Key Literature Related to Dynamic Reference Points

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Document Overview

This document summarizes key literature related to the need for Dynamic Reference Points (DRPs), key approaches for estimating them, and considerations for incorporating them into fisheries management processes. Collectively, the 15 peer-reviewed publications reflect a growing recognition of the need for both assessment and management approaches to account for non-stationarity in stock productivity. While DRPs are a tool for addressing this challenge, their estimation and implementation can also introduce new risks when compared with conventional static reference points.

The publications in this review have been divided into four major themes:

- Theme 1: When/Why Dynamic Reference Points/Control Rules Are Needed
- Theme 2: Technical Approaches for Estimating Dynamic Reference Points
- Theme 3: Harvest Strategies Under Changing Conditions
- Theme 4: Management and Implementation Considerations

Each page of this document summarizes pertinent information for one publication, including the citation, abstract (with critical elements highlighted in bold by staff), and list of key points. Full PDFs of all papers can be accessed via a folder on Google Drive.

Theme 1: When/Why Dynamic Reference Points/Control Rules Are Needed

1.1 Morgan et al. (2014)

Full reference: Morgan, M. J., Shelton, P. A., & Rideout, R. M. (2014). *An evaluation of fishing mortality reference points under varying levels of population productivity in three Atlantic cod (*Gadus morhua*) stocks*. ICES Journal of Marine Science, 71(6), 1407–1416. https://doi.org/10.1093/icesjms/fsu092.

Abstract [staff highlights in bold]:

Variation in productivity will affect the level of fishing mortality that a population can sustain without decline. We examined three Atlantic cod (*Gadus morhua*) stocks off Canada for evidence of changing productivity and determined the impact this variation would have on different fishing mortality reference points and their sustainability. Productivity was found to vary greatly over time within all three cod stocks. **Under high productivity conditions, G_0 (i.e. the potential growth in spawning-stock biomass at a fishing mortality of zero) for the three populations was 20–30%. But under low productivity conditions, G_0 was much less. Two of the populations had G_0 that was near zero or negative when productivity was low, indicating the possibility of population decline even in the absence of fishing**. The degree to which the levels of common fishing mortality reference points (F_{MSY}, F_{MAX}, $F_{0.1}$, and $F_{40\%SPR}$) changed across productivity periods was variable. All showed significant variation with changing productivity; however, the differences in reference points between productivity periods were generally very small except for F_{MAX} and F_{MSY}. All four reference points examined here were sustainable under conditions of high and average productivity. **YPR and SPR reference points do not incorporate recruitment in their calculation. During periods of low productivity, recruitment was reduced and these reference points generally became unsustainable.** F_{MAX} was similar to F_{MSY} only under high and average productivity but was not a good proxy for F_{MSY} under lower levels of productivity. **Reference points should incorporate recruitment because of its importance in determining the productivity of the stock and should be updated as productivity changes.**

Key Points:

- Four main determinants of stock productivity: growth, maturity, recruitment, and mortality.
- Of the three categories of *F*-based reference points—maximum sustainable yield (MSY), yield per recruit (YPR), and spawner per recruit (SPR)—only MSY-based reference points incorporate recruitment.
- "Under low-productivity conditions F_{MSY} is achievable, but the YPR or SPR reference points are not sustainable.
- "The analyses presented here for Newfoundland and Labrador cod stocks show that variation in population productivity should be an important consideration for the sustainable management of fisheries resources."
- At the same time, the causes of changes for each stock's productivity are not known and may differ among stocks.
- This analysis did not include any variation in natural mortality, which is an important factor influencing productivity and can be influenced by environmental conditions and predation.
- "There is a need to develop reference points that respond to changes in population productivity. Growth, maturity, and recruitment need to be regularly examined to determine if productivity has changed (Brooks, 2013) and allowable catch adjusted if required."

1.2 Klaer et al. (2015)

Full reference: Klaer, N. L., O'Boyle, R. N., Deroba, J. J., Wayte, S. E., Little, L. R., Alade, L. A., & Rago, P. J. (2015). *How much evidence is required for acceptance of productivity regime shifts in fish stock assessments: Are we letting managers off the hook?* Fisheries Research, 168, 49–55. https://doi.org/10.1016/j.fishres.2015.03.021.[Paywall]

Abstract [staff highlights in bold]:

A difficult question often confronting fisheries assessment scientists and managers is whether or not to accept that a shift in stock productivity has occurred. This is particularly the case when a stock has remained at historically low biomass despite management intervention and when there is an expectation that there should have been a stock recovery. **We outline a weight-of-evidence approach that provides a structured means to evaluate this questio**n. The approach, which scores a range of attributes, was applied to five fisheries from the NW Atlantic and SE Australia, chosen to provide a range of supporting evidence, as well as different potential causal mechanisms for a productivity shift. Given the resulting scores for the example stocks, and whether a productivity shift has been accepted for those stocks, a score of between 7 and 12 indicated a level required for acceptance of a productivity shift. The approach has highlighted areas of future research that would improve individual species scores. **It is hoped that the paper will encourage a more systematic examination of potential stock productivity shifts in assessments than has hereto been the case.**

Key Points:

- "The decision on whether or not there has been a change in stock productivity is a difficult one. Accepting that there has been a shift in productivity moves the cause of the (usually) low biomass away from fishing to an external cause such as unfavourable environmental conditions. The responsibility for low stock status is thus removed from fisheries management as the cause is out of management control, and management is therefore "off the hook". On the other hand, if the stock biomass is low and productivity has not changed, there can be severe consequences for the future yield prospects of the resource – possible fishery closure or severe restriction of fishery effort."
- "We contend that as acceptance of a productivity shift can have a very a profound influence on stock status and management responsibility, an evidence-based approach is required to justify such acceptance."
- Four criteria (Table 1):
    1. Observed change in a productivity indicator (e.g., recruitment, biomass, natural mortality)
    2. Understanding of assessment model input data (e.g,, biological characteristics, abundance indices, catch, stock boundaries)
    3. Understanding of assessment model structural assumptions—extent to which it can be determined that the apparent productivity shift is not due to model assumptions
    4. Explanatory hypothesis (studies/indicators that have provided independent evidence of a change in productivity)
- Describes examples of NEFMC-managed species: Atlantic herring and Southern New England/Mid-Atlantic yellowtail flounder.

1.3 Berger (2019)

Full reference: Berger, A. M. (2019). *Character of temporal variability in stock productivity influences the utility of dynamic reference points*. Fisheries Research, 217, 185–197. https://doi.org/10.1016/j.fishres.2018.11.028.

Abstract [staff highlights in bold]:

Reference points identify benchmarks, thresholds, or decision points for fisheries management, and are commonly defined by stock status indicators that presume equilibrium population conditions in the absence of fishing (e.g., equilibrium biomass, B_0). However, equilibrium population biomass may be an inappropriate reference level when stock productivity is influenced by environmental change, predator-prey dynamics, ecosystem thresholds, and myriad other factors. Simulations were conducted to compare equilibrium-based (static B_0) and non-equilibrium based (dynamic B_0) indicators of stock status under alternative states of nature driven by time-varying recruitment dynamics (productivity regime), fishing dynamics (mortality regime), and species life history. **Using dynamic B_0 often implied a different state of the stock under directional productivity regime shifts, but was more similar to static B_0 reference points under cyclic or white noise productivity scenarios. Uncertainty in stock status arising from incorrectly identifying changes in system productivity generally outweighed the uncertainty associated with initial equilibrium conditions**. Empirical results across 18 U.S. West Coast groundfish stock assessments indicated predominantly small differences (< 10%) between static B_0 and dynamic B_0 indicators of stock status, although in some cases differences were large (up to 72%) or spanned reference points that trigger management action**. Although caution is warranted when considering dynamic reference points, this paper shows these approaches are likely to be most useful when stock productivity shifts directionally, if that productivity signal can be correctly ascertained.**

Key Points:

- "In general, the dynamic B_0 approach will perform better when broad, persistent spatiotemporal shifts or trends in relative stock productivity are known and management objectives focus on a stock's present reproductive capacity rather than historical capabilities (Szuwalski and Punt, 2012). However, changes in productivity are often unknown or poorly linked to oceanographic conditions over time (see Punt et al., 2014a, 2014b), such that predictive power to estimate present status or population forecasts decreases with time (Walters and Collie, 1988; Haltuch and Punt, 2011). Therefore, species with low–medium recruitment variability (high variability can swamp the ability to decipher stock productivity signals) and short–medium life spans (improved ability to link changes in ecosystem productivity to stock productivity, i.e., less time lag) may benefit most from using dynamic B_0 stock status and reference points."
- "However, caution is warranted when using environmental indices to inform stock productivity because linkages can be variable and nonstationary over time (Myers, 1998; Punt et al., 2014a, 2014b)."
- "In addition to further research on the interaction of stock assessment model uncertainties (process, observation and model errors) associated with derived management model quantities (static and dynamic reference points), there is a need to better understand the performance of the management system and harvest rules when using alternative indicators of stock status to ensure robust outcomes despite plausible productivity and fishing regimes."
- "In theory, dynamic B_0 indicators of stock status and reference points are appealing, but in practice it is challenging to predict changes in stock productivity, or even retrospectively understand the mechanisms driving observed change. In general, simulations indicate that the level of uncertainty arising from incorrectly identifying changes in system productivity will depend on the life history of the species under consideration."
- "Managers are encouraged to use a combination of indicators, static equilibrium based measures to provide historical or 'on average' context and dynamic measures to inform current capacity limits and the relative impact of fishing, when making decisions about stock status and resource use relative to management goals."

1.4 Hansell et al. (2025)

Full reference: Hansell, A. C., Barrett, M., Cadrin, S. X., Carrano, C., Kittel, J., & Legault, C. M. (2025). *Collapse, recovery and collapse of an important fishery*. Journal of Northwest Atlantic Fishery Science, 56, 31–46. https://doi.org/10.2960/J.v56.m752.

Abstract [staff highlights in bold]:

Georges Bank is a shallow plateau off the coast of New England that has supported productive fisheries for centuries. One of these fisheries targeted yellowtail flounder (*Limanda ferruginea*), which at its peak caught over 21,000 mt a year. However, the stock has fluctuated, with periods of high abundance (1970s and 2000s) and low stock size (1990s and 2020s). A review published twenty years ago documented the collapse of the stock in the 1990s and subsequent recovery in the 2000s, hypothesizing the major reason for recovery was bilateral science and successfully coordinated management intervention. Unfortunately, by the time that review was published, the stock had started to decrease again and collapsed in the 2010s. We provide an updated historical review of the fishery and past stock assessments. We conduct new analyses of empirical indicators of spatial distribution and growth for Georges Bank yellowtail flounder and project the stock into the future using the most recent stock assessment. **Results suggest that fishing was the likely cause of initial stock depletion while environmental changes, particularly bottom temperature, has limited recovery in recent years. Projections suggest that the population can increase in the future but its ability to increase is related to bottom temperature on Georges Bank**. These results give insight into the dynamics an iconic New England fishery and stock, as well as, provide a unique opportunity to study the fluctuations of a stock through multiple periods of recovery and collapse.

Key Points:

- "Overfishing is often attributed as the primary cause of stock depletion, but changes in the environment can also lead to reductions in fish productivity. For example, the collapse of the Pacific sardine fishery in the 1940s (Jacobson and MacCall, 1995) and the Peruvian anchoveta fishery in the 1970s (Pauly and Tsukayama, 1987) were hypothesized to be the result of a combination of fishing and changes in sea surface temperatures. The collapse of the Southern New England lobster fishery has been attributed to warming water temperatures linked to shell disease (Glenn and Pugh, 2006)."
- Analysis of fishery-independent survey data for Georges Bank yellowtail demonstrated a general decrease in length/size at age over time, especially for older fish.
- 2024 Woods Hole Assessment Model (WHAM) allowed for inclusion of environmental variables on population dynamic processes. The stock-recruit relationship used assumed that both stock size and bottom temperature impacted recruitment, and analyses indicate that periods of warmer bottom temperature were associated with periods of lower recruitment.
- Despite low fishing mortality since the late 1990s, spawning stock biomass and recruitment have remained low since 2010, primarily due to warmer temperatures.
- It is unclear what specific mechanism of recruitment (e.g., timing, egg viability, food availability, etc.) is affected by temperature.
- "Observed changes in size at age could be the result of environmental factors, such as changes in water temperature or prey composition. Future work should explore potential drivers of observed changes in size."
- Projections indicate that the stock can increase again in the future, but likely not high enough to support the amount of removals that were historically taken: "As a result, scientists and managers need to adapt expectations (e.g., biological reference points) to account for these changes."

Theme 2: Technical Approaches for Estimating Dynamic Reference Points

2.1 A'mar et al. (2009)

Full reference: A'mar, Z. T., Punt, A. E., & Dorn, M. W. (2009). *The evaluation of two management strategies for the Gulf of Alaska walleye pollock fishery under climate change*. ICES Journal of Marine Science, 66, 1614–1632.

Abstract [staff highlights in bold]:

Management strategy evaluation (MSE) is the process of using simulation testing with feedback to examine the robustness of candidate management strategies to error and uncertainty. The structure of the management strategy can be selected to attempt to satisfy desired (but conflicting) management objectives. **MSE was used to assess the performance of the current management strategy and an alternative management strategy (the "dynamic B_0" strategy) for the fishery for walleye pollock (*Theragra chalcogramma*) in the Gulf of Alaska (GOA), when age-1 recruitment was driven by climate.** The relationships between age-1 abundance and climate indices (and the uncertainties associated with these relationships) were characterized within an age-structured operating model that was fitted to the data for GOA walleye pollock. Projections into the future were based on the fitted relationships and predictions of those indices from the Intergovernmental Panel on Climate Change (IPCC) models, using the current or the alternative management strategy to determine catch limits. Management performance (the ability to leave the stock close to the management reference level and achieve high and stable catches) deteriorated when age-1 recruitment was forced by climate, although stocks were kept near the reference level on average. In addition, the ability to estimate management-related quantities, such as spawning biomass, deteriorated markedly when recruitment was forced by climate. Performance was sensitive to the choice of IPCC dataset and, in particular, estimation and management performance was poorest (outcomes most variable) for the IPCC datasets that led to the greatest variation in recruitment to the fishery. **Although basing management on a "dynamic B_0" management strategy led to improved management and estimation performance, the magnitude of the improvement was slight.**

Key Points:

- "The current management strategy kept the stock close to the reference level $SB_{40\%}$ on average. However, this management strategy allowed the stock to be reduced to very low levels (below the 2006 estimate of $SB_{20\%}$) under some climate scenarios. The dynamic B_0 management strategy kept spawning biomass closer to the reference level $SB_{40\%}$ and had a lesser probability of reducing the spawning biomass to below $SB_{20\%}$. However, the dynamic B_0 management strategy also had a higher probability of the catch exceeding the overfishing limit. The dynamic B_0 management strategy was based on the correct model for $SB_{40\%}$ and hence (potentially) had an unrealistic advantage over the current management strategy. Given this, and the results of this study, there seems little reason to advocate the dynamic B_0 management strategy."

2.2 O'Leary (2020)

Full reference: O'Leary, C. A., Thorson, J. T., Miller, T. J., & Nye, J. A. (2020). *Comparison of multiple approaches to calculate time-varying biological reference points in climate-linked population-dynamics models*. ICES Journal of Marine Science, 77(3), 930–941. https://doi.org/10.1093/icesjms/fsz215

Abstract [staff highlights in bold]:

Fisheries managers use biological reference points (BRPs) as targets or limits on fishing and biomass to maintain productive levels of fish stock biomass. There are multiple ways to calculate BRPs when biological parameters are time varying. Using summer flounder (*Paralichthys dentatus)* as a case study, we investigated time-varying approaches in concert with climate-linked population models to understand the impact of environmentally driven variability in natural mortality, recruitment, and size-at-age on two commonly used BRPs [$B_0(t)$ and $F_{35\%}(t)$]. We used the following two approaches to calculate time-varying BRPs: dynamic-BRP and moving-average-BRP. We quantified the variability and uncertainty of different climate dependencies and estimation approaches, attributed BRP variation to variation in life-history processes, and evaluated how using different approaches impacts estimates of stock status. **Results indicate that the dynamic-BRP approach using the climate-linked natural mortality model produced the least variable reference points compared to others calculated. Summer flounder stock status depended on the estimation approach and climate model used. These results emphasize that understanding climate dependencies is important for summer flounder reference points and perhaps other species, and careful consideration is warranted when considering what time-varying approach to use, ideally based upon simulation studies within a proposed set of management procedures.**

Key Points:

- Good overview of BRPs in general and linkage to harvest control rules
- Tailoring BRPs to the climate state is important if future conditions will differ (e.g., due to a regime shift)—but even if the influence of climate on a stock is understood/modeled, there is still a choice to be made regarding how to fold these changing dynamics into BRP calculations.
- "The differences in BRP uncertainty and variability for both approaches and climate dependencies may be greater if we calculate BRPs for a fish stock with more variable productivity, productivity closer to a threshold tipping point, or with a greater magnitude response to climate. This is particularly relevant for the current management process in many regions, where BRPs include temporal variation by conditioning them on information and stock-assessment estimates from the most recent years. Therefore, we suggest that there should be a consultative, iterative process with stakeholders to identify the method used to calculate BRPs. As well, plausible climate hypotheses should be developed and used to test climate dependencies relevant to the managed fish stock."
- Management recommendation: "Take into account the timeline and management goals of the various stakeholders to determine how to incorporate BRP uncertainty, variability, and probability of overfishing the stock. A "stable" reference point does not necessarily imply the "best" advice. For example, the assessment for summer flounder occurs every 5 years and the Acceptable Biological Catch is set every 3 years. In this case, the moving-average-BRPs are more uncertain. Therefore, we advise using these moving-average BRPs over a longer time frame to more cautiously approach 3–5-year management timeframe of a fish stock whose natural mortality temporally varies from year to year. Using this moving-average approach, a fish stock's temporally varying life-history and productivity conditions are more likely captured by the greater uncertainty."

2.3 Howell et al. (2021)

Full reference: Howell, D., Schueller, A. M., Bentley, J. W., Buchheister, A., Chagaris, D., Cieri, M., Drew, K., Lundy, M. G., Pedreschi, D., Reid, D. G., & Townsend, H. (2021). *Combining ecosystem and single-species modeling to provide ecosystem-based fisheries management advice within current management systems*. Frontiers in Marine Science, 7, 607831. https://doi.org/10.3389/fmars.2020.607831.

Abstract [staff highlights in bold]:

Although many countries have formally committed to Ecosystem-Based Fisheries Management (EBFM), actual progress toward these goals has been slow. This paper presents two independent case studies that have combined strategic advice from ecosystem modeling with the tactical advice of single-species assessment models to provide practical ecosystem-based management advice. **With this approach, stock status, reference points, and initial target *F* are computed from a single-species model, then an ecosystem model rescales the target *F* according to ecosystem indicators without crossing pre-calculated single-species precautionary limits.** Finally, the single-species model computes the quota advice from the rescaled target *F*, termed here F_{eco}. **Such a methodology incorporates both the detailed population reconstructions of the single-species model and the broader ecosystem perspective from ecosystem-based modeling, and fits into existing management schemes.** The advocated method has arisen from independent work on EBFM in two international fisheries management systems: (1) Atlantic menhaden in the United States and (2) the multi species fisheries of the Irish Sea, in the Celtic Seas ecoregion. In the Atlantic menhaden example, the objective was to develop ecological reference points (ERPs) that account for the effect of menhaden harvest on predator populations and the tradeoffs associated with forage fish management. In the Irish Sea, the objective was to account for ecosystem variability when setting quotas for the individual target species. These two exercises were aimed at different management needs, but both arrived at a process of adjusting the target *F* used within the current single-species management. Although the approach has limitations, it represents a practical step toward EBFM, which can be adapted to a range of ecosystem objectives and applied within current management systems.

Key Points:

- Single-species assessments focus on a smaller set of processes (e.g., population/harvest dynamics) than ecosystem models and thus can be more easily created, updated and reviewed.
- This approach leverages full ecosystem models that have been developed for certain ecoregions to track the flow of energy through an ecosystem.
- Case studies for a) Atlantic menhaden on the U.S. east coast and b) commercial fish stocks in the Irish Sea: "In both cases, an approach was developed which allowed ecosystem modeling results to be incorporated into the existing management structure, while retaining the single species assessment models used to support existing management… Based on the success of these two case studies, we propose using ecosystem or multispecies models to adjust single species reference points to account for ecosystem understanding when providing management advice."
- Important step: Determination of the ecosystem indicator(s) to use to adjust single-species *F*—e.g., for Irish sea commercial stocks, sea surface temperature, zooplankton abundance, and predator abundance were used.
- "The strength of this approach is that the assessment and management of fish stocks remains with the single species assessment models and within the current management structure as much as possible... Only the adjustment of the target *F* is influenced by the ecosystem modeling."
- "By only adjusting the existing F_{target}, this method avoids directly transferring values between different models, and by remaining within existing limit reference points the method imposes no additional risk of stock collapse."

2.4 Bessell-Browne et al. (2022)

Full reference: Bessell-Browne, P., Punt, A. E., Tuck, G. N., Day, J., Klaer, N., & Penney, A. (2022). *The effects of implementing a 'dynamic* B_0*' harvest control rule in Australia's Southern and Eastern Scalefish and Shark Fishery*. Fisheries Research, 252, 106306. https://doi.org/10.1016/j.fishres.2022.106306.

Abstract [staff highlights in bold]:

The harvest control rules for many fish and invertebrate stocks, managed using stock assessments based on fitting population dynamics models to monitoring data, rely on biological reference points. These reference points are often related to unfished conditions ('B_0') and are calculated assuming that biological parameters and their associated functional forms (e.g., unfished recruitment ('R_0'), natural mortality, growth) are stationary. However, there is increasing evidence that the assumption of stationarity is untenable in the face of environmental change**. In principle, non-stationarity can be addressed by defining stock status (i.e., spawning biomass relative to unfished spawning biomass) using 'dynamic B_0' (the spawning biomass that would be expected in the absence of fishing).** We show how catch limits (Recommended Biological Catches) for stocks in Australia's Southern and Eastern Scalefish and Shark Fishery would have differed had management been based on dynamic B_0. We also explore the performance of static and dynamic B_0-based harvest control rules using simulations where various biological parameters (R_0, B_0, L_∞, κ, natural mortality, and stock-recruitment steepness) exhibit trends over time**. The results confirm previous work that the implications of adopting a dynamic B_0 approach would differ among species, with quite major changes in stock status and catch limits for some species and negligible changes for others. In terms of management performance in projections, there are species-specific trade-offs, with a dynamic B_0 approach tending to lead to higher catches, lower biomass on occasion and less inter-annual variation in catches than a static B_0 approach.** The implications of harvest control rules based on static and dynamic B_0 also differ depending on which biological parameter is changing over time.

Key Points:

- Dynamic B_0 can account for non-stationarity in biological parameters
  - "A dynamic B_0 approach to calculating reference points for fisheries management acknowledges that drivers other than fishing pressure influence population size, even where these cannot be explicitly identified."
  - "The dynamic B_0 approach differs from the traditional 'static' B_0 approach, which uses the average (expected) unfished biomass based on the values of biological parameters at the start of fishing as a fixed reference point for calculating stock status estimates (Ricker, 1975; Hilborn, 2002)."
- The implications of the approach (e.g., effect on stock status compared to static approach) can differ drastically depending on the species

2.5 Silvar-Viladomiu et al. (2022)

Full reference: Silvar-Viladomiu, P., Minto, C., Brophy, D., & Reid, D. G. (2022). *Peterman's productivity method for estimating dynamic reference points in changing ecosystems*. ICES Journal of Marine Science, 79(4), 1034–1047. https://doi.org/10.1093/icesjms/fsac035.

Abstract [staff highlights in bold]:

Target and limit reference points are fundamental management components used to define sustainable harvest strategies. Maximum Sustainable Yield (MSY) and the precautionary principle underpin many reference points. Non-proxy reference points based on MSY in age-based single-species assessments depend on the stock–recruitment (SR) relationship, which can display complex variability. Current reference points ignore persistent dynamic change by assuming that the SR relationship is stationary and with constant recruitment parameters over selected time periods. **We highlight Peterman's productivity method (PPM), which is capable of tracking temporal dynamics of recruitment productivity *via* time-varying SR parameters. We show how temporal variability in SR parameters affects fishing mortality and biomass MSY-based reference points. Implementation of PPM allows for integrated dynamic ecosystem influences in tactical management while avoiding overwrought and sometimes ephemeral mechanistic hypotheses tested on small and variable SR datasets.** While some of these arguments have been made in individual papers, in our opinion the method has not yet garnered the attention that is due to it.

Key Points:

- "There is a "gap" between single-species methods that provide reference points for advice to trigger tactical management and ecosystem-based methods that often do not have clearly defined operative standards for tactical management (Fogarty, 2014)."
- "In this article, we focus on how to deal with changing ecosystems within tactical fisheries management. We present a possible bridge to align stock reference points with ecosystem concerns."

2.6 Turcotte et al. (2026)

Full reference: Turcotte, F., McDermid, J. L., Ricard, D., & Swain, D. P. (2026). *Defining a biomass limit reference point under time-varying productivity: A case study of Atlantic cod in the southern Gulf of St. Lawrence, Canada*. Canadian Journal of Fisheries and Aquatic Sciences, 83, 1–12. https://doi.org/10.1139/cjfas-2025-0147.

Abstract [staff highlights in bold]:

Many commonly used fisheries reference points assume stable population processes, yet time-varying productivity is increasingly observed among fish stocks. Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence (sGSL) collapsed in the 1990s and has not recovered, with nonstationarity in recruitment, growth, maturity, and natural mortality preventing equilibrium conditions. In Canada, the biomass limit reference point (LRP) defines the threshold below which a stock is considered to experience serious harm to its productivity and requires rebuilding. **We used life-history data, stock recruit models, a statistical catch at age model and a surplus production model to evaluate candidate LRPs while accounting for nonstationarity in sGSL cod productivity. Two indicators of serious harm were identified: a persistent low production–low biomass state and a breakpoint in production suggesting the stock crossed an Allee threshold in 1992.** Three candidate LRPs were supported and produced similar stock status, whereas other commonly used static or dynamic methods generated values below the threshold of serious harm. **These findings highlight the importance of testing multiple approaches when estimating LRPs for stocks experiencing shifting productivity.**

Key Points:

- Beyond a brief period of equilibrium conditions in the 1950s, "directional changes in growth, maturity, and natural mortality resulted in persistent nonstationarity, complicating the estimation of biomass LRPs. These findings reinforce concerns that time-varying productivity undermines equilibrium-based reference points widely used in fisheries management (Hebert et al. 2025)."
- "Our results and previous studies highlight that defining LRPs based on recent productivity can create overly optimistic perceptions of stock status under declining productivity (Table 1), a manifestation of the shifting baseline syndrome (Pauly 1995)."
- "Dynamic estimates of B_0 and BMSY in our study collapsed after 1990, illustrating the risk of moving baselines when productivity shifts persistently."

Theme 3: Harvest Strategies Under Changing Conditions

3.1 Punt et al. (2014)

Full reference: Punt, A. E., A'mar, T., Bond, N. A., Butterworth, D. S., de Moor, C. L., De Oliveira, J. A. A., Haltuch, M. A., Hollowed, A. B., & Szuwalski, C. (2014). *Fisheries management under climate and environmental uncertainty: control rules and performance simulation*. ICES Journal of Marine Science, 71(8), 2208–2220. https://doi.org/10.1093/icesjms/fst057.

Abstract [staff highlights in bold]:

The ability of management strategies to achieve the fishery management goals are impacted by environmental variation and, therefore, also by global climate change. Management strategies can be modified to use environmental data using the "dynamic B_0" concept, and changing the set of years used to define biomass reference points. Two approaches have been developed to apply management strategy evaluation to evaluate the impact of environmental variation on the performance of management strategies. The "mechanistic approach" estimates the relationship between the environment and elements of the population dynamics of the fished species and makes predictions for population trends using the outputs from global climate models. In contrast, the "empirical approach" examines possible broad scenarios without explicitly identifying mechanisms. **Many reviewed studies have found that modifying management strategies to include environmental factors does not improve the ability to achieve management goals much, if at all, and only if the manner in which these factors drive the system is well known. As such, until the skill of stock projection models improves, it seems more appropriate to consider the implications of plausible broad forecasts related to how biological parameters may change in the future as a way to assess the robustness of management strategies, rather than attempting specific predictions *per se*.**

Key Points:

- "The examples above show that environmental and climate impacts on the population dynamics of marine species can be taken into account in the simulations used to evaluate management strategies and in the strategies themselves. These simulations can be used to evaluate the benefits of adopting a management strategy that explicitly accounts for environmental and climate impacts."
- "The option of basing forecasts on models that link biological parameters to environmental variables is attractive in principle and seems to be more biologically realistic than the empirical approach. However, while providing useful information retrospectively, understanding the mechanisms underlying shifts in production is necessary to project future responses to climate variability and change."
- "Many of the studies covered in detail above, along with more generic studies, such as those of Basson (1999), De Oliveira and Butterworth (2005), De Oliveira (2006), and Brunel et al. (2010), found that modifying management strategies to include environmental covariates did not improve the ability to achieve management goals over time-scales relevant to short- and medium-term fisheries management decision-making much, if at all. They did so only if information on the environmental factors driving the system were very well known."

3.2 Collie et al. (2021)

Full reference: Collie, J. S., Bell, R. J., Collie, S. B., & Minto, C. (2021). *Harvest strategies for climate-resilient fisheries*. ICES Journal of Marine Science, 78(8), 2774–2783. https://doi.org/10.1093/icesjms/fsab152.

Abstract [staff highlights in bold]:

A pressing challenge for climate-vulnerable fisheries is how to manage now for present and future climate change. In contrast to climate forecasting approaches, we track integrated signals of change for example populations in a climatically forced region and use stochastic dynamic programming to compare the performance of a range of management-ready policies over all possible future states. **Our main results highlight: (i) that biomass-linked harvest control rules (HCRs) can partially compensate for changing production, even if the HCR is time invariant; and (ii) that the form of utility (e.g. risk neutral or risk averse) can result in remarkably different optimal decision paths.** Performance over future horizons degrades marginally from dynamic HCRs to static HCRs (except at low productivity where differences are more pronounced) but markedly when the biomass level is ignored altogether, as is the case in many managed fish populations globally. Understanding the processes whereby climate affects productivity is important for interpreting past data, but forecasts are not needed for tactical decision making now. **Instead, we argue that the priorities for managing fish stocks influenced by climate change are to: measure the current productivity, assess the current abundance of the stock, and respond with a dynamic HCR.**

Key Points:

- Comprehensive overview, from assessment to management implementation
- Two categories for considering climate change impacts:
    - 1) Those associated with the assessment process (has generally been the focus); and
    - 2) Those associated with how assessment results are used for management decision-making
- "Harvest strategies operating in data-poor environments will often be limited to modifying decision rules, whereas more options are available for data-rich cases."
- There has been a broad focus on trying to incorporate environmental drivers into assessments, but that isn't always possible/appropriate.
- Section 2.4 (p. 947) provides an overview of strategies for adjusting reference points.
- "While a range of approaches are being considered and/or tested, to date, there is limited implementation in actual fisheries. This is owing to the lack of (or substantial uncertainty related to) a scientific basis for accounting for climate effects and/or a management system that is unable (or unwilling) to make use of such information."

3.3 Bessell-Browne et al. (2025)

Full reference: Bessell-Browne, P., Punt, A. E., Smith, D. C., Fulton, E., McDonald, A., Dickey-Collas, M., Duplisea, D. E., Haltuch, M. A., Mace, P., Penney, A., Plagányi, É., & Scott, R. (2025). *Incorporating climate change impacts within harvest strategies: An overview of approaches*. Fish and Fisheries, 26, 942–956. https://doi.org/10.1111/faf.70010.

Abstract [staff highlights in bold]:

Ensuring that harvest strategies are robust to climate change is a top priority for many fisheries jurisdictions globally. This is because climate change is altering ecosystem structure and the productivity of marine species. We outline a range of approaches for incorporating climate change impacts within harvest strategies, including how a harvest strategy is specified and changes to monitoring requirements. **Approaches evaluated include the use of extended stock assessments, multi-species and ecosystem models, revised management reference points, implementing regime shifts in model parameters, the provision of climate-sensitive catch advice, projections under alternative climate change scenarios and expanded use of management strategy evaluation.** We evaluate the utility of these approaches against cost, data needs and uncertainty criteria; highlight key learnings from a range of global jurisdictions and demonstrate the broad array of options available outside of direct incorporation of climate variables within stock assessments. **We identify approaches that have been successfully implemented and show that the most complex responses are not always the most successful. While there is no one-size-fits-all way to incorporate climate change within harvest strategies, we outline the need for flexible management arrangements.** We also provide examples of approaches that have been successfully implemented, demonstrating that many of the most data-intensive responses will only be applicable in a few cases, necessitating the application of cheaper, less data-intensive approaches that are associated with greater uncertainty.

Key Points:

- Comprehensive overview, from assessment to management implementation
- Two categories for considering climate change impacts:
  - 1) Those associated with the assessment process (has generally been the focus); and
  - 2) Those associated with how assessment results are used for management decision-making
- "Harvest strategies operating in data-poor environments will often be limited to modifying decision rules, whereas more options are available for data-rich cases."
- Has been a broad focus on trying to incorporate environmental drivers into assessments, but that isn't always possible/appropriate.
- Section 2.4 (p. 947) provides overview of strategies for adjusting reference points.
- "While a range of approaches are being considered and/or tested, to date, there is limited implementation in actual fisheries. This is owing to the lack of (or substantial uncertainty related to) a scientific basis for accounting for climate effects and/or a management system that is unable (or unwilling) to make use of such information."

Theme 4: Management and Implementation Considerations

4.1 Eddy et al. (2023)

<u>Full reference</u>: Eddy, T. D., Duplisea, D., Robertson, M. D., Ruiz-Díaz, R., Solberg, C. A., & Zhang, F. (2023). *Barriers to implementation of dynamic reference points in fisheries management*. FACETS, 8, 1–10. https://doi.org/10.1139/facets-2022-0216.

<u>Abstract [staff highlights in bold]</u>:

Fish populations are dynamic; their productivity depends on the environment, predator and prey interactions, and fisheries harvest rates. Failure to account for these factors in fisheries science and management can lead to a misestimation of stock dynamics and productivity, resulting in overexploitation or forgone fisheries yield. Using an online survey, we asked fisheries scientists, industry stakeholders, Indigenous partners, and non-governmental organizations whether changing ecosystem productivity was a problem in their experience, how often dynamic approaches to fisheries reference points have been adopted, what methods had been used, and what fisheries they had been applied to. **Changing fisheries or ecosystem productivity was reported as an issue by 96% of respondents; however, 74% of respondents said they had never seen dynamic reference points implemented, 16% said in very few instances, while 10% said frequently. The most common barriers to implementation of dynamic approaches in fisheries management were institutional inertia and uncertainty about whether a change in productivity was lasting. We discuss trade-offs between fisheries management performance and stability.**

<u>Key Points</u>:

- Biological reference point definition: "Reference points are tools to quantify management objectives, which often include target and limit reference points of resource biomass and associated fishing pressure (Caddy and Mahon 1995). Reference points help to define fisheries sustainability by balancing fisheries yield, sustainability, and conservation objectives (Carpenter et al. 2017)…Estimating biomass reference points for species with highly variable abundance and recruitment dynamics provides a challenge, and choice of reference point estimation method should consider species life history (Haltuch et al. 2009)… We refer to the process of allowing changes in reference points over time as *dynamic reference points*."
    - "Despite the existence of these methods, the practical application of dynamic reference points in fisheries management remains a challenge."
- There were 82 respondents to the survey representing expertise in 29 fishery types.
- "There are tradeoffs between management stability and management performance. Stability can be used as a metric of management performance, as it facilitates the implementation of management policies, maintains the credibility of management agencies, and allows for long-term planning by industry (Walters and Martell 2005)."
- "The scientific threshold of evidence for changing reference points within government departments may be high, and the resistance of the management system to allow large changes translates into a barrier of institutional inertia, resisting changes in reference points."

4.2 Szuwalski et al. (2023)

Full reference: Szuwalski, C. S., Hollowed, A. B., Holsman, K. K., Ianelli, J. N., Legault, C. M., Melnychuk, M. C., Ovando, D., & Punt, A. E. (2023). *Unintended consequences of climate-adaptive fisheries management targets*. Fish and Fisheries, 24(3), 439–453. https://doi.org/10.1111/faf.12737.

Abstract [staff highlights in bold]:

Climate change is projected to affect the productivity of global fisheries. Management based on maximum sustainable yield (MSY) has been effective at eliminating overfishing in many regions. However, continuing to use yield-maximizing targets under climate-driven changes in productivity can result in higher anthropogenic pressure on populations subject to climate-related stress than maintaining *status quo* management targets. We demonstrate this effect using a theoretical example and case studies from snow crab in the eastern Bering Sea and a global marine fisheries database. **In these examples, the conservation gain (i.e. biomass in the ocean) of maintaining *status quo* management targets is larger than the small gain in harvest made through climate adaptation in MSY-based management. The aggregate conservation gain of maintaining management targets increases as the harmful impacts of climate change on productivity worsen. Instead of climate-adaptive MSY-based targets, new management tools are needed to balance conservation and food production in ecosystems of populations displaying non-stationary productivity.**

Key Points:

- Makes the conservation case for maintaining *status quo* management targets in cases of harmful impacts of climate impacts on productivity
- Adjusting reference period for productivity: "For example, groundfish stocks reviewed by the North Pacific Fisheries Management Council use recruitment time series from 1977 to the most recent year of reliably estimated recruitment to estimate MSY-proxy reference points. This decision is based on a perceived ecological regime shift in the late 1970s and consistent data availability after this time period (see assessment documents at NOAA Fisheries, 2021)."
- "Climate-adaptive management targets resulted in slightly higher aggregate yields for our global fisheries case study, but losses in biomass disproportionately incurred by populations under stress overshadowed the small gains in yield."
- "It may be necessary to reconsider the use of yield-maximizing strategies to accommodate both conservation goals and food production under widespread changes in productivity."
- Managers will need to think about goals and tradeoffs: "In particular, managers may be faced with a choice of pursuing biomass levels similar to a pre-warming past, or yields reflective of a post-warming future."
- "We reinforce previous literature which showed that following the MSY paradigm may produce undesirable conservation outcomes for single populations and add that, when considered in aggregate, populations under climate stress would receive the brunt of the harm from MSY-based adaptation.