressing various reference points are estimated.

Estimation of parameters

Parameters relevant for the assessment and management of the stock were estimated, based on a stochastic version of a surplus-production model that included an explicit term for predation by cod (*Gadus morhua*). The model was formulated in a state-space framework and Bayesian methods were used to construct "posterior" likelihood distributions of for the parameters. A complete description of the model, input priors, estimation and validation techniques are given in Hvingel and Kingsley (this meeting).

The model synthesized information from input priors (Hvingel 2002b) and the following data: a 14-year series of a survey biomass indices of shrimp larger than 17 mm cpl. (Kanneworff and Wieland, 2002); a 26-year series of combined CPUE indices (Hvingel, 2002a); a 47-year series of a cod biomass estimates (Hvingel and Kingsley, 2002); and a very short series (4 years) of estimates of the shrimp biomass consumed by cod (Hvingel and Kingsley, 2002) (see Fig. 1).

Assessment results

The shrimp stock has been exposed since the 1950s to two different environmental regimes: one with high and the other with low cod abundance. The analysis indicates that the stock dynamics have responded to the difference. The trajectory of the median estimate of ‘biomass -ratio’ (B_t/B_{MSY}) plotted against ‘mortality -ratio’ (Z_t/Z_{MSY}) (Fig. 3A) starts in 1956 at half the optimum biomass ratio and at a mortality-ratio well above 1. The stock maintains itself in this region during the years when cod were abundant. When the cod stock declined in the late 1960’s, and predation pressure was lifted (Fig. 2), shrimp stock biomass increases and eventually began cycling in the left upper corner of the graph during the current regime of low cod abundance (Fig. 3).

During the period of the developing offshore fishery (since the early 1970s) the estimated median biomass-ratio ranged from about 0.96 to 1.67 (Fig. 3B) and the probability that it had been below the optimum level was small for most years (Fig. 4). I.e. under the hypotheses of the assessment model it seemed likely that the stock had been at or above its MSY level throughout the modern fishery. A steep decline in CPUE was noted in the late 1980s and early 1990s following a short-lived resurgence of the cod stock and the median estimate of biomass-ratio dipped just below the optimum in 1990-1991 (Fig. 3). The stock has increased since then and reached its highest level ever in 2002 with a median estimate of biomass-ratio of 1.67, corresponding to about 82% of estimated median carrying capacity.

The mortality ratio (which includes mortality by fishing and predation by cod) has been below 1 for most of the time since 1970, except for the period of high cod predation in the late 1980s (Fig. 3B and Fig. 4).

The median estimate of the maximum annual production surplus, available equally to the fishery the cod (*MSY*) was estimated to 101.4 thousand tons (fig. 5). The risk function relating the probability of exceeding MSY to the combined removal by fishery and cod predation is given as the integral of this distribution (Fig. 5).

Ten-year projections of stock development were made for five levels of annual catch: 80, 90, 100, 110 and 120 thousand tons (Fig. 6). The cod stock is currently at a very low level and it is considered unlikely that it will reestablish itself in the offshore areas and grow to high levels within the next 5-10 years. The predictions were therefore made under the assumption that the cod stock will remain at the current level.

For the 80- and 90-thousand-ton annual catches, the stock is likely to remain above B_{MSY} and the combined relative fishing and cod predation mortality, Z_t/Z_{MSY}, has a high probability of being below 1 within the ten-year period of projection (Fig. 7).

A catch option of 100 thousand tons pr year will just about meet the estimated median *MSY* and is not likely to drive the stock below B_{MSY} in the short to medium term, i.e. the risk is less than 10% within the first five years and just above 25% after year 10. However, this level of exploitation might not be sustainable in the longer term, as risk of exceeding B_{MSY} continues to increase through time.

Fishing110000 tons/yr bears a 75% risk of being above *MSY* (Fig. 5), thus this catch level is not likely to be sustainable in the longer term. Owing to the current high stock level the risk of transgressing B_{MSY} is still less than 20% after five years at this catch level, although after 10 years it is close to 50%.

A catch of 120 thousand tons/yr is associated with an 85% risk of exceeding *MSY* (Fig. 5) and the stock biomass will rapidly decline to below B_{MSY} (Fig. 6). After just two years there is a 50% risk of exceeding Z_{MSY} (Fig.7).

Precautionary approach

So-called "precautionary" reference points of stock or fishery status are defined as guidelines for management to comply with the concept of the "precautionary approach" (FAO, 1996). NAFO define a limit reference point for mortality, F_{lim}, as equal to F_{MSY}. If that is exceed the stock is "overfished". B_{lim} is the spawning stock biomass below which unknown or "low" recruitment is expected (Anon., 1998). Buffer reference points, B_{buf} and F_{buf}, are also defined to provide a safety margin that will ensure that there is little probability that the limits reference points are crossed. The distance of the buffer reference point from the limit reference point should reflect uncertainty i.e. distance should be greater the greater the uncertainty in defining the limits. In this stochastic state-space Bayesian approach to deriving fisheries advice there is little need for the buffer reference points as the risk of exceeding the limit reference is directly calculated and uncertainty associated with the entire process is taken into account.

The limit reference point for mortality in the current assessment framework is Z_{MSY}, i.e. Z-ratio=1. It is hard to define an area of "low recruitment" without knowing what "low" means; the limit reference point for the biomass-ratio therefore remains unclear. However an area of "unknown" recruitment could be defined as the one below the estimated level of the 1950s and 1960s (Fig. 3). The limit biomass-ratio could then be defined as a normal distribution with a mean of 0.4 and a standard deviation of 0.1 in the interval 0.4 to K—but then the appropriateness of the term reference "point" starts to fade. However using a probability distribution instead of a point estimate accommodates the uncertainty associated with the determination of where the border of the dangerous area actually lies.

For all catch options investigated the risk of exceeding this biomass limit reference is less than 1%. The risk of transgressing the limit mortality is explained in the previous section.

References

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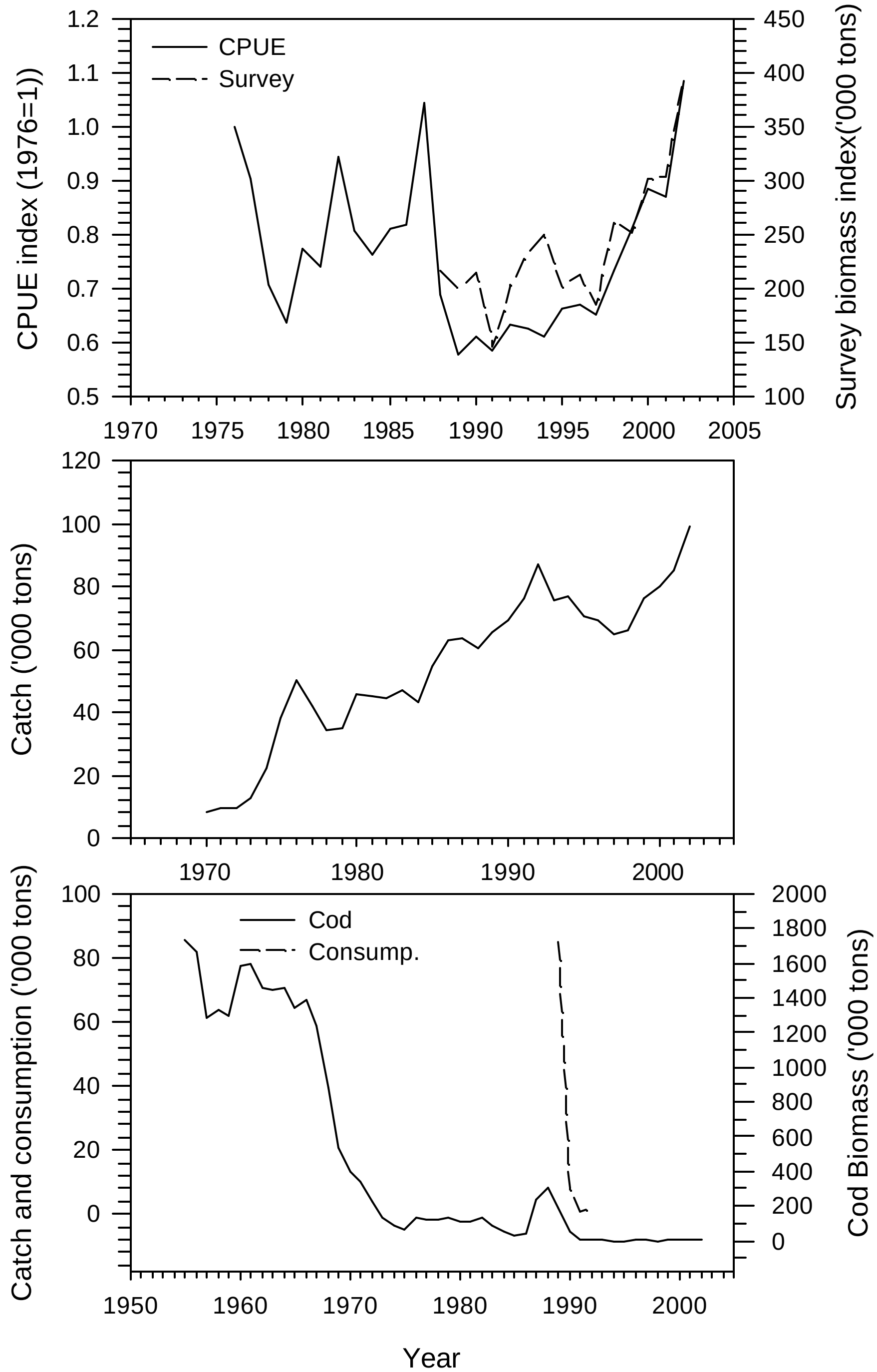

Figure 1. Data series providing information for the assessment model. Left panel: Shrimp biomass indices based on 1. standardised commercial catch rates (CPUE-index) and 2. research survey data. Right panel: Catch by the fis hery, absolute biomass estimates of cod and a four year series of consumption estimates based on stomach sampling.

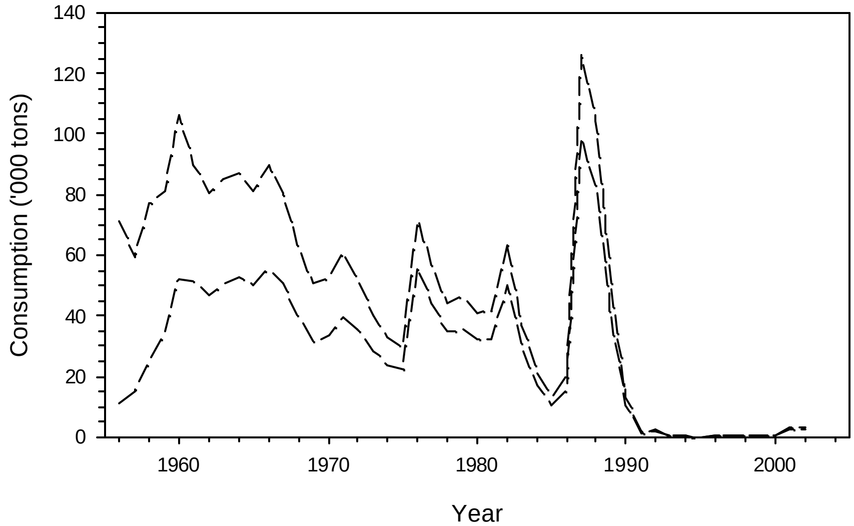

Figure. 2. Estimated consumption of shrimp by cod. Dashed lines indicate 25th and 75th percentiles respectively.

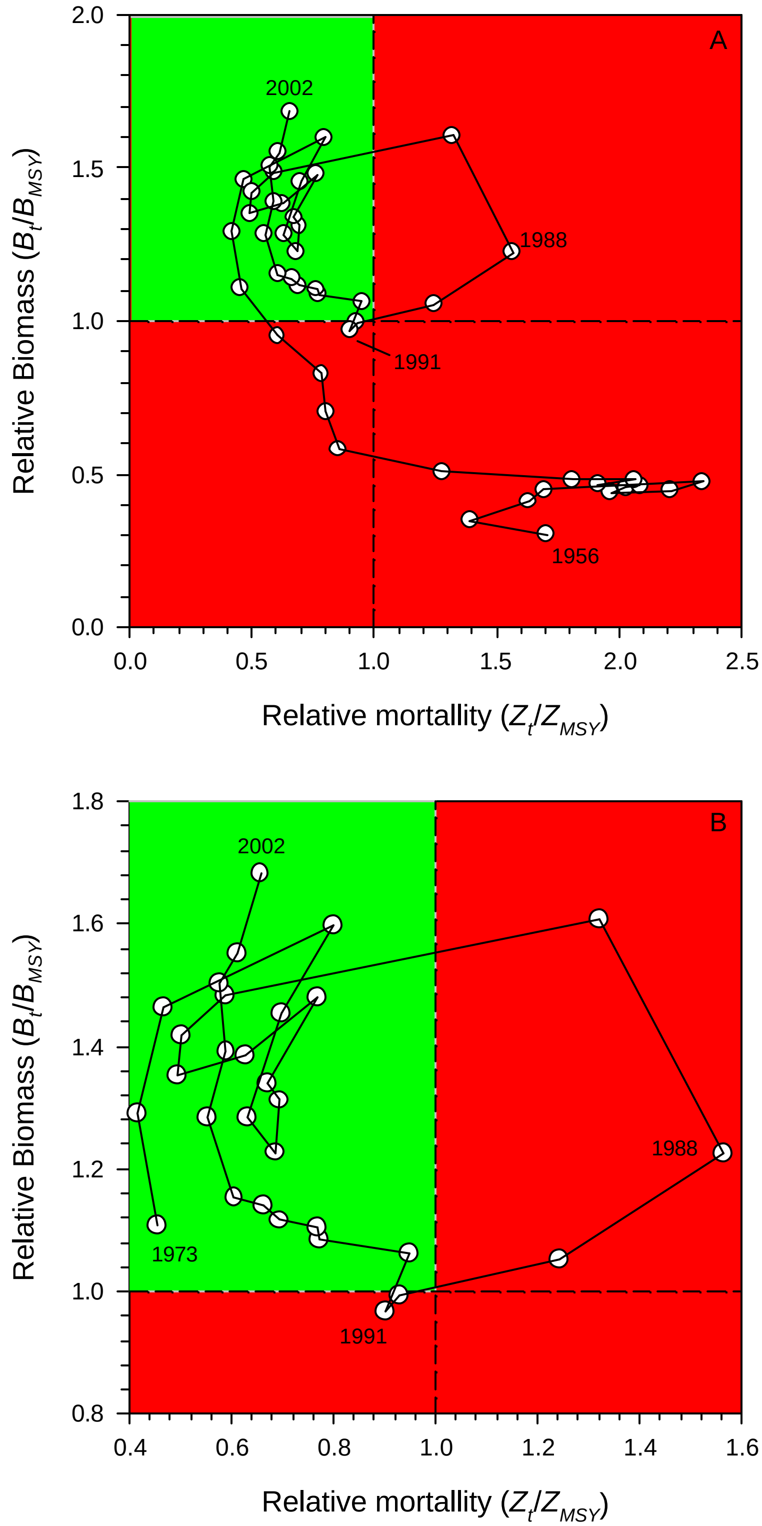

Figure 3. Estimated development of annual median biomass (B/B_{MSY}) and mortality (Z/Z_{MSY}) 1956-2002 (panel A) and 1973-2002 (panel B)

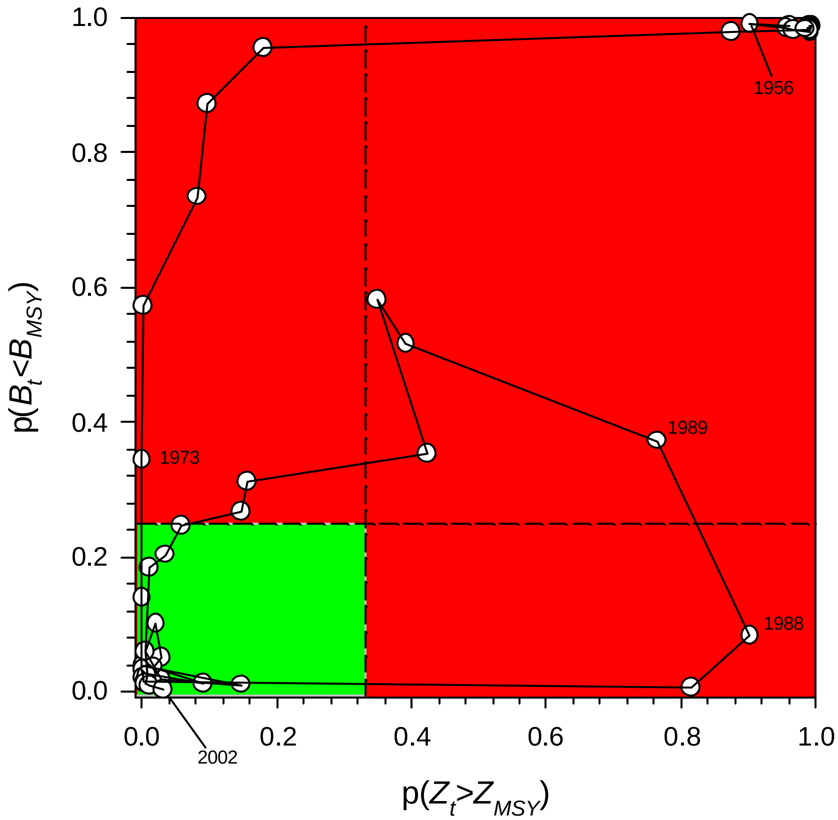

Figure 4. Risk of annual biomass being below and mortality being above the MSY-level 1956-2002

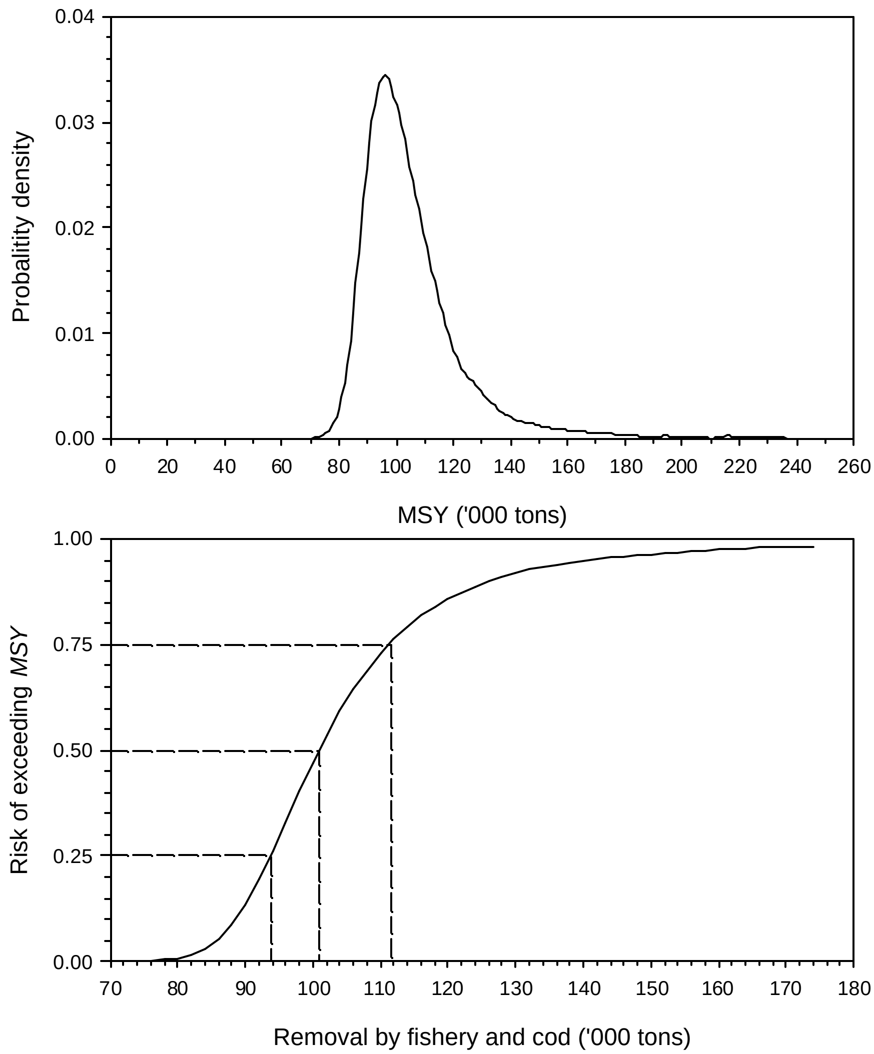

Figure 5. Posterior probability distribution of Maximum Sustainable Yield (MSY) (upper panel) and the cumulative probability of exceeding MSY i.e. risk of long-term non-sustainability under the assumption that the cod stock remains at the current low level.

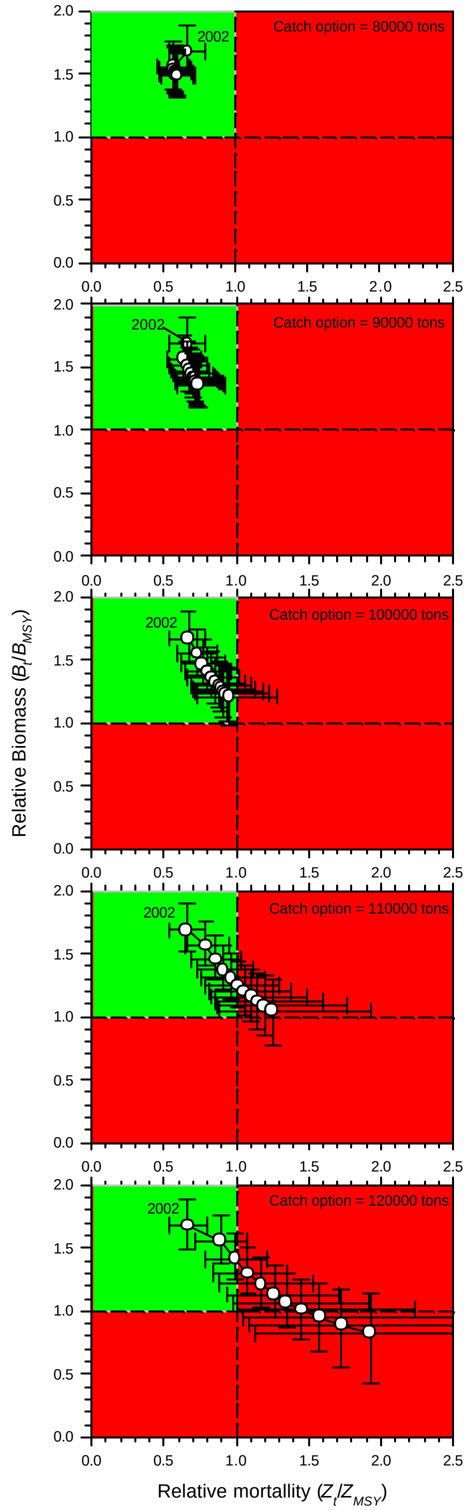

Figure 6. Predictions of stock development for the period 2002-2012 quantified in a biomass (B/B_{MSY})-mortality ($Z(Z_{MSY}$) continuum. Dynamics at 80, 90, 100, 110 and 120 thousand tons of fixed annual catch levels are displayed by the medians and error-bars at the 25th and 75th percentiles. Level of biomass and mortality at *MSY* is indicated by the dotted lines.

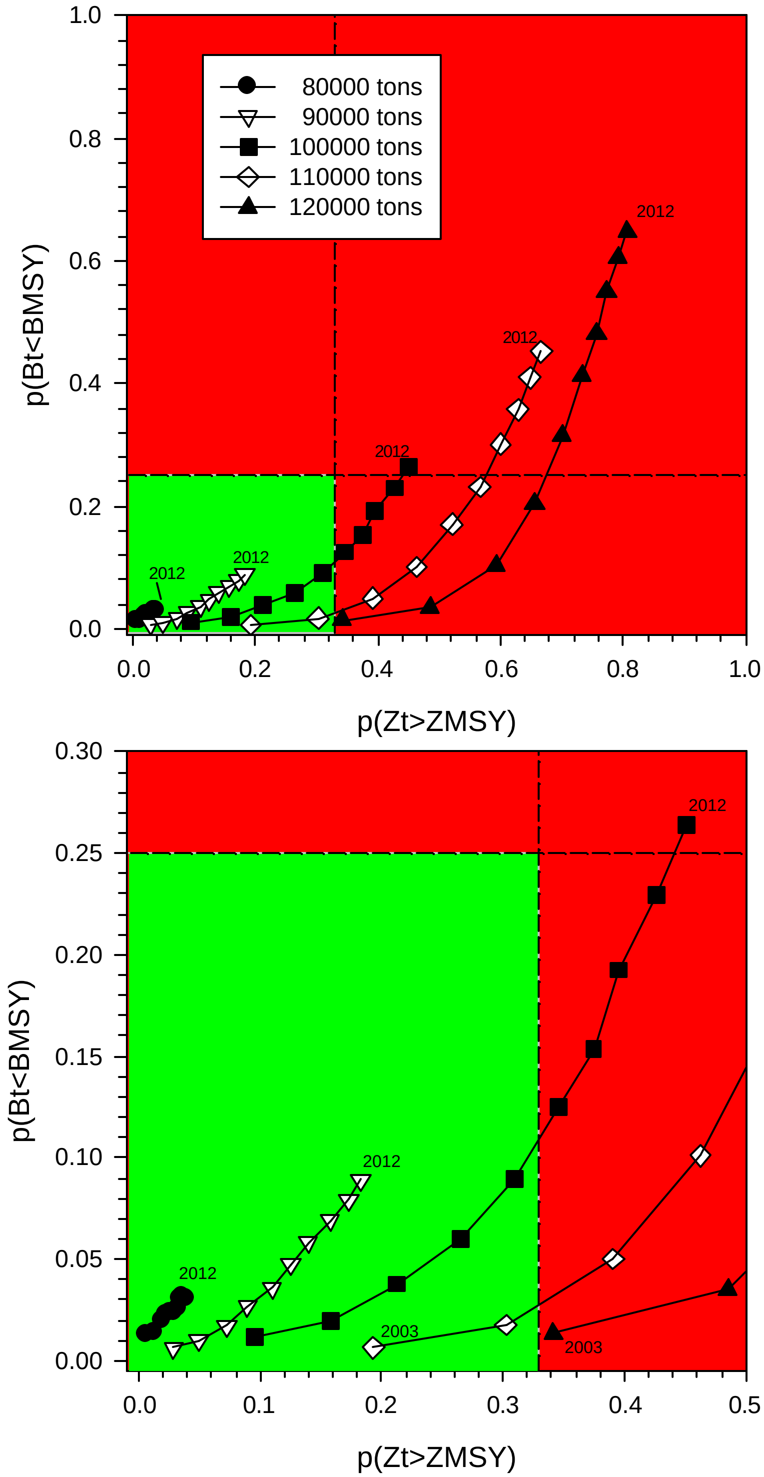

Figure 7. Risk of exceeding Z_{MSY} and of driving the stock below B_{MSY} by maintaining optional annual catch levels of 80, 90, 100, 110, and 120 thousand tons during the period 2003-2012. Arbitrary areas of “acceptable”/”unacceptable” risk is indicated by the green and red background colors respectively. Lower panel is a magnification of upper panel.