Joint Norwegian-Russian Fisheries Commission request to establish a management plan for northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES subareas 1 and 2).

Advice summary

A management plan based on a harvest control rule (HCR) was evaluated for northern shrimp (*Pandalus borealis*) in the Barents Sea (ICES subareas 1 and 2). A management strategy evaluation (MSE) was conducted to assess the performance of six different HCRs. Two HCRs that allow fishing below B_{lim} were found to be not precautionary due to their elevated mid-term risk, whereas four of the evaluated HCRs without fishing below B_{lim} were found to be precautionary under current conditions and an alternative scenario of decreased productivity. The two precautionary HCRs with $F_{target} = F_{MSY}$ met all the criteria for the management plan while achieving the highest catches, with only very minor performance differences between them. The more conservative HCRs with F_{target} at 80% and 90% of F_{MSY} resulted in lower median catches, but also lower risk, higher stock sizes, and lower interannual catch variability. These contrasts in performance were more pronounced for the HCRs with F_{target} at 80%. Because all four HCRs were precautionary and met all performance criteria, they are considered appropriate for the management of the stock. Minor differences in risk, catch and variability result in trade-offs and will require a selection based on management and stakeholder preferences.

Request

The Joint Norwegian-Russian Fisheries Commission (JNRFC) requested in 2023 advice on the appropriate management strategy for northern shrimp in the Barents Sea, to be presented in 2024. The Institute of Marine Research (IMR) developed a MSE framework to investigate possible HCRs for the shrimp stock. At two meetings with managers and stakeholders (Norwegian Directorate of Fisheries, Fiskarlaget, Fiskebåt, Sjømat Norge and Norges Råfisklag) in 2023, and the Russian-Norwegian March meeting between IMR and VNIRO, an agreement was reached on the MSE framework, the evaluated HCRs, and the main performance criteria in terms of risk and catch.

Elaboration on the advice

Evaluations of HCRs were conducted in the selected MSE framework whereby six HCRs were defined based on alternative combinations of three reference points: the fishing mortality gives the maximum sustainable yield, F_{MSY}, the minimum biomass $B_{trigger}$ that allows the application of F_{target}, and the limit biomass B_{lim} (Figure 1). The fishing mortality rate, *F*, is set to F_{target} (corresponding to F_{MSY} or a fraction thereof, depending on the HCR) when biomass is above Btrigger, $B_{trigger}$ and B_{lim} were defined relative to the biomass that produces maximum sustainable yield as $B_{trigger} = 0.5\ B_{MSY}$ and $B_{lim} = 0.3\ B_{MSY}$. All HCRs include a catch constraint that limits changes in total allowable catch (TAC) from year to year to +20%/-20%.

- **HCR A**: *F* is set equal to F_{MSY} when biomass is above $B_{trigger}$ and reduced linearly from F_{MSY} at $B_{trigger}$ to 0 at biomass equal to B_{lim}.
- **HCR B**: Like HCR A, but *F* is reduced linearly from F_{MSY} at $B_{trigger}$ to 50% F~MSY at B_{lim}, and then directly to 0 when below B_{lim}.
- **HCR C**: Like HCR A, but *F* is reduced linearly from F_{MSY} at $B_{trigger}$ to 0 at biomass equal to 0.
- **HCR D80 and D90**: Like HCR A, but F_{target} is set to a) 80% of F_{MSY} (D80) or b) 90% of F_{MSY} (D90).
- **HCR E**: Like HCR B, but where *F* remains at 50% of F_{MSY} when bioamss is below B_{lim}.

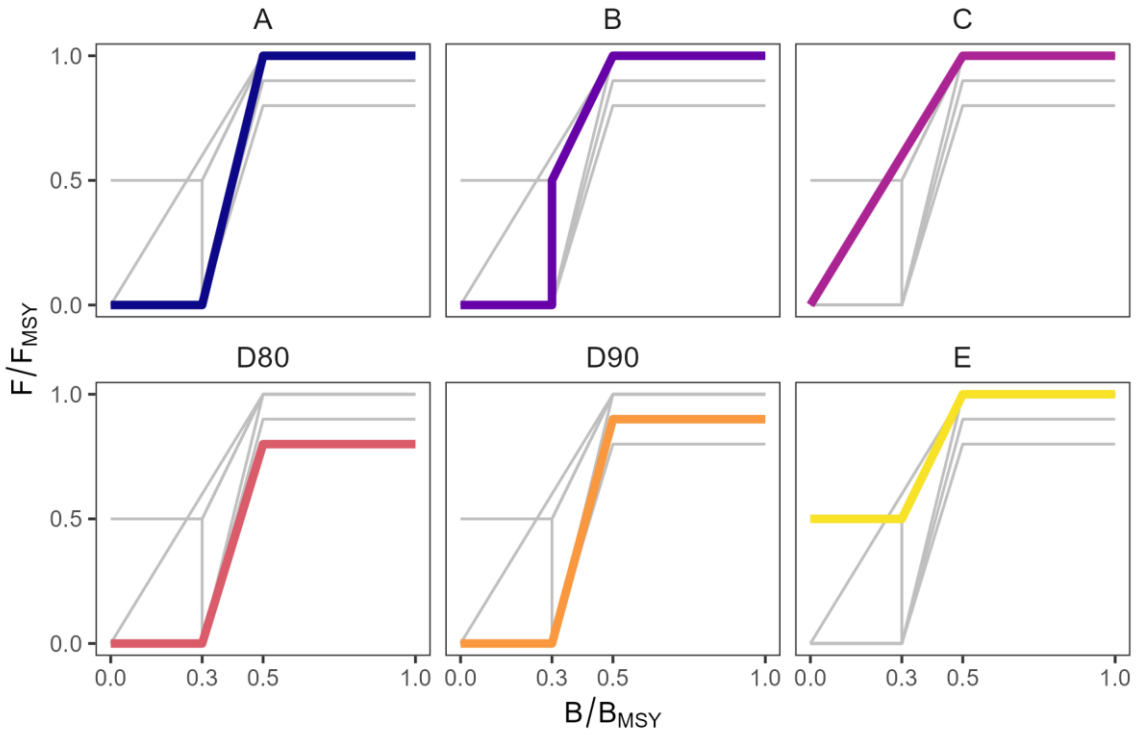

Figure 1: Proposed HCRs for Barents Sea shrimp. Each panel shows one candidate HCR (thick colored line) overlaid over the other HCRs (thinner gray lines). The HCRs are defined in respect to the reference points B~trigger (0.5 B/B_{MSY}), B_{lim} (0.3 B/B_{MSY}) and at an F_{target} at 1.0, 0.9 or 0.8 F_{MSY}, respectively.

All HCRs were tested against a scenario of current conditions and an alternative scenario where the underlying productivity of the stock is reduced by reducing the carrying capacity of the ecosystem for this stock by 50%.

The consequences of the HCRs were assessed in a short (5 years), medium (10 years), and long-term (40 years) perspective, with a focus on the following performance metrics: 1. probability of biomass falling below B_{lim}, 2. probability of biomass falling below $B_{trigger}$, 3. biomass relative to B_{MSY}, 4. yield relative to MSY, 5. *F* relative to F_{MSY}, 6. mean relative change in TAC from year to year.

To communicate MSE results, the HCR performance was evaluated based on the following three main criteria:

1. The probability of SSB falling below B_{lim} in any single year should not exceed 5%.
2. High long-term yield should be achieved relative to the median long-term yield attained by fishing at the deterministic F_{MSY}.
3. Median biomass should be above B_{MSY}.

Of these, managers/stakeholders only explicitly defined criterion 1. (precautionary criterion) for determining a final set of acceptable HCRs. Criteria 2. and 3. were devised together with further performance metrics to differentiate HCR performance within this final set and are consistent with the general objectives of maintaining relatively high catches and biomass. It is important to note that in contrast to MSEs for other fish stocks no specific performance criteria for long-term yield was set, foremost because the current catch is at less than 50% of the estimated catch at deterministic F_{MSY} (IMR-PINRO 2023). Catch levels approaching MSY imply therefore a substantial increase in catch compared to historic catches, adding uncertainty to the MSE.

Basis of the advice

Background

An updated stock assessment method was adopted for northern shrimp in the Barents Sea (ICES subareas 1 and 2) at the 2022 benchmark meeting (ICES 2022). In both 2021 and 2022, the Joint Norwegian-Russian Fisheries Commission discussed a management plan for the stock and requested in 2023 advice on the appropriate management strategy until the commission meeting in 2024.

Methods

The management strategy evaluated was based on the current ICES assessment for Northern shrimp and its stock assessment model SPiCT (Hvingel and Zimmermann 2024). SPiCT is a continuous-time surplus production model that fits time series of catches and indices of biomass (survey or commercial CPUE) to estimate the parameters of a generalized state-space surplus production model (Pedersen and Berg 2017).

The operating model was based on the assessment model, using a surplus production model with parameter and uncertainty estimates from the stock assessment. The estimation model corresponded the assessment model (SPiCT) used currently to conduct annual assessments with the same model configurations and data inputs. The data inputs were updated in every projection year with the simulated survey-based and catch-based indices, and catch. The same settings in the assessment were used, to the closest extent possible, for running the short-term forecast and were based on built-in functions within the spict R package. The simulations were conducted with the 'mse' package available in FLR (https://github.com/flr/mse). Methods and results are described in detail in IMR-PINRO 2024.

Results and conclusions

All six evaluated HCRs performed similarly, but showed some key differences (Figure 2, Table 1). The two HCRs which allow fishing below B_{lim}, HCRs C and E, were least precautionary and were discarded due to more than 5% probability of falling below B_{lim} in the medium-term. HCRs A and B met all the acceptance criteria with a balanced performance in terms of risk, stock size and catch. Although nearly identical, HCR B showed a very minor tendency towards higher risk, but also higher catches and less variability compared to HCR A. HCRs D80 and D90 resulted in the lowest risk, higher stock levels and - partially - lower interannual catch variability, but this came at the expense of lower median catches. These characteristics were stronger for D80, with long-term median catches that fell below 80% of MSY. The four precautionary HCRs A, B, D80 and D90 should be further considered based on their risk level. The specific performance of these four HCRs should be evaluated based on their trade-off between risk and catches, with D90 and especially D80 being more precautionary than A and B at the expense of median catch. HCRs A, B, D80 and D90 remained precautionary and showed similar performance trade-offs in a low-productivity scenario where carrying capacity was reduced during the projection period.

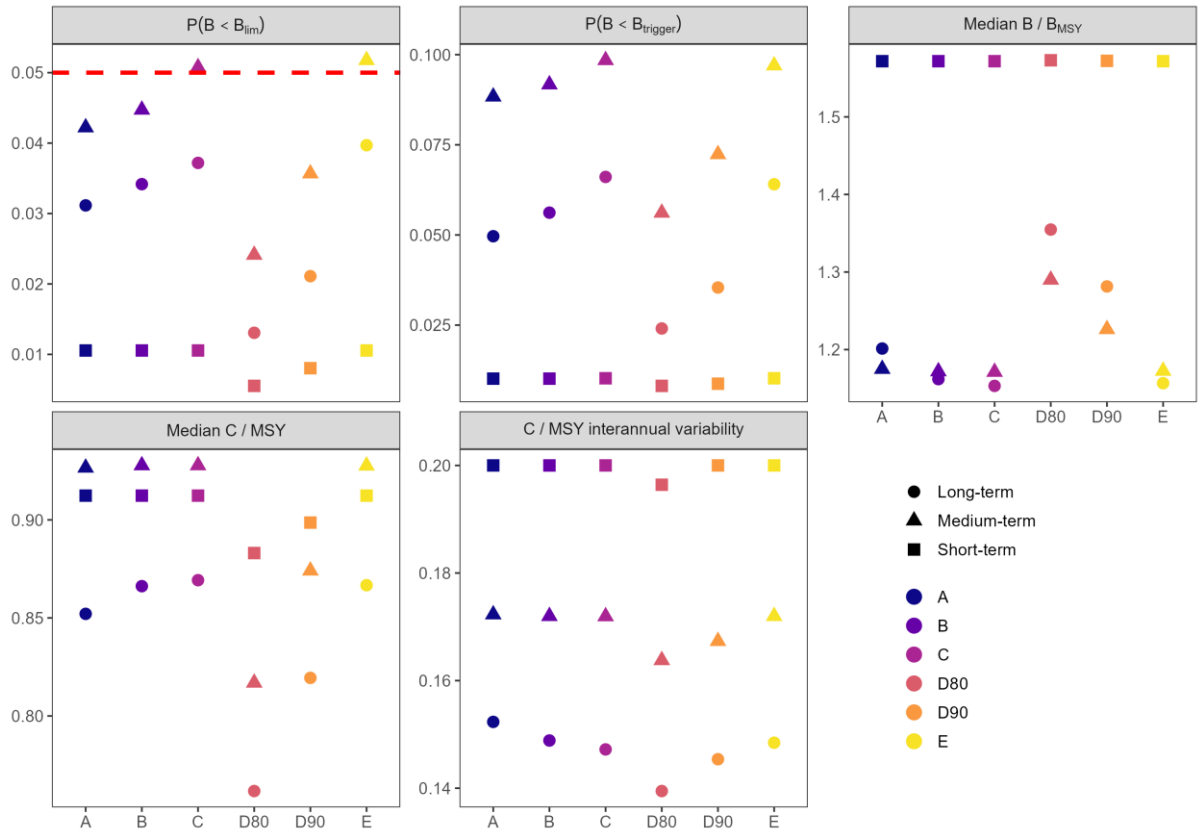

Figure 2: Performance metrics for each HCR in the short-term (2025-2029), medium-term (2030-2039), and long-term (2040-2064) under the default operating model. Shown are the median values for the risk of falling below B_{lim} ($P(B<B_{lim})$), the risk of falling below $B_{trigger}$ ($P(B<B_{trigger})$), biomass (B) relative to B_{MSY}, catch (C) relative to MSY, and the interannaual catch variability. Risks are probabilities, biomass, catch and variability are relative values. For values see also Table 1.

Table 1: Performance metrics table of median values for each HCR in the short-term (2025-2029), medium-term (2030-2039), and long-term (2040-2064) under the default operating model. Shown are the median values for the risks, biomass, catch, and the interannaual catch variability. Risks are percentages, biomass, catch and variability are relative values.

HCR	Period	P(B<B_{lim}) (%)	P(B<$B_{trigger}$) (%)	Median B/B_{MSY}	Median C/MSY	C/MSY interannual variability
A	Short-term	1.06	1.02	1.57	0.91	0.20
	Medium-term	4.22	8.83	1.17	0.93	0.17
	Long-term	3.12	4.96	1.20	0.85	0.15
B	Short-term	1.06	1.02	1.57	0.91	0.20
	Medium-term	4.47	9.17	1.17	0.93	0.17
	Long-term	3.42	5.62	1.16	0.87	0.15
C	Short-term	1.06	1.03	1.57	0.91	0.20
	Medium-term	5.08	9.84	1.17	0.93	0.17
	Long-term	3.72	6.61	1.15	0.87	0.15

HCR	Period	P(B<B_{lim}) (%)	P(B<$B_{trigger}$) (%)	Median B/B_{MSY}	Median C/MSY	C/MSY interannual variability
D90	Short-term	0.80	0.87	1.57	0.90	0.20
	Medium-term	3.57	7.24	1.23	0.87	0.17
	Long-term	2.11	3.54	1.28	0.82	0.15
D80	Short-term	0.55	0.81	1.57	0.88	0.20
	Medium-term	2.41	5.61	1.29	0.82	0.16
	Long-term	1.31	2.41	1.35	0.76	0.14
E	Short-term	1.06	1.03	1.57	0.91	0.20
	Medium-term	5.18	9.70	1.17	0.93	0.17
	Long-term	3.97	6.41	1.16	0.87	0.15

References

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