Accounting for closed areas in assessments: A mini-review of the literature

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1 Introduction

Inquiry into how unfished areas may affect population dynamics and be accounted for in mathematical models dates back to Beverton and Holt (1957). Establishing areas where fishing is prohibited gained popularity as a management tool in the late 1990s and early 2000s (Guénette et al. 1998), and when stock assessment results indicated that many U.S. West Coast rockfish species were overfished in the 2000s, fisheries managers established a series of Marine Protected Areas (MPAs) and Rockfish Conservation Areas (RCAs) along the U.S. West Coast where fishing was restricted (see Section 6.8 of the Pacific Coast Groundfish Fisheries Management Plan (FMP)). Such restrictions result in spatial heterogeneity in the rate of fishing mortality experienced by individuals of a stock that in turn can result in differing population structure across space. This poses a challenge for traditional stock assessment methods that assume spatial homogeneity in the effects of fishing on fish populations (Field et al. 2006). Whether the portion of a fished stock residing in areas that are closed to fishing is accounted for can influence the sustainability of management advice (Field et al. 2006).

The Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council (PFMC) raised and discussed the question of how to model closed areas within stock assessments during reviews of nearshore rockfish stock assessments in 2021 (Supplemental SSC Report 1, September 2021). This topic was again brought up during discussion of the 2023 quillback rockfish rebuilding plan (Supplemental SSC Report 1, March 2024). Nearshore rockfish fishing is excluded from relatively unchanging rockfish conservation areas and across depth restrictions that vary in space and time and by species. Limited information is available with which to monitor fish in closed areas, let alone determine the proportion of the stock in closed areas as well as movement of the stock across areas. As such, the assessments in 2021 modeled the stock by state areas, which were later codified within the FMP, and not by areas where fishing is restricted.

There is limited information with which to base a decision on how best to model closed areas within stock assessments. Therefore, the SSC has requested that this area be a topic of further research (e.g. Supplemental SSC Report 1, March 2024). While reviews have been conducted on the effect of closed areas on populations (e.g. Guénette et al. 1998) and considerations for management (Field et al. 2006), little has been done to synthesize how closed areas are modeled within assessment methods. The purpose of this report is to provide a description for how closed areas have been modeled within assessment methods in the literature. We do this by conducting a mini-review, which is a "direct, concise, and timely review article that tackles emerging issues" (Donaldson et al. 2011). While the issue of closed areas is not emerging *per se*, the questions raised during reviews in the PFMC reveal that the question of how to account for closed areas remains of interest. Our objective is not to prescribe in this report one approach over another. Rather, it is our belief that once the various approaches that have been used in the literature are described in one place, the SSC can then use this as a baseline to begin to discuss how might closed areas best be incorporated for PFMC assessments, or what information is first needed so that closed areas can best be incorporated into assessments. While our focus in this report is on assessments for the PFMC, it is our hope that this information will be of use to other regions and council bodies.

2 Methods

2.1 Literature search

To determine how closed areas have been modeled within assessment methods in the literature, we conducted a mini-review using the Web of Science database. Keywords used in our review were a combination of those associated with area closures ('protect*' OR 'closed' OR 'close' OR 'closing' OR 'closure*') AND ('area' OR 'areas' OR 'spatial') and stock assessment modeling ('stock assessments' OR 'stock assessment') AND ('model*'). Given the specificity of our question to fisheries management we also used ('fish*') to constrain the domain to articles with applications to fisheries. In the above keywords, the use of the asterisk (*) was to allow appropriate suffices, such as making a word plural, without specifying every possibility. All keywords were applied to titles, abstracts, keywords, and author keywords, which within Web of Science are included within the 'topic' category. Our search was constrained to articles published through 2023 by applying a cutoff publication date of December 31, 2023. We selected Web of Science as it provided search criteria specific for titles, abstracts, or keywords, and resulted in a manageable subset of articles that could be read and summarized within a reasonable amount of time. In contrast, using similar keywords within Google Scholar resulted in a prohibitively high number of articles as the keywords were applied also to the text of the article. No other databases beside Google Scholar were explored. Our choice of using only Web of Science limited our review to primary publications that are indexed by Web of Science.

2.2 Article selection

Among the articles that satisfied the keyword criteria, only a subset were selected for thorough consideration. The process of selecting articles followed the updated guidelines in the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al. 2021). Articles were initially culled from consideration based on reading the abstract and considering how the keywords were selected within our database search. We refer to this initial filtering as 'Step 1'. Articles with keywords or abstracts describing analyses that did not relate to our specific question of how to model closed areas within assessment methods were excluded from future consideration. This process can be subjective and so to reduce the chance of bias in excluding relevant articles, we separately determined relevance for each article. Articles where both authors of this review recommended exclusion were excluded, while articles where there was disagreement were discussed before removing or retaining. Articles without a clear reason for exclusion were kept for Step 2. Exclusion categories in Step 1 included articles

1. With unrelated keywords,
2. Not involving closed areas,
3. Not incorporating an assessment framework,
4. A combination of factors two and three,
5. Not related to the modeling of closed areas within a stock assessment framework, and
6. Simulation studies without a corresponding assessment/estimation method.

These categories were sequential, meaning that the broadest category (i.e. the lower numbered category) was selected first, followed by more specific categories. Once Step 1 was complete, and the full number of articles selected via keywords were reduced, the remaining articles were read in their entirety. Upon reading the full article, the same exclusion categories were applied to further reduce the domain of articles. We refer to this second stage of filtering as 'Step 2'. The determination of articles in Step 2 was done by the lead author.

Over the course of reading each of the articles in Step 2, references of potentially relevant articles that were not captured within our original keyword search were documented. These articles were filtered following the same process as those selected via keywords, first by reading the abstract, and then if relevant, by reading the full article, but the exclusion categories were not formally documented for these articles. We elected to expand our domain in this way to both maintain reproducibility of our methods, but also to potentially document ways of including closed areas within articles that our keywords did not initially access. After obtaining articles relevant to our question, the way in which closed areas were modeled was determined and described.

We are aware that various types of closed areas come with different naming terminology and restrict access at varying degrees. While our literature search was focused on marine protected areas, which typically allow some fishing activities, closed areas in fisheries can represent marine reserves or exclusion areas that restrict all extraction, depth closures, or gear based limitations. We use the term closed areas throughout this paper to reflect areas closed to harvest for the species of interest throughout an entire year. We do not focus on closures in time, such as over a single season, because these can be modeled differently. We also do not focus on natural refugia, which could occur due to inaccessibility of the resource to the fleet, such as with distance from shore or depth, or due to unfishable habitat.

3 Results

3.1 Literature search and article selection

We assume that the primary interest of the Groundfish Subcommittee of the SSC is accounting for closed areas. Our focus here then is on how closed areas were modeled within assessment methods. Therefore, only a high-level summary of article selection is provided here, while more details will be included in the manuscript for journal submission.

The keyword search produced 158 potentially relevant articles. Using ‘stock’ with ‘assessment’ and ‘assessments’ reduced the domain of possible articles (down from 825) to those focused on our application of modeling these methods in stock assessments, and not the much broader definition of ‘assessment’ to evaluate or estimate something. Similarly, connecting stock assessments with ‘model*’ (through the use of AND) as opposed to allowing one or the other (through the use of OR) substantially reduced the domain of possible articles (down from approximately 5,000). Among the keywords related to closures, “protect*” had the greatest effect in expanding the domain of possible articles, nearly doubling the number (up from 82).

The majority of articles that were removed from consideration were removed in Step 1. A total of 95 of the 158 articles were removed by reading through the abstracts and evaluating how the keywords were selected and potential relevance to our question. Of the remaining 63 articles, a total of 49 were removed after reading through the entire text, leaving 14. In addition to the 14 articles resulting from the keyword search, another 7 articles that were found among the references from the articles read during Step 2 were relevant. Collectively, 21 articles provide a picture of the ways closed areas have been incorporated in assessment methods within the peer-reviewed literature.

3.2 Ways to model closed areas

Closed areas are incorporated within assessment methods in a number of ways, from inclusion within integrated statistical catch-at-age models to empirical harvest control rules. We refer to these as model-based and data-based categories, respectively. Approaches within each category are listed below with details provided in Table 1. Multiple modeling approaches were applied in some articles so the sum across approaches is greater than the number of model-based articles.

1. Model based (11 articles)
    a) Aggregate: Model closed and open areas together (7 articles)
    b) Separate: Model closed and open areas as separate models (5 articles)
    c) Spatial: Model closed and open areas distinctly within a spatial model (7 articles)
2. Data based (10 articles)
    a) Sampling in closed areas to estimate model parameters (4 articles)
    b) Sampling in closed areas to approximate status (3 articles)
    c) Sampling in closed areas as empirical harvest control rules (3 articles)

3.2.1 Model closed and open areas together (Aggregate)

At its core, this approach treats closed areas the same as open areas. This approach is more common than our review would suggest. Unless specific consideration of open and closed area is an objective of an article, and therefore mentioned, any application with closed areas would fall under this category. We include this category for two reasons. First, most articles where this approach was considered compared it to other approaches. This was the case in Punt et al. (2016), Punt et al. (2017), McGilliard et al. (2015), Punt and Methot (2004), Garrison et al. (2011), and Pincin and Wilberg (2012). Second, some articles using this approach utilized an additional mechanism to account for closed areas. Two different alternative mechanisms were used to account for closed areas despite aggregating open and closed areas within the same model. The first mechanism was to allow dome-shaped selectivity; that is to allow fleet selectivities to be estimated such that selectivity declines at larger sizes (Hart et al. 2013; McGilliard et al. 2015). The logic is that with a closed area, a portion of the population is inaccessible to the fishery, and that portion typically includes larger-sized individuals. The second mechanism was to allow fleets to indirectly represent area closures (Punt et al. 2016, 2017). This approach establishes separate fleets corresponding to open and closed areas, where selectivity can either be the same across fleets (i.e. a “data-weighted” approach), or estimated independently (i.e. a “fleets-as-areas” approach). While our objective was not to rank across approaches, all of the above articles compared combining closed and open areas to other approaches. Consequently, we summarize those comparisons in Section 3.3.

3.2.2 Model closed and open areas as separate models (Separate)

Some articles modeled closed and opened areas within separate models. Articles where this was done include McGilliard et al. (2015), Hart et al. (2013), Hart and Chang (2022), Garrison et al. (2011), and Damiano and Wilberg (2019). Ideally, this approach is done with data that have sufficient spatial resolution so as to be attributable to a specific area. For this approach, movement among areas was generally not considered, and recruitment was assumed to be local to each area. However, natural mortality (M) was estimated by McGilliard et al. (2015) to serve as a proxy for movement.

3.2.3 Model closed and open areas distinctly within a spatial model (Spatial)

The third approach within the modeling category represents the most model intensive way of incorporating closed areas. Closed and open areas were modeled separately within a single model, often with movement being estimated and localized recruitment apportioned from a global recruitment estimate. Articles with this approach include Punt et al. (2016), McGilliard et al. (2015), Garrison et al. (2011), Pincin and Wilberg (2012), Hobday et al. (2005), Little et al. (2017), and Punt and Methot (2004). Among these, adult movement was not estimated in Punt et al. (2016), Little et al. (2017), and Punt and Methot (2004). As when closed and open areas are modeled across separate models, data with sufficient spatial resolution are ideal, but when not available, some authors apportioned catch based on the proportion of areas that are closed (e.g. Hobday et al. 2005).

3.2.4 Sampling in closed areas to estimate modeled parameters

Whereas the above approaches involve modeling of closed areas in assessment methods, many articles incorporated closed areas by collecting data (really using collected data) to estimate fishing intensity. While these are not traditional stock assessments approaches, they inform quantities used for management actions. Belharet et al. (2020) used size structure data from closed areas to estimate M and from open areas to estimate total mortality (Z). They then used these estimates to derive fishing mortality (F) estimates that they applied to a detailed spatial simulation. Willis and Millar (2005) utilized a similar approach by using data collected in open and closed areas to estimate an upper limit of exploitation rate for a seasonally migrating fish. In another application, a mark-recapture study design was simulated from closed and open areas to estimate F directly and shown to be less biased from known stockwide F compared to depletion model estimates of F in open areas (Harford et al. 2015). Lastly, Wilson et al. (2014) used length frequency distributions from open and closed areas along with knowledge of life-history parameters to develop distinct spawner-per-recruit (SPR) estimates that were then weighted based on the proportion of area closed to fishing to obtain a stockwide SPR estimate.

3.2.5 Sampling in closed areas to approximate status

Data sampling was also conducted within closed areas as a proxy for stock status. This method was applied only to mollusks and arthropods, whereas other approaches were applied to fish populations. Hanns et al. (2022) applied linear regressions of catch rate and biomass estimates at sites sampled by surveys in and around MPAs for rock lobster. They used the ratio of the regression coefficients of closure status (open vs. closed) as an approximation of stock status. Diaz et al. (2016) also used ratios of density (from data, not regression coefficients) of spiny lobster in open versus closed areas as a proxy for stock status of spiny lobster based on published targets (Babcock and MacCall 2011). They also calculated SPR to determine a measure of fishing intensity by assuming the closed areas represented unfished conditions. A similar approach of calculating SPR based on the assumption that closed areas reflect unfished conditions was also made for queen conch (Acosta 2006).

3.2.6 Sampling in closed areas as empirical harvest control rules

The last approach of incorporating closed areas in assessment methods was through the use of applying empirical harvest control rules. Here, the process of data collection acts as the assessment method, thus this approach is generally considered for data-poor applications. With that said, the articles using this approach did so within a simulation framework to explore the viability of this approach. Articles used CPUE in closed versus open areas (Wilson et al. 2010) and ratios of density in closed versus open areas (Babcock and MacCall 2011; McGilliard et al. 2011) as empirical control rules. Wilson et al. (2010) simulated their control rule within a management strategy evaluation (MSE) and found it could maintain SPR levels of around 40 percent, though did apply other factors from open areas within the control rule. McGilliard et al. (2011) also tested their control rule within an MSE framework, and found that the performance of the control rule depended on the number of years since closures were applied. Babcock and MacCall (2011) simulated their approach across many scenarios and density thresholds to find ones that were robust to model assumptions, and therefore provide targets for density ratios equal to 60 percent if based on mature fish, and 80 percent if based on all fish.

3.3 Comparisons among model-based approaches

Although our objective for this review was to describe ways closed areas have been incorporated in assessment methods, the articles described in Section 3.2.1 compared across different approaches, and so we provide a summary of those comparisons here. Unfortunately, no comparisons were made within articles accounting for closed areas through data-based approaches. Earlier modeling studies compared two approaches, modeling closed and open areas together within a single area model, and modeling closed and open areas either as sub-models within a single spatially explicit model (Punt and Methot 2004) or as distinct areas within separate models (Hart et al. 2013). These studies found that in general aggregate models performed worse than models where closed and open areas were accounted for separately (either by separate models or within spatially explicit models), and the benefit of modeling closed and open areas increased with the degree of biological difference between the two regions. These findings were supported in later studies that compared across different approaches. McGilliard et al.

(2015) found that adding dome-shaped selectivity or excluding fishery CPUE during periods where closed areas existed improved performance when closed and open areas were aggregated, but that separate models performed better than any type of aggregate model. They also found that spatial assessments with movement performed the best among all approaches. Punt et al. (2016) compared similar approaches as McGilliard et al. (2015) and came to similar conclusions. When considered within an MSE framework, Punt et al. (2017) found that closures introduce bias in assessments that can negatively affect the ability to reach management goals, but that bias due to not accounting for closures did not necessarily preclude attainment of management goals.

4 Discussion

Relatively few articles within the primary literature describe ways to incorporate closed areas within assessment methods. Only 21 articles were selected from our mini-review, but both model-based and data-based approaches were applied. Our work shows that there are a number of ways to account for closed areas, and these invariably depend on the underlying dynamics of the species being assessed as well as the data available and needs for which assessments are being applied. This level of diversity is not surprising, given that there is a continuum of stock assessment approaches (Cope 2024).

4.1 Common Themes

While our objective was to describe the approaches for incorporating closed areas in assessment methods within the literature, a number of common themes were present. One common theme is that approaches exist from data rich to data poor applications. Approaches to account for closed areas exist within stock assessments with a suite of data types available (Punt et al. 2017), to estimate specific parameters, or when only density estimates are available (Babcock and MacCall 2011). Accounting for closed areas improved (or allowed) estimates of M (Garrison et al. 2011; Belharet et al. 2020; Hart and Chang 2022), whereas growth and recruitment estimates were less improved (Garrison et al. 2011), though improvements were not universally considered meaningful (Punt and Methot 2004). While comparisons among modeling approaches were made, the literature lacks comparisons of empirical data-based approaches within the same study, or a combination of approaches for modeling applications with limited data.

Where comparisons were made among modeling approaches, it was clear that specifically accounting for closed and open areas as opposed to aggregating data in each area improves model estimates. As shown by Punt et al. (2017), the bias imposed by not accounting for closed areas need not preclude achievement of management goals, however general patterns showed that accounting for closed areas improved model performance over not accounting for closed areas. This shows that closed and open areas within assessments should be accounted for (as feasible) given the data available for each application.

A third common theme across articles was that having data available within closed areas is valuable. The majority of articles exploring approaches for modeling included survey data within closed areas. Pincin and Wilberg (2012) found that modeling closed and open areas explicitly without a relative index of abundance in the closed area reduced model performance such that the model performed worse than when aggregating open and closed areas together. Thus they consider monitoring the population within the closed areas to be essential. This makes sense given that they applied a surplus production model, and so in their application removing a relative abundance index removes the primary signal of population trends. However, other studies with additional data types (i.e. age or length compositions) also found that the presence of survey data in closed areas resulted in improved model performance compared to when survey data were not included (Punt and Methot 2004; Punt et al. 2016; Little et al. 2017). The lone potential contradicting article was Punt et al. (2017), which found that excluding survey data in closed areas only had a limited effect on management outcomes.

The final common theme was that details of closed areas or the underlying populations influenced the performance of the approach. While these details were primarily compared among model-based approaches, data-based approaches also considered these. The primary detail was that the underlying movement of the populations influenced performance of the approaches. This is not surprising in that movement can influence the magnitude of differences between closed and open areas. Movement increased model error when closed areas were accounted for (Punt and Methot 2004), and had a large influence on the performance of approaches (McGilliard et al. 2015). In fact, among empirical approaches, the magnitude of movement was the greatest biological factor on approach effectiveness (Hobday et al. 2005; Babcock and MacCall 2011; McGilliard et al. 2011).

The other two details include the time since closed areas were established, and the relative size of closed areas. Time since inception matters. Punt and Methot (2004) found that modeling closed and open areas together resulted in similar performance to modeling closed and open areas spatially after 20 years since the inception of closures, but were different after 60 years. Pincin and Wilberg (2012) found that estimates were more precise after approximately 20 to 30 years had passed since closures were implemented, and McGilliard et al. (2011) noted their approach achieved a higher percentage of optimal catch the more time had past since implementing closures. The relative proportion of closed areas also matters. Larger fractions of closed areas have greater effects on the underlying population (Pincin and Wilberg 2012; Punt et al. 2017). Wilson et al. (2014) noted that marine reserve fractions above 40 percent were able to maintain management objectives. Larger areas have the potential to increase difference between modeling approaches. While Pincin and Wilberg (2012) found that the accuracy of either approach improved as closed area size increased when survey data were present (they tested up to 40 percent), accuracy greatly decreased with closed area size when survey data were absent.

4.2 Future work

There remain areas where work on this topic can continue. First and foremost, it is possible additional articles exist that were not selected within our keyword search. Modeling closed areas is a combination of the MPA and spatial modeling literature, which is large in the case of MPAs (e.g. Guénette et al. 1998; Pelletier and Mahévas 2005) and growing larger in the case of spatial modeling (e.g. Punt 2019; Berger et al. 2024). To offset this concern, we considered, and included when applicable, additional articles from the references of articles found from our keyword search. Searching across formal stock assessment reports may be another way to identify additional approaches for incorporating closed areas in assessment methods. Assessments are often published as agency reports or technical memorandums, and housed on websites without an efficient way for determining whether closed areas are incorporated. Future efforts could more formally search through assessment reports to find additional approaches, possibly using methods developed for searching key terms in assessment reports (Wetzel et al. 2024).

We also noted that comparisons among approaches were often focused on modeling approaches. This is sensible but comparisons among empirical methods, or a mix of empirical and modeling approaches could be done in future efforts. Comparisons among methods could also be recreated with more restrictive data availability scenarios. Inclusion or exclusion of survey data in closed areas were often explored, as were changing the dynamics of the underlying population structure (e.g. movement), but changing the availability of fishery data was less often considered. Questions around data availability, like "How can closed areas be modeled when fishery data are not attributable to areas that were open in the past but are now closed?" can allow for situations that simulations with full data series for fishery-dependent sources cannot.

The last area were closed areas research can be advanced is in advocating for data collection. For PMFC applications, the proportion of area closed relative to open is not known for many species. Our literature search revealed that the effect on performance of not accounting for closed areas depends on the relative size of areas that are closed. Moreover, there is limited sampling within closed areas apart from some sampling by the California Collaborative Fisheries Research Program in and around MPAs, and fishery independent survey stations within Cowcod Conservation Areas. Nearshore fisheries are not always well-sampled in existing fishery-independent surveys and therefore monitoring fish within closed areas (e.g. RCAs) or nearshore depth restrictions can be used to understand differences in population dynamics, if they exist. Our literature search showed that among simulations, effects of not including closed areas were noticeable after 20 years for two U.S. West Coast rockfish species (Punt and Methot 2004), a timeframe that approximates the current time over which closed areas have existed. Lastly, information on movement was also found to be important to performance of approaches for modeling closed areas. Studies on site fidelity exist but this differs from movement rates in and out of closed areas. However, McGilliard et al. (2015) showed that accounting for closed areas regardless of whether movement was known produced robust results, so knowing movement may be less critical for applying modeling approaches compared to other data collection efforts.

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6 References

A full list of references from our literature search is available from the author at brian.langseth@noaa.gov. Only references cited in this report are provided below.

Acosta, C.A. 2006. Impending trade suspensions of caribbean queen conch under CITES: A case study on fishery impacts and potential for stock recovery. Fisheries **31**(12): 601–606. doi:10.1577/1548-8446(2006)31{[}601:itsocq]2.0.co;2.

Babcock, E.A., and MacCall, A.D. 2011. How useful is the ratio of fish density outside versus inside no-take marine reserves as a metric for fishery management control rules? Canadian Journal of Fisheries and Aquatic Sciences **68**: 343–359.

Belharet, M., Di Franco, A., Calo, A., Mari, L., Claudet, J., Casagrandi, R., Gatto, M., Lloret, J., Seve, C., Guidetti, P., and Melia, P. 2020. Extending full protection inside existing marine protected areas, or reducing fishing effort outside, can reconcile conservation and fisheries goals. Journal Of Applied Ecology **57**(10): 1948–1957. doi:10.1111/1365-2664.13688.

Berger, A.M., Barceló, C., Goethel, D.R., Hoyle, S.D., Lynch, P.D., McKenzie, J., Dunn, A., Punt, A.E., Methot, R.D., Hampton, J., Porch, C.E., McGarvey, R., Thorson, J.T., A'mar, Z.T., Deroba, J.J., Elvarsson, B.Þ., Holmes, S.J., Howell, D., Langseth, B.J., Marsh, C., Maunder, M.N., Mormede, S., and Rasmussen, S. 2024. Synthesizing the spatial functionality of contemporary stock assessment software to identify future needs for next generation assessment platforms. Fisheries Research **275**: 107008. doi:https://doi.org/10.1016/j.fishres.2024.107008.

Beverton, R.J.H., and Holt, S.J. 1957. On the dynamics of exploited fish populations. Her Majesty's Stationery Office, London.

Cope, J.M. 2024. The good practices of practicable alchemy in the stock assessment continuum: Fundamentals and principles of analytical methods to support science-based fisheries management under data and resource limitations. Fisheries Research **270**: 106859. doi:https://doi.org/10.1016/j.fishres.2023.106859.

Damiano, M.D., and Wilberg, M.J. 2019. Population dynamics of eastern oysters in the choptank river complex, maryland during 1989-2015. Fisheries Research **212**: 196–207. doi:10.1016/j.fishres.2018.12.023.

Diaz, D., Mallol, S., Parma, A.M., and Goni, R. 2016. A 25-year marine reserve as proxy for the unfished condition of an exploited species. Biological Conservation **203**: 97–107.

Donaldson, M.R., Aday, D.D., and Cooke, S.J. 2011. A call for mini-reviews: An effective but underutilized method of synthesizing knowledge to inform and direct fisheries management, policy, and research. Fisheries **36**(3): 123–129.

Field, J.C., Punt, A.E., Methot, R.D., and Thomson, C.J. 2006. Does MPA mean "major problem for assessments"? Considering the consequences of place-based management systems. Fish And Fisheries **7**(4): 284–302. doi:10.1111/j.1467-2979.2006.00226.x.

Garrison, T.M., Hamel, O.S., and Punt, A.E. 2011. Can data collected from marine protected areas improve estimates of life-history parameters? Canadian Journal Of Fisheries And Aquatic Sciences **68**(10): 1761–1777. doi:10.1139/f2011-073.

Guénette, S., Lauck, T., and Clark, C. 1998. Marine reserves:: From beverton and holt to the present. Reviews In Fish Biology And Fisheries **8**(3): 251–272. doi:10.1023/a:1008859130275.

Hanns, B.J., Haggitt, T., and Shears, N.T. 2022. Marine protected areas provide unfished reference information to empirically assess fishery status. Biological Conservation **276**. doi:10.1016/j.biocon.2022.109775.

Harford, W.J., Ton, C., and Babcock, E.A. 2015. Simulated mark-recovery for spatial assessment of a spiny lobster (*panulirus argus*) fishery. Fisheries Research **165**: 42–53. doi:10.1016/j.fishres.2014.12.024.

Hart, D.R., and Chang, J.-H. 2022. Estimating natural mortality for atlantic sea scallops (*placopecten magellenicus*) using a size-based stock assessment model. Fisheries Research **254**. doi:10.1016/j.fishres.2022.106423.

Hart, D.R., Jacobson, L.D., and Tang, J. 2013. To split or not to split: Assessment of georges bank sea scallops in the presence of marine protected areas. Fisheries Research **144**(Si): 74–83. doi:10.1016/j.fishres.2012.11.004.

Hobday, D., Punt, A.E., and Smith, D.C. 2005. Modelling the effects of marine protected areas (MPAs) on the southern rock lobster fishery of victoria, autralia. New Zealand Journal of Marine and Freshwater Research **39**(3): 675–686.

Little, L.R., Punt, A.E., Tuck, G.N., and Mapstone, B.D. 2017. Exploring the effect of sampling, protogyny, and larval advection on stock estimates subject to no-take closures in a spatially complex coral reef fishery on the great barrier reef australia. Canadian Journal of Fisheries and Aquatic Sciences **74**: 1950–1959.

McGilliard, C.R., Hilborn, R., MacCall, A., Punt, A.E., and Field, J.C. 2011. Can information from marine protected areas be used to inform control-rule-based management of small-scale, data-poor stocks? ICES Journal of Marine Science **68**(1): 201–211.

McGilliard, C.R., Punt, A.E., Methot, R.D., Jr., and Hilborn, R. 2015. Accounting for marine reserves using spatial stock assessments. Canadian Journal Of Fisheries And Aquatic Sciences **72**(2): 262–280. doi:10.1139/cjfas-2013-0364.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., and Moher, D. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ **372**. doi:10.1136/bmj.n71.

Pelletier, D., and Mahévas, S. 2005. Spatially explicit fisheries simulation models for policy evaluation. Fish and Fisheries **6**(4): 307–349. doi:https://doi.org/10.1111/j.1467-2979.2005.00199.x.

Pincin, J.S., and Wilberg, M.J. 2012. Surplus production model accuracy in populations affected by a no-take marine protected area. Marine And Coastal Fisheries **4**(1): 511–525. doi:10.1080/19425120.2012.685145.

Punt, A.E. 2019. Spatial stock assessment methods: A viewpoint on current issues and assumptions. Fisheries Research **213**: 132–143. doi:10.1016/j.fishres.2019.01.014.

Punt, A.E., Haddon, M., Little, L.R., and Tuck, G.N. 2016. Can a spatially-structured stock assessment address uncertainty due to closed areas? A case study based on pink ling in australia. Fisheries Research **175**: 10–23. doi:10.1016/j.fishres.2015.11.008.

Punt, A.E., Haddon, M., Little, L.R., and Tuck, G.N. 2017. The effect of marine closures on a feedback control management strategy used in a spatially aggregated stock assessment: A case study based on pink ling in australia. Canadian Journal Of Fisheries And Aquatic Sciences **74**(11, Si): 1960–1973. doi:10.1139/cjfas-2016-0017.

Punt, A., and Methot, R. 2004. Effects of marine protected areas on the assessment of marine fisheries. *In* Aquatic protected areas as fisheries management tools. *Edited by* J. Shipley. pp. 133–154.

Wetzel, C.R., Stawitz, C.C., Li, B., Johnson, K.F., and Schmitz, G.M. 2024. Ordering the alphabet soup: Strategies to improve consistency and develop a framework of tools for fisheries science vocabulary. Fisheries Research **278**: 107104. doi:https://doi.org/10.1016/j.fishres.2024.107104.

Willis, T.J., and Millar, R.B. 2005. Using marine reserves to estimate fishing mortality. Ecology Letters **8**: 47–52.

Wilson, J.R., Prince, J.D., and Lenihan, H.S. 2010. A management strategy for sedentary nearshore species that uses marine protected areas as a reference. Marine And Coastal Fisheries **2**(1): 14–27. doi:10.1577/c08-026.1.

Wilson, J.R., Valencia, S.R., Kay, M.C., and Lenihand, H.S. 2014. Integration of no-take marine reserves in the assessment of data-limited fisheries. Conservation Letters **7**(5): 451–458.

Table 1: Ways in which closed areas are accounted for within assessment methods in the primary literature

Category	Groupings	Approach	Location	Application species	Source
Model-based	Spatially Aggregated	Combine open and closed areas in single model	Australia	Pink ling	Punt et al. 2016; 2017
			U.S. West Coast	Rockfish species	McGilliard et al. 2015
			U.S. West Coast	Rockfish species	Punt and Methot 2004
			Unspecified	Unspecified	Garrison et al. 2011
			Unspecified	Unspecified	Pincin and Wilberg 2012
		Dome-shaped selectivity in years with closed areas	Georges Bank	Scallops	Hart et al. 2013
			U.S. West Coast	Rockfish species	McGilliard et al. 2015
		Fleets-as-areas	Australia	Pink ling	Punt et al. 2016; 2017
	Spatially Separate	Open and closed areas modeled separately	U.S. West Coast	Rockfish species	McGilliard et al. 2015
			Georges Bank	Scallops	Hart et al. 2013
			Georges Bank	Scallops	Hart and Chang 2022
			Unspecified	Unspecified	Garrison et al. 2011
			Chesapeake Bay	Eastern oyster	Damiano and Wilberg 2019
	Spatially Explicit	Open and closed areas as sub-regions, no movement	Australia	Pink ling	Punt et al. 2016
			Australia	Coral trout	Little et al. 2017
			U.S. West Coast	Rockfish species	Punt and Methot 2004
		Open and closed areas as sub-regions, with movement	U.S. West Coast	Rockfish species	McGilliard et al. 2015
			Unspecified	Unspecified	Garrison et al. 2011
			Unspecified	Unspecified	Pincin and Wilberg 2012
			Australia	Rock lobster	Hobday et al. 2005
Data-based	Parameter Estimation	Stockwide F (via tagging)	Belize	Rock lobster	Harford et al. 2015
		Exploitation rate	New Zealand	Snapper	Willis and Millar 2005
		Stockwide SPR	U.S. West Coast	Grass rockfish	Wilson et al. 2014
		Estimate M in closed areas to estimate F in open areas	Mediterranean	Seabream and Grouper	Belharet et al. 2020
	Approximate Status	Linear model coefficient ratio	New Zealand	Rock lobster	Hanns et al. 2022
		SPR from SSB in survey	Belize	Queen conch	Acosta 2006
		Density ratios and SPR	Mediterranean	Spiny lobster	Diaz et al. 2016
	Harvest Control Rule	CPUE	U.S. West Coast	Grass rockfish	Wilson et al. 2010
		Density ratio	U.S. West Coast	Various rockfish	Babcock and MacCall 2011
			Unspecified	Unspecified	McGilliard et al. 2011