Peer Review Summary: Shetland Shellfish Stock Assessment Report for the SSMO

The Shetland Shellfish stock assessment report provides a comprehensive description of data sources, analysis methods, and stock assessment techniques used to inform the Shetland Shellfish Management Organisation (SSMO) on the sustainable exploitation of shellfish in Shetland's coastal waters. The fishery is predominantly composed of vessels under 10 metres in length, reflecting the small-scale nature of the fleet.

Data Sources

- The primary data source is fishery-dependent logbook data from all vessels, detailing landings and effort by location. This core data is supplemented with biological sampling conducted at ports and at sea.
- These data sources provide a strong foundation for stock assessment and management advice. The value of this dataset will grow over time, enabling the use of additional and potentially more robust assessment methods as the time series expands.

Generalised Additive Mixed Models (GAMM) for LPUE Time Series

Strengths:

- GAMs are appropriate for analysing catch and effort data and can generate indicators of abundance trends.

Limitations:

- The current GAM does not construct a formal abundance index.

Recommendations:

- Provide a detailed description of the GAM, including family distributions, treatment of zeros, spline types, and rug plots to illustrate data distributions.
- Explore recent methodological advancements in modelling spatio-temporal LPUE data could reduce bias and improve management advice.

Management Responses

The management strategy relies on pre-set measures triggered by fleet performance trends (e.g., LPUE).

Recommendations:

- Include an annex detailing prior management decisions based on scientific advice, such as licence removals, effort limitations, area-based conservation measures, and size limit adjustments.

- Document consultation processes with industry stakeholders and decision-making frameworks.

Reference Points

Current reference points are pragmatic and based on historical LPUE data, but they are not biological reference points.

Recommendations:

- Provide clearer reasoning behind reference point selection (e.g., why 80% of the 2006-2010 mean is used).
- Include an annex describing harvest control rules and their basis (e.g., short-term versus long-term trends, expert consensus).

Management Advice

- The report currently emphasises yield-based advice but would benefit from incorporating precautionary measures, such as Spawner Per Recruit (SPR) methods, to protect spawning stock.

Brown Crab (*Cancer pagurus*)

Length Cohort Analysis (LCA)

Strengths and Limitations:

- The sensitivity of LCA to growth parameters is acknowledged, though growth data for crustaceans remain limited and challenging to model.
- Equilibrium assumptions are frequently violated, which questions the validity of the LCA outputs.
- The method's reliance on size distribution data, particularly at larger sizes, often results in flat assessments that are unresponsive to changes in fishing effort.
- Mean length is confounded by recruitment and fishing mortality, making interpretation challenging.

Recommendations:

- Provide further discussion and presentation of growth data.
- Consider grouping annual data as the time series increases to address equilibrium assumption violations.
- Clarify the relationship between fishing effort and mortality rates (F).
- Clarify whether the LPUE maps (e.g., Fig 3.12) represent observed or modelled data.

Short-term recommendations:

1. <u>Rescale per-recruit</u> plots to show % virgin levels for spawning potential and absolute values for relative yield. This would improve interpretation of stock status relative to proxy reference points.
2. <u>Sum absolute yield per recruit values</u> across males and females to assess status in relation to Fmax as an FMSY proxy.
3. <u>Provide full outputs of LCA</u>, including fishing mortality at size for both sexes, to compare exploitation pressure and biomass patterns.
4. <u>Justify biological parameters</u> used in the assessment, including growth, natural mortality (M), and maturity values. Include a stock annex detailing these parameters and their supporting evidence.

Medium-term:

5. <u>Rationalise raw LPUE trends with GAMM outputs</u> to produce a standardised LPUE index. Use logbook data from vessels targeting brown crab for better abundance signals.
6. Treat <u>year as a factor variable in GAMM</u> analyses to isolate relative abundance signals and avoid smoothing artefacts.

7. Incorporate discarded catch and associated mortality into LCA and per-recruit analyses to explore the impacts of selectivity changes.

8. Define biological reference points on per-recruit plots, using metrics such as $F_{35\%\ virgin\ ssb/r}$ as a target and $F_{15\%\ virgin\ ssb/r}$ as a limit.

Long-term:

9. Transition from LCA to dynamic population models, utilising the 20-year logbook and catch data time series for probabilistic stock assessments. Investigate alternative length-based indicators, such as those discussed within ICES data-limited methodologies and the MSFD Descriptor 3 framework.

10. Revisit the pre-recruit index and explore recruitment indicators from alternative sources (e.g., bycatch in other surveys).

11. Geographical Scale of Stock. Investigate the relationship between the SSMO fishery and the broader brown crab stock to align assessments with biological stock structure.

Scallop (*Pecten maximus*)

Scallops are assessed using Virtual Population Analysis (VPA), which traces age classes through the fishery.

Recommendations

- Provide detailed descriptions of the VPA model, including spatial differences in age structure and outputs such as SSB, F, and recruitment over time.
- Compare the current VPA approach with methodologies used by Marine Scotland Science.
- Emphasise spatial management strategies to optimise yields and monitor settlement events.

Key Considerations

- Regional and Spatial Factors: The sedentary nature of scallops makes spatial dynamics critical. Regional LPUE values inform harvest control rules, but the specifics of their application need clarification. The potential for hyperstability, where targeted fishing may obscure declines in abundance, should be assessed.
- Dynamic Analytical Models: The tuned VPA applied to catch-at-age data requires greater transparency, particularly regarding biological parameters (e.g., natural mortality, maturity) and input data. Spatial complexities may also bias trends.
- Potential Discrepancies: Differences between LPUE trends and VPA outputs highlight the need to reconcile these analytical approaches. Improved understanding of spatial structure and population dynamics through age-sampling could resolve such discrepancies.
- Management Implications: Consistent integration of VPA and traffic light systems is essential. Spatially explicit management approaches could optimise yields, particularly in areas with variable recruitment.

Short-term recommendations:

1. LPUE Calculation Consistency: Use a single approach to calculate LPUE for clarity, potentially excluding dredge width if standard gear is prevalent.
2. Temporal Spatial Patterns: Include time-series maps of LPUE, landings, and effort to evaluate spatial stability and patch dynamics over time.
3. Regional Patterns in LPUE Models: Incorporate region-by-year effects into the GAMM to improve the representation of regional dynamics in stock status assessments.
4. Retrospective Analyses: Perform retrospective analyses to identify biases in VPA estimates for recent years.

Medium-term recommendations:

5. Standardisation of LPUE Indices: Align raw LPUE trends with GAMM outputs to establish unbiased indices of abundance, using factors for the year effects in GAMMs.
6. Yield and Spawning Potential Analysis: Develop age-based per-recruit analyses to better inform status determinations.

Long-term

7. Internal Consistency: Reconcile stock assessment outputs from VPA and traffic light systems for unified management advice, especially regarding spawning stock biomass (SSB) and LPUE.
8. Statistical Models: Explore statistical stock assessment models, such as Stock Synthesis, to better incorporate spatial structure and quantify uncertainty.