MSE Case Studies & Literature

List of Papers

Developing and evaluating a management strategy evaluation framework for the Gulf of Maine cod (Gadus morhua)

Sun et al (2019)
https://doi.org/10.1016/j.ecolmodel.2019.04.007
Management strategy evaluation (MSE) is an effective tool to evaluate the performance of harvest control rules (HCRs) and alternative management strategies. However, a comprehensive MSE framework advising management is still absent for the severely depleted Gulf of Maine (GoM) cod (Gadus morhua). In the present study, we developed a conceptual MSE framework and conditioned on this stock utilizing stock-specific parameterization. We highlighted the simulation of a few key processes with semi-independent sub-models and accounted for uncertainties from multiple sources. The simulated population dynamics was calibrated and validated against the historical trend in hindcasting. Forecasting simulations were also conducted and validated to examine the effectiveness in the context of uncertainty. Hindcasting results suggested that the calibrated MSE framework could capture the stock dynamics assuming different recruitment dynamics indicated by residuals lower than 5%. Forecasting stochastic runs demonstrated a minor disparity between management effects of fishing-mortality-based and catch-based HCRs when the segregated stock recruitment relationship was adopted with a difference in simulated spawning stock biomass lower than 10%. Additionally, the results were comparable to assessment and projections made in the stock assessment, indicating the robustness of the framework. The framework can potentially help disentangle complex issues related to the mixed fishery, decision-making, and performance evaluation of a monitoring system.

Management strategies for spasmodic stocks: a Canadian Atlantic redfish fishery case study

Licandeo et al (2019)
https://doi.org/10.1139/cjfas-2019-0210
There exist few recommendations for managing stocks with spasmodic recruitment, despite such stocks being not uncommon. Management procedures (MPs), developed for two species of redfish (Sebastes mentella and Sebastes fasciatus) in eastern Canada, are recommended for setting catch limits during periods of high and low abundance. A well-designed fishery-independent trawl survey is essential to provide advance warning of strong recruitment events and project future recruitment. Under an "inventory management" strategy, a more appropriate aim in spasmodic stocks may be to maximize the number of years with "good catches," instead of maximizing total catches, as is traditionally considered in management strategy evaluation (MSE). Following a spasmodic recruitment event, an empirical harvest control rule based on larger fish delays the harvest of large cohorts by a few years, targets more commercially valuable fish sizes, and reduces the risk of growth overfishing. Capped MPs produced longer periods of large catches than uncapped MPs. MPs allowed for low harvests during periods of low abundance, thus avoiding unnecessary hardship in the industry. MPs evaluated here could be good candidates for other stocks with similar or less extreme recruitment variability.

The eastern Baltic cod fishery: a fleet-based management strategy evaluation framework to assess the cod recovery plan of 2008

Bastardie et al (2010)
https://doi.org/10.1093/icesjms/fsp228

A management strategy evaluation framework was developed for the international Baltic cod fishery to evaluate the performance and robustness of the 2008 multi-annual management plan for the eastern stock. The spatially explicit management evaluation covered two cod recruitment regimes and various fleet adaptation scenarios. The tested management options included total allowable catch control, direct effort control, and closed areas and seasons. The modelled fleet responded to management by misreporting, improving catching power, adapting capacity, and reallocating fishing effort. The model was calibrated with spatially and temporally disaggregated landings and effort data from five countries covering 83% of the total cod catches. The simulations revealed that the management plan is robust and likely to rebuild the stock in the medium term even under low recruitment. Direct effort reduction limited underreporting of catches, but the overall effect was impaired by the increased catching power or spatio-temporal effort reallocation. Closures had a positive effect, protecting part of the population from being caught, but the effect was impaired if there was seasonal effort reallocation. Over the entire 15-year simulation period, all fleets could realize variable but positive profits under all scenarios tested, owing to stock recovery.

A bio-economic management strategy evaluation for a multi-species, multi-fleet fishery facing a world of uncertainty

Ives et al (2013)

https://doi.org/10.1016/j.ecolmodel.2013.01.022

A bio-economic analysis was conducted for two fisheries using a multi-species size-based meta-population model built using the BIOMAS modelling system. The model was built to represent the prawn fisheries of northern New South Wales, Australia and calibrated against 26 years of catch and effort data from this region. A number of alternative management strategies, including the use of more size selective gear and a cap on total effort, were evaluated for their impact on the sustainability of the fish stocks and the profitability of the fleets as well as their robustness to future biological, climatic and economic uncertainties. Although the differences in management strategies were blurred by the uncertainty incorporated into the model there were still some very interesting high-level insights to be gained from the analysis. The modelled prawn species appear to be much more robust to changes in management strategies and product prices than the fleet profits, suggesting the stocks are less vulnerability to such uncertainties than the fleets that harvest them. We also found larger differences in profitability from changes in product prices than from changes in management strategies, indicating that strategies to protect product prices may be of more importance to the profitability of the fisheries than changes to fishing gear or effort levels. Such results highlight the complexity of multi-species, multi-fleet fisheries and the importance of including all relevant species and fisheries in any management strategy evaluations. This complexity can however sometimes mask simple economic truths, such as the need for strategies to maintain the market price of locally caught seafood products under the increasing pressures of international competition.

Use of management strategy evaluation to understand the value of citizen science in managing an iconic California recreational fishery

Bellquist et al (2022)

https://doi.org/10.1016/j.ecss.2022.108112

Data-limited fisheries present significant challenges to fisheries management around the world. Landings data represent the simplest and most common source of fishery information, but length data of harvested species can offer particularly useful insight into the strength of fishing pressure and the

status of stocks. However, unbiased length data can be difficult and costly to collect, which highlights a need for understanding the utility of non-conventional data collection programs, such as those generated by community members and citizen science programs to improve management decision-making. In this study, our objective was to understand the value of citizen science for management using the iconic California recreational red abalone (Haliotis rufescens) dive fishery. To accomplish this, we employed management strategy evaluation (MSE) to simulate this benthic invertebrate fishery that was sampled by two different fishery independent survey protocols: a community science survey program led by trained volunteers and a professional science survey program led by a state agency. We subjected the data to a range of uncertainties, by including time-varying life history parameters, environmental variability, and effective sample size scenarios, to understand the management level consequences of each survey methodology. Our results show that community science program data collection can serve as a high-quality data source, can be linked directly to fisheries management decisions via a Harvest Control Rule (HCR), and can be a useful information source even in the absence of conventional data sources. Our results are specific to the California red abalone fishery, but they also highlight the potential broader value of community science data collection programs for improving information content of small-scale and recreational fisheries.

Integrating management strategy evaluation into fisheries management: advancing best practices for stakeholder inclusion based on an MSE for Northeast US Atlantic herring

Feeney et al (2018)

https://doi.org/10.1139/cjfas-2018-0125@cjfas-mse.issue01

The New England Fishery Management Council used management strategy evaluation (MSE) to evaluate possible harvest control rules for Atlantic herring (Clupea harengus), the first MSE in the US and perhaps globally to use open-invitation, public workshops for input. Stakeholder inclusion can increase both realism and likelihood of use by managers, but inclusivity is not achieved easily. Here, self-selected participants had diverse backgrounds and differing levels of interest and preparedness. We describe some challenges with directly engaging the public in MSE and offer broader insights for obtaining effective public participation during a decision-making process. Conducting an open MSE aligns well with publicly driven management but requires clear goals and communication. Investment in effective organizers, impartial facilitators, and knowledgeable analysts can improve communication and understanding of MSE to the betterment of fisheries management. We aim to further MSE best practices on integrating stakeholders and hope that our lessons learned on communication, engagement, and integration of MSE into an existing management arena will be useful to other practitioners.

Review of progress in the introduction of management strategy evaluation (MSE) approaches in Australia's South East Fishery

Punt et al (2001)

https://doi.org/10.1071/MF99187

The MSE approach provides a simulation-based framework within which harvest strategies, stock assessment methods, performance indicators and research programmes can be compared. This approach has been used in the Australian South East Fishery (SEF) to assess harvest strategies for the over-exploited eastern gemfish resource and to compare different levels of discard monitoring for blue grenadier. The main challenges to use of the MSE approach in the SEF are poorly specified management

objectives and the lack of quantitative stock assessments on which to build operating models for many of the species.

A management strategy evaluation of the commercial sockeye salmon fishery in Bristol Bay, Alaska

Cunningham et al (2018)
https://doi.org/10.1139/cjfas-2018-0133
Bristol Bay, Alaska, is home to the largest sockeye salmon (Oncorhynchus nerka) fishery in the world, harvesting an average of 25 million fish with an ex-vessel value exceeding US$100 million annually. Daily fishing effort is adaptively managed to achieve stock-specific escapement goals. Traditional methods for defining these goals relied on stock–recruitment analysis; however, this approach often ignores three fundamental sources of uncertainty: estimation error, implementation uncertainty, and time-varying recruitment dynamics. To compare escapement goal alternatives, we conducted a management strategy evaluation that simulated time-varying recruitment across production regimes and replicated the daily in-season management process. Results indicate (i) implementation uncertainty can be reasonably approximated with simple rules reflecting fishery managers' daily decision process; (ii) despite implementation uncertainty, escapement goals are likely to be realized or exceeded, on average; and (iii) management strategies targeting escapement levels estimated by traditional methods to produce maximum sustainable yield may result in lower catch and greater variability in fishing opportunity compared with a strategy with defining high and low escapement goals that are targeted depending on assessed run size, which may maximize future catch while reducing the frequency of extremely low harvests.

Management strategy evaluation for North Sea haddock

Needle (2008)
https://doi.org/10.1016/j.fishres.2008.03.004
North Sea haddock (Melanogrammus aeglefinus) are managed under a plan agreed between the European Union (EU) and Norway. This management plan was reviewed during 2006. As part of the review process, a quantitative management strategy evaluation (MSE) was undertaken, both of the existing plan and of proposed modifications. The evaluation was implemented in the R programming system, using FLR libraries, and was based on stochastic simulations of the complete fishery system (including a biological operating model, a knowledge production model with "live" stock assessments, and a simple implementation model). The generation of appropriate time-series of recruitment was of key importance for a stock like North Sea haddock which produces sporadic large year-classes. Although some refinement of growth and discard models is still required, tentative conclusions can be reached on the likely efficacy of different management plans. Well-defined MSEs have the potential to impart useful information for assessment scientists, fisheries managers and stakeholders.

Management strategy evaluation for line fishing in the Great Barrier Reef: Balancing conservation and multi-sector fishery objectives

Mapstone et al (2008)
https://doi.org/10.1016/j.fishres.2008.07.013
Modern fisheries operate in circumstances of contested demands on resources from multiple stakeholders and management under different legislative jurisdictions. Formal management strategy

evaluation (MSE) facilitates quantitative assessment of strengths and weaknesses of alternative management strategies designed to meet multiple agenda. The reef line fishery on the Great Barrier Reef (GBR, Australia) operates under multiple jurisdictions in a World Heritage Area with diverse stakeholder agenda for conservation and commercial and recreational harvest. We worked with stakeholders to identify: (i) specific objectives; (ii) alternative management strategies; and (iii) performance indicators to compare likelihoods of meeting economic, recreational and stock objectives for the fishery and conservation objectives for the effects of line fishing on the GBR. Stakeholders identified objectives and associated performance indicators in four categories, for: (1) conservation of unfished populations; (2) the harvestable stock; (3) economic performance of the fishery; (4) satisfaction of recreational fishers. We used a metapopulation and fishing simulation model (ELFSim) to assess the effects of three effort regimes in combination with three area closure regimes on the primary target species, common coral trout (Plectropomus leopardus). The nine management strategies were also compared with a zero fishing scenario for reference. Controlling fishing effort most improved prospects of meeting economic, stock and recreational satisfaction objectives for the fishery. Nine of ten performance indicators across all stakeholder objectives were maximised when fishing effort was at the lowest non-zero level tested. Maximising the area closed to fishing with reduced fishing effort was most likely to achieve the conservation objectives. This research provides a case study of productive engagement with stakeholders to address fisheries and conservation management needs in a multi-sectoral spatial management context. Together, we provided a common currency (the prospect of meeting quantified objectives) for impartial evaluation of performance of alternative management options against diverse and often competing stakeholder agenda.

Lessons learned for collaborative approaches to management when faced with diverse stakeholder groups in a rebuilding fishery

Deith et al (2021)

https://doi.org/10.1016/j.marpol.2021.104555

There is increasing demand within fisheries management for the adoption of management approaches that incorporate in-depth stakeholder participation, scientific uncertainty, multiple objectives, and characterizations of risk. One such approach—management strategy evaluation (MSE)—relies on participation with fishery interest groups to consolidate knowledge of the fishery system, define goals, and evaluate feasible management options. However, the focus of much of the literature on MSE emphasizes steps in implementation and its practical application, despite the fact that technical aspects of MSE have the potential to alienate participants without MSE experience. Using the Units 1 and 2 Canadian Atlantic redfish fishery as a case study, we here describe lessons learned from the MSE developed for this rebuilding fishery, focusing on four key challenges: identifying participants for MSE processes; clearly defining their roles; educating participants on the purpose, benefits, and scope of MSE; and mediating disagreements to acquire critical cooperation, inputs, and feedback from the different stakeholder groups within the MSE process.

Management strategy evaluation using the individual-based, multispecies modeling approach

Gruss et al (2016)

https://doi.org/10.1016/j.ecolmodel.2016.09.011

End-to-end ecosystem modeling platforms, including OSMOSE, are key tools for informing ecosystem-based fisheries management (EBFM). End-to-end models ideally implement two-way interactions

between model components, yet two-way interactions between high trophic level (HTL) functional groups and humans (fisheries managers and fishers) are currently missing in OSMOSE. We developed a management strategy evaluation (MSE) framework for OSMOSE, which allows for feedback between HTL functional groups and fisheries managers. This framework couples OSMOSE to a management procedure integrating decision rules and accounting for scientific uncertainty and the acceptable risk of overfishing. We applied the MSE framework to the OSMOSE model of the West Florida Shelf, so as to conduct an evaluation of total allowable catch (TAC) strategies for red grouper (Epinephelus morio) in a context of episodic events of natural mortality. Our simulations indicate that TAC strategies that assume higher scientific uncertainty and/or lower acceptable risk of overfishing result in higher biomass-related metrics for red grouper. However, the levels of scientific uncertainty and acceptable risk of overfishing impose a trade-off between biomass-related and catch-related metrics for red grouper. Our simulations also indicate that updating red grouper TAC more frequently in a context of episodic events of natural mortality does not have a large impact on biomass-related and catch-related metrics for red grouper and other functional groups. The MSE we conducted for red grouper is strategic, and its outcomes, which were obtained under a specific set of assumptions, must be considered preliminary. We discuss how future research could help enhance understanding of the possible impacts of TAC strategies for red grouper. The MSE framework designed for OSMOSE links the dynamics of HTL functional groups to that of fisheries managers, thereby allowing OSMOSE to be better suited for informing EBFM. This framework is an invaluable asset in assessing the performance of fisheries management strategies, but could also be used for other purposes, such as the evaluation of research monitoring programs.

Stakeholder participation in management planning for grouper and snapper fisheries in West Nusa Tenggara Province, Indonesia

Retnoningtyas et al (2021)

https://doi.org/10.1016/j.marpol.2021.104452

Abstract: In 2016, a collaborative management planning for grouper and snapper fisheries started in Saleh Bay, West Nusa Tenggara Province, Indonesia, as the first attempts to adapt a national fisheries management plan engaging local stakeholder (such as government units, fishers, traders, academics, and non-governmental organisations). In this work, we describe a management planning based on stakeholders over two years. We found that engaging stakeholders from the beginning fostered a strong sense of ownership within the planning process; enabled scientifically generated recommendations to lead to the most suitable management measures; and facilitated early communication leading to acceptance of the proposed fishing rules during public consultations. To synthesis the process, we propose and discuss a framework aiming to guide management planning in other parts of Indonesia.

A decision support tool for integrated fisheries bycatch management

Gilman et al (2022)

https://link.springer.com/article/10.1007/s11160-021-09693-5

Participatory decision tools enable stakeholders to reconcile conflicting natural resources management objectives. Fisheries targeting highly productive species can have profound impacts on co-occurring bycatch species with low fecundity and other life history traits that make them vulnerable to anthropogenic sources of mortality. This study developed a decision tool for integrated bycatch

management for data-limited to data-rich fisheries, improving upon current piecemeal approaches. First, through a systematic literature review, participants compile a comprehensive database of methods to mitigate the catch and fishing mortality of threatened bycatch species. These mitigation methods are then categorized into tiers of a sequential mitigation hierarchy, where interventions that avoid capture are considered before those that minimize catchability, followed by methods that minimize fishing mortality, before approaches that offset residual impacts. The methods are also assembled within an evidence hierarchy, where findings from meta-analytic modelling studies are more robust and generalizable than from individual studies. The decision tool enables stakeholders to evaluate alternative bycatch management strategies' efficacy at meeting specific and measurable objectives for mitigating the catch and mortality of bycatch and for costs from multispecies conflicts, economic viability, practicality and safety, while accounting for the fishery-specific feasibility of compliance monitoring of alternative bycatch management measures. Ongoing adaptation of the bycatch management framework addresses findings from performance assessments, updated evidence, new mitigation methods and changes to governance systems. The proposed decision tool therefore enables stakeholders to develop bycatch management frameworks that provide precautionary protection for the most vulnerable populations with acceptable tradeoffs.

Comparing Dynamic and Static Time-Area Closures for Bycatch Mitigation: A Management Strategy Evaluation of a Swordfish Fishery

Smith et al (2021)

https://doi.org/10.3389/fmars.2021.630607

Time-area closures are a valuable tool for mitigating fisheries bycatch. There is increasing recognition that dynamic closures, which have boundaries that vary across space and time, can be more effective than static closures at protecting mobile species in dynamic environments. We created a management strategy evaluation to compare static and dynamic closures in a simulated fishery based on the California drift gillnet swordfish fishery, with closures aimed at reducing bycatch of leatherback turtles. We tested eight operating models that varied swordfish and leatherback distributions, and within each evaluated the performance of three static and five dynamic closure strategies. We repeated this under 20 and 50% simulated observer coverage to alter the data available for closure creation. We found that static closures can be effective for reducing bycatch of species with more geographically associated distributions, but to avoid redistributing bycatch the static areas closed should be based on potential (not just observed) bycatch. Only dynamic closures were effective at reducing bycatch for more dynamic leatherback distributions, and they generally reduced bycatch risk more than they reduced target catch. Dynamic closures were less likely to redistribute fishing into rarely fished areas, by leaving open pockets of lower risk habitat, but these closures were often fragmented which would create practical challenges for fishers and managers and require a mobile fleet. Given our simulation's catch rates, 20% observer coverage was sufficient to create useful closures and increasing coverage to 50% added only minor improvement in closure performance. Even strict static or dynamic closures reduced leatherback bycatch by only 30–50% per season, because the simulated leatherback distributions were broad and open areas contained considerable bycatch risk. Perfect knowledge of the leatherback distribution provided an additional 5–15% bycatch reduction over a dynamic closure with realistic predictive accuracy. This moderate level of bycatch reduction highlights the limitations of redistributing fishing effort to reduce bycatch of broadly distributed and rarely encountered species, and indicates that, for these species, spatial management may work best when used with other bycatch mitigation approaches. We recommend future research explores methods for considering model uncertainty in the spatial and temporal resolution of dynamic closures.

Learning from three decades of Management Strategy Evaluation in South Africa

De Moor et al (2022)

https://doi.org/10.1093/icesjms/fsac114

Abstract: South Africa is well known for being one of the first countries to implement management procedures that had been fully tested using Management Strategy Evaluation (MSE). Beginning in the early 1990s, Operational Management Procedures (OMPs) have been developed and implemented for the fisheries for seven important commercial species. Barring a few teething problems, for the first two decades, South Africa's track record of OMP implementation, with OMP-recommended catch limits being signed off by the responsible Minister without change, was exemplary. The sustainable management of some fisheries using OMPs continues without mishap, with regular reviews. However, the past decade has resulted in a number of deviations of decisions from OMP outputs following the declaration of “Exceptional Circumstances” (ECs). This occurred when a resource moved outside the range of scenarios tested at the time the OMP was developed. The reasons why ECs were declared, the methods used to recommend catch limits during ECs and whether ECs might have been avoided are reviewed. The experience gained over three decades of managing fisheries using MSE provides a basis to assess whether the highly time-intensive task of developing these OMPs has been worth the expected benefits, and to provide recommendations related to lessons learned.

Considerations for management strategy evaluation for small pelagic fishes

Siple et al (2021)

https://doi.org/10.1111/faf.12579

Abstract: Management strategy evaluation (MSE) is the state-of-the-art approach for testing and comparing management strategies in a way that accounts for multiple sources of uncertainty (e.g. monitoring, estimation, and implementation). Management strategy evaluation can help identify management strategies that are robust to uncertainty about the life history of the target species and its relationship to other species in the food web. Small pelagic fish (e.g. anchovy, herring and sardine) fulfil an important ecological role in marine food webs and present challenges to the use of MSE and other simulation-based evaluation approaches. This is due to considerable stochastic variation in their ecology and life history, which leads to substantial observation and process uncertainty. Here, we summarize the current state of MSE for small pelagic fishes worldwide. We leverage expert input from ecologists and modellers to draw attention to sources of process and observation uncertainty for small pelagic species, providing examples from geographical regions where these species are ecologically, economically and culturally important. Temporal variation in recruitment and other life-history rates, spatial structure and movement, and species interactions are key considerations for small pelagic fishes. We discuss tools for building these into the MSE process, with examples from existing fisheries. We argue that model complexity should be informed by management priorities and whether ecosystem information will be used to generate dynamics or to inform reference points. We recommend that our list of considerations be used in the initial phases of the MSE process for small pelagic fishes or to build complexity on existing single-species models.

Evaluating performance of data-limited management procedures in an ecosystem perspective: A case study for Larimichthys crocea (Sciaenidae) in the Min River Estuary, China

Ren et al (2023)

https://doi.org/10.1016/j.ecolind.2022.109772

Abstract: Management Strategy Evaluation (MSE) evaluates the performance of alternative management strategies. However, the potential ecosystem effects of the management procedures (MPs) are less evaluated. As one of the four top commercial marine fisheries of China, the fishery of the large yellow croaker Larimichthys crocea (LYC) collapsed in the late 1980s due to the exceeded fishing pressure on spawning and over-wintering aggregations. Long-term and large scale restocking programs for the recovery of LYC fishery have been conducted widely along the eastern coast of China, but its ecosystem impacts and ecological carrying capacity (ECC) were not well understood and assessed. The species-specific assessment and management for LYC fishery were lack due to limited data availability. In this study, an Ecopath model was built as the operating model in MSE to evaluate the effects of MPs for the LYC fishery and estimate the LYC ECC in the Min River Estuary to explore the optimal management measure. A total of 12 candidate MPs were identified and tested, including 5 input controls (2 fishing-effort-based and 3 length-based) and 7 catch-based output controls. A 20-year simulation showed that only 4 MPs fully achieved the performance criteria in maintaining biomass and avoiding further overfishing, including curE75 (75 % of current fishing effort levels), minlenLopt1 (the minimum length of retention for maximizing biomass), matlenLim (fishing retention-at-length related to the maturity curve: 100 %) and matlenLim2 (fishing retention-at-length related to the maturity curve: 110 %). The Min River Estuary ecosystem could support up to 17 kg/km2 of LYC. The Ecosim model projects that the LYC biomass increased over 20 % after the application of curE75, and over 37 % with the combination of curE75 and national fishing moratorium policy after the 20-year simulation. The combination of releasing, fishing effort reduction and fishing moratorium is the optimal measure within current management systems for the recovery of LYC fishery in the Min River Estuary. This study provides an ecosystem-based fishery management approach to plan and evaluate restocking programs using data-limited methods and MSE for the LYC and other fisheries.

Herring supports Northeast Pacific predators and fisheries: Insights from ecosystem modelling and management strategy evaluation

Surma et al (2018)

https://doi.org/10.1371/journal.pone.0196307

This paper analyzes the trophic role of Pacific herring, the potential consequences of its depletion, and the impacts of alternative herring fishing strategies on a Northeast Pacific food web in relation to precautionary, ecosystem-based management. We used an Ecopath with Ecosim ecosystem model parameterized for northern British Columbia (Canada), employing Ecosim to simulate ecosystem effects of herring stock collapse. The ecological impacts of various herring fishing strategies were investigated with a Management Strategy Evaluation algorithm within Ecosim, accounting for variability in climatic drivers and stock assessment errors. Ecosim results suggest that herring stock collapse would have cascading impacts on much of the pelagic food web. Management Strategy Evaluation results indicate that herring and their predators suffer moderate impacts from the existing British Columbia harvest control rule, although more precautionary management strategies could substantially reduce these impacts. The non-capture spawn-on-kelp fishery, traditionally practiced by many British Columbia and Alaska indigenous peoples, apparently has extremely limited ecological impacts. Our simulations also suggest that adopting a maximum sustainable yield management strategy in Northeast Pacific herring

fisheries could generate strong, cascading food web effects. Furthermore, climate shifts, especially when combined with herring stock assessment errors, could strongly reduce the biomasses and resilience of herring and its predators. By clarifying the trophic role of Pacific herring, this study aims to facilitate precautionary fisheries management via evaluation of alternative fishing strategies, and thereby to inform policy tradeoffs among multiple ecological and socioeconomic factors.

Management strategy evaluation: best practices

Punt et al (2014)

https://doi.org/10.1111/faf.12104

Abstract: Management strategy evaluation (MSE) involves using simulation to compare the relative effectiveness for achieving management objectives of different combinations of data collection schemes, methods of analysis and subsequent processes leading to management actions. MSE can be used to identify a 'best' management strategy among a set of candidate strategies, or to determine how well an existing strategy performs. The ability of MSE to facilitate fisheries management achieving its aims depends on how well uncertainty is represented, and how effectively the results of simulations are summarized and presented to the decision-makers. Key challenges for effective use of MSE therefore include characterizing objectives and uncertainty, assigning plausibility ranks to the trials considered, and working with decision-makers to interpret and implement the results of the MSE. This paper explores how MSEs are conducted and characterizes current 'best practice' guidelines, while also indicating whether and how these best practices were applied to two case-studies: the Bering–Chukchi–Beaufort Seas bowhead whales (Balaena mysticetus; Balaenidae) and the northern subpopulation of Pacific sardine (Sardinops sagax caerulea; Clupeidae).

An Integrated Approach Is Needed for Ecosystem Based Fisheries Management: Insights from Ecosystem-Level Management Strategy Evaluation

Fulton et al (2014)

https://doi.org/10.1371/journal.pone.0084242

Abstract: An ecosystem approach is widely seen as a desirable goal for fisheries management but there is little consensus on what strategies or measures are needed to achieve it. Management strategy evaluation (MSE) is a tool that has been widely used to develop and test single species fisheries management strategies and is now being extended to support ecosystem based fisheries management (EBFM). We describe the application of MSE to investigate alternative strategies for achieving EBFM goals for a complex multispecies fishery in southeastern Australia. The study was undertaken as part of a stakeholder driven process to review and improve the ecological, economic and social performance of the fishery. An integrated management strategy, involving combinations of measures including quotas, gear controls and spatial management, performed best against a wide range of objectives and this strategy was subsequently adopted in the fishery, leading to marked improvements in performance. Although particular to one fishery, the conclusion that an integrated package of measures outperforms single focus measures we argue is likely to apply widely in fisheries that aim to achieve EBFM goals.

Evaluating marine spatial closures with conflicting fisheries and conservation objectives

Dichmont et al (2013)

https://doi.org/10.1111/1365-2664.12110

Summary:

Spatial management is used extensively in natural resource management to address sustainability and biodiversity issues, for example through declaration of terrestrial National Parks and marine protected areas (MPAs).

Spatial management is used also to optimize yields or protect key parts of the life cycle of species that are utilized (hunted, farmed or fished), for example through rotational harvesting.

To evaluate the effectiveness of marine spatial closures with conflicting fisheries and conservation objectives, a series of marine fisheries closures are here analysed using an integrative modelling tool known as management strategy evaluation (MSE).

This modelling framework combines a food web model of a tropical ecosystem fished by a prawn (shrimp) fishery that emulates the resource being managed, together with the present management system and risk-based tools of fishing the prawn species at maximum economic yield.

A series of spatial closures are designed and tested with the aim of investigating trade-offs among biodiversity (MPA), benthic impacts, ecosystem function, key species at risk to fishing, economic and sustainability objectives.

Synthesis and applications. This paper illustrates that existing tools often available in actively managed fisheries can be linked together into an effective management strategy evaluation framework. Spatial closures tended to succeed with respect to their specific design objective, but this benefit did not necessarily flow to other broad-scale objectives. This demonstrates that there is no single management tool which satisfies all objectives, and that a suite of management tools is needed.

Using management strategy evaluation to establish indicators of changing fisheries.

Caruthers, T.R. and A.R. Hordyk (2018)
https://doi.org/10.1139/cjfas-2018-0223
Abstract: A new indicator is described that uses multivariate posterior predictive data arising from management strategy evaluation (MSE) to detect operating model misspecification (exceptional circumstances) due to changing system dynamics. The statistical power of the indicator was calculated for five case studies for which fishery stock assessments have estimated changes in recruitment, natural mortality rate, growth, fishing efficiency, and size selectivity. The importance of the component data types that inform the indicator was also calculated. The indicator was tested for multiple types of management procedures (e.g., catch limits by stock assessment, size limits, spatial closures) given varying qualities of data. The statistical power of the indicator could be high even over short time periods and depended on the type of system change and quality of data. Statistical power depended strongly on the type of management approach, suggesting that indicators should be established that rigorously account for feedbacks between proposed management and observed data. MSE processes should use alternative operating models to evaluate protocols for exceptional circumstances to ensure they are of acceptable statistical power.

Evaluating fishery management strategies using an ecosystem model as an operating model

Lucey et al. (2021)

https://doi.org/10.1016/j.fishres.2020.105780

Management Strategy Evaluation (MSE) is an effective tool to gauge the relative performance of fishery management options. For the most part, MSEs have been applied to single-species management procedures. However, to be more inclusive of all the biological and technical interactions occurring within a system, ecosystem-based strategies are emerging. In order to test the feasibility of these strategies, a full ecosystem model should be used as an operating model. Mass balance food web models include many features that managers are interested in and therefore can be useful as an operating model. Until recently, full feedback interactions between a management strategy and a mass balance operating model were impractical. However, with the development of Rpath, users now have the ability to fully customize their mass balance models. We developed new functionality for the Rpath modelling framework that allows it to be used as a flexible operating model. Using an example Georges Bank model, we demonstrate how Rpath can now pause the simulation, evaluate an external model, and use the results to modify the parameters of the operating model. This new flexibility will allow users to test a variety of management strategies or couple to other models making Rpath a valuable tool for conducting MSEs.

Why a management procedure approach? Some positives and negatives

Doug S. Butterworth (2007)

https://doi.org/10.1093/icesjms/fsm003

The origin of the management procedure (MP) approach (sometimes termed management strategy evaluation), with its simulation testing of feedback-control algorithms as a necessary and structured basis for dealing with the inevitable uncertainties associated with fisheries assessments, is briefly reviewed. Also discussed are the advantages that overcome some of the difficulties of the “traditional” approach of coupling an annual “best” assessment to some harvest control rule, such as a failure to consider longer-term trade-offs properly. The MP approach does, however, also have disadvantages, such as the length of time typically required for its development and an argued inflexibility after implementation. Solutions that have been developed to overcome some of these difficulties are discussed.

Experiences in the evaluation and implementation of management procedures

Butterworth D.S. and A.E. Punt 1999

https://doi.org/10.1006/jmsc.1999.0532

Abstract: A synthesis of the authors' experience with the evaluation and implementation of management procedures in Australasia, southern Africa, and the International Whaling Commission (IWC) is presented. The development of operating models for testing such procedures for the fisheries in question over their respective ranges of uncertainty, together with the statistics used to assess procedure performances, are considered first, and then suggestions are made that increasing experience is making it possible to develop a minimal set of key factors to include in such robustness trials. Some general lessons are drawn, primarily from the IWC's process of developing its Revised Management Procedure. Further implementation issues discussed are: candidate procedure selection in principle and practice, the extent of robustness testing desirable, the link to the evaluation of research priorities, and the reception accorded the management procedure approach by industry and decision-

makers. Management procedures are seen to have potential benefits over the annual assessment basis for determination of Total Allowable Catch, but key problem areas that remain concern the definition of risk and the relative weights to be accorded to the various scenarios (of differing plausibilities) considered in robustness tests.

The dream and the reality: meeting decision-making time frames while incorporating ecosystem and economic models into management strategy evaluation.

Deroba et al. 2018

https://doi.org/10.1139z/cjfas-2018-0128@cjfas-mse.issue01

Abstract: Atlantic herring (Clupea harengus) in the Northwest Atlantic have been managed with interim harvest control rules (HCRs). A stakeholder-driven management strategy evaluation (MSE) was conducted that incorporated a broad range of objectives. The MSE process was completed within 1 year. Constant catch, conditional constant catch, and a biomass-based (BB) HCR with a 15% restriction on the interannual change in the quota could achieve more stable yields than BB HCRs without such restrictions, but could not attain as high of yields and resulted in more negative outcomes for terns (Sterna hirundo; a predator of herring). A similar range of performance could be achieved by applying a BB HCR annually every 3 years or every 5 years. Predators (i.e., dogfish (Squalus acanthias), bluefin tuna (Thunnus thynnus), and terns) were generally insensitive to the range of HCRs. While median net revenues were sensitive to some HCRs, time series analysis suggests that most HCRs produced a stable equilibrium of net revenue. To meet management needs, some aspects of the simulations were less than might be considered scientifically ideal, but using "models of intermediate complexity" were informative for managers and formed a foundation for future improvements.

On scientists' discomfort in fisheries advisory science: the example of simulation-based fisheries management-strategy evaluations

Kraak et al. 2010

http://dx.doi.org/10.1111/j.1467-2979.2009.00352.x

Scientists feel discomfort when they are asked to create certainty, where none exists, for use as an alibi in policy-making. Recently, the scientific literature has drawn attention to some pitfalls of simulation-based fisheries management-strategy evaluation (MSE). For example, while estimates concerning central tendencies of distributions of simulation outcomes are usually fairly robust because they are conditioned on ample data, estimates concerning the tails of distributions (such as the probability of falling below a critical biomass) are usually conditional on few data and thus often rely on assumptions that have no strong knowledge base. The clients of scientific advice, such as the European Commission, are embracing the mechanization of the evaluation of proposed Harvest Control Rules against the precautionary principle and management objectives. Where the fisheries management institutions aim for simple answers from the scientists, giving 'green/red light' to a proposed management strategy, the scientists are forced into a split position between satisfying the demands of their advisory role and living up to the standards of scientific rigour. We argue against the mechanization of scientific advice that aims to incorporate all relevant processes into one big model algorithm that, after construction, can be run without circumspection. We rather encourage that fisheries advice should be a dynamic process of expert judgement, incorporating separate parallel concurrent, lines of scientific evidence, from quantitative and qualitative modelling exercises and factual knowledge of the biology and the fishery dynamics. This process can be formalized to a certain degree and can easily accommodate stakeholder viewpoints.

Empirical harvest strategies for data-poor fisheries: A review of the literature

Dowling et al. (2015)

https://www.sciencedirect.com/science/article/pii/S0165783614003300

Harvest strategy approaches based around empirical indicators and/or control rules are beginning to be accepted in a growing range of data- and capacity-poor fisheries. While there is an increasing body of work around developing empirical indicators and control rules in data-poor contexts, this has typically been done on a case-specific basis. There remains a need for general guidance on formulating control rules that link empirical indicators with suitable management responses. Additionally, in the data-poor context, most literature has focused on empirical indicators and assessments, with less focus on decision rules and the incorporation of indicators and assessments in a harvest strategy framework. This review considers a range of harvest strategy options, focusing on empirical indicators and decision rules available for data-poor species and fisheries. These clearly illustrate that a paucity of information is not a reason to avoid developing harvest strategies, and that a range of pragmatic approaches are available regardless of the available data, life-history of the target species, nature of fishing operations, or the available research capacity. There is considerable scope for further work in this field, but arguably there is a comprehensive repository of approaches and decision rules that, when combined with the guidelines, form a solid foundation and toolkit for all but the most data-poor species and fisheries.

Misspecification in stock assessments: Common uncertainties and asymmetric risks

Hordyk et al. 2019

https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12382

Common uncertainties in stock assessment relate to parameters or assumptions that strongly determine both the estimates of quantities of management interest (e.g. stock depletion) and related reference points (e.g. biomass at maximum sustainable yield). The risks associated with these uncertainties are often presented to managers in the form of decision tables. However, a formal evaluation of the risks from misspecifying an assessment model over time-horizons spanning multiple assessment cycles requires closed-loop simulation. There were two aims of this study: (a) develop an approach to identify and evaluate asymmetries in risk to yields and spawning biomass due to biases in key parameters and data sources in a stock assessment model, (b) quantify the relative importance of correctly specifying the various assessment attributes. A computationally efficient stock reduction analysis was evaluated using closed-loop simulation to identify risks associated with a stock assessment with persistent positive and negative biases in the key parameters and inaccurate assumptions regarding data sources. Six types of assessment misspecification were examined, namely the assumed natural mortality rate, the assumed recruitment compensation ratio, the assumed age of maturity, a hyper-stable or hyper-deplete index of abundance, over- or under-reporting of historical catch, and misspecification of the assumed shape of the selectivity curve. This study reveals large asymmetries in risk associated with common uncertainties in stock assessment processes. We highlight the value of reproducible and computationally efficient stock assessment models that can be investigated by closed-loop simulation before being used for fisheries management.

The interim management procedure approach for assessed stocks: Responsive management advise and lower assessment frequency

Huynh et al. 2020

https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12453

Stock assessments are often used to provide management advice, such as a total allowable catch (TAC), to fishery managers. Many stocks are not assessed annually, and the TAC from the previous assessment is often maintained in years between assessments. We developed two interim management procedures (MPs) that update the estimate of current vulnerable biomass from a surveyed index of abundance to adjust the TAC from a previous assessment. These MPs differ in how they handle uncertainty in observed indices. Using closed-loop simulation, we evaluated the two interim MPs (with 10- and 5-year assessment intervals) against several "status quo" approaches: (1) an annual assessment, and (2) a stock assessment every 5 or 10 years with (a) fixed TACs or (b) projections between assessments. We evaluated performance across three life-history types and six operating model scenarios. The interim MPs performed similarly to annual assessments in terms of trends in biomass and yield, regardless of the assessment interval of the interim MPs. The interim MPs often produced more yield than the Fixed TAC MP with 10-year assessment intervals, for example, in depleted scenarios. The Fixed TAC MP performed more similarly to interim MPs when the assessment interval for the Fixed TAC MP was decreased to five years. The interim MPs can also perform well when circumstances arise that are not accounted for in the Projection MP. Our results show that interim MPs should be considered for infrequently assessed stocks or rebuilding stocks, and highlight potential cost savings of interim MPs over annual assessments.