Differential impacts of shifting species distributions on Closed Areas

DK

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## Intro

1. Georges Bank (GB) has historically been one of the world’s most productive fishing grounds. Several formerly abundant groundfish stocks have experienced declines that have resulted in the cessation of directed fisheries.
2. Subsequently, management agencies in both Canada and the United States (U.S.) have implemented various restrictions in an effort to rebuild these stocks; these restrictions include the implementation of closures. Yellowtail Flounder (*Limanda ferruginea*) and Atlantic Cod (*Gadus morhua*) are two groundfish stocks which have substantially declined and the rationale for closures on GB has included the need to protect these stocks.
3. In the U.S. these closures were relatively large and focused more broadly on rebuilding these and other stocks on GB. A number of closures have been implemented over the last several decades in large part to protect groundfish on Georges Bank (Murawski 2000), specifically Atlantic cod, haddock, and yellowtail flounder. These closures were initially linked to recovery of several stocks on GB, including yellowtail and cod (Murawski 2000), but these recoveries were ephemeral and both of these stocks are currently near historical low biomass across Georges Bank. CA-II was one of the first and largest of these closures, the footprint of CA-II has largely remained unchanged since first being put in place in December of 1994, while management measures have varied over time to allow some activity in this closure, it is the longest serving and largest year-round closure on GB.
4. Meanwhile, in Canada the closures are directed towards the protection of these cod/yellowtail stocks during spawning. There are 3 notable seasonal closures designed to protect spawning aggregations of groundfish in Canada. Define goals of closures as best as possible given documentation available. Groundfish closure is to not disturb spawning aggregations, what is objective of scallop closures, low bycatch or no disturbance (to KVs point). For groundfish this is easy as we will just point out where core area is during spawning, for scallop closures want to point out that we don’t know if closures overlap with core area, cite the PLOS One paper.
5. Our objectives are to use a spatio-temporal species distribution model to
   * Quantify the size of and changes in ‘core area’ for each stock in CA-II and compare with trends observed within the rest of the U.S. waters on GB.
   * Quantify the size of and changes in ‘core area’ for three spawning closures located in Canadian waters.

## Methods

1. Simplify from last paper and point there for detailed model bits, here just point out what model was used for analyses based on that paper. Talk about closures and overlap mostly. Need to clarify that for CA I and CA II we are including the portions of these closures within our analysis domain.

## Results

1. U.S. story
   1. U.S. waters outside of CA-II have experienced substaintial declines in the size of the core area of both cod and yellowtail and excluding CA-II there is almost no core area remaining for either cod or yellowtail. For both stocks the size of the core area has declined steadily over time.
   2. CA-II has experienced significant declines in the size of core area of Atlantic cod, but the size of the core area has rebounded after a substainal decline in the 1980s for yellowtail flounder despite widespread declines in the size of the core area throught the rest of US-GB. CA-II contains the vast majority of core area found within U.S. waters for yellowtail. It is also now the primary area within the U.S. portion of GB that core area for cod is observed on the U.S. side of the bank.
2. Canadian story
   1. The size of the core area in the Canadian groundfish closure has been relatively consistent through time during spawning for both stocks. The percentage of core area on GB located within this closure has increased substatially during spawning over time for both stocks. For yellowtail this is due in part to an increase in the size of the core area in Candian waters, but also due to the decline in core area within U.S. waters outside of CA-II. The size of the core area for cod has declined slowly over time in the fall as the distribution of cod appears to be shifting outside the GB domain used for this study at this time of year.
   2. The cod closures have primarly been located inside the cod core area during spawning, but the size of the core area in Canada is substantially larger than this closure. This closure only protects a small fraction of the core area that is avaialbe to the COSF.
   3. The yellowtail closures have primarly been located inside of yellowtail core area during spawning, but the size of the core area in Canada is substantially larger than this closure. This closure only protects a small fraction of the core area that is avaialbe to the COSF.

## Discussion

1. Within U.S. waters the majority of core area remaining for both stocks is found within CA-II. For yellowtail CA-II has remained an important area for yellowtail throughout time, despite the collapse of core area from the remainder of U.S. waters. For cod, the remaining core area in U.S. water is only a fraction of what was observed in the past, with CA-II again housing the majority of the core area in U.S. waters. Within the Canadian groundfish spawning closure the size of the yellowtail core area has generally increased while the cod core area is relatively unchanged. Given the trends in U.S. outside of CA-II this has resulted in CA-II and the Canadian closures containing an increased percentage of core area during spawning over time for both stocks.
2. Previous analyses within U.S. waters on GB have shown widespread benefits to the broader GB ecosystem. These benefits were evident for yellowtail and cod in the early years of the closures (Murawski 2000) but this analysis suggests that neither stock has been consistently observed outside of CA-II in almost 3 decades. While CA II contains much of the remaining core area for yellowtail in U.S. waters, cod have basically emigrated into Canadian waters.
3. The smaller time-area closures that are in place for the COSF are also largely located core area, but the small size of these closures results in these closures protecting a small fraction of the core area for both stocks. A previous non-spatial analysis for the COSF closures revealed little evidence of an impact of these closures. This analysis augments those results indicating that the core spawning area for both stocks is much larger than the size of these closures, thus these closures would have little impact on the interactions between the COSF and spawning aggregations. Other measures, such as reduced effort and voluntary move protocols, have resulted in a substantial decline in bycatch/discards from the COSF and other more adaptive management measures would (O’Keefe) would likely be more effective if further reductions in discards from this fishery during spawning were deemed to be necessary.
4. Proper monitoring of closures is necessary to ensure they a continuing to meet their conservation objectives. Broad ecosystem objectives for static closures likely to be more effective than closures with a narrow scope that focus on particular species given the potential for the species to move out of these areas over time when exposed to directional shifts in environmental conditions. When developing MPAs and conservation based closures we need to be mindful of the potential for species distributions to change over time, if the scope of the closure is too narrow it may no longer meet the original objectives, but of course it may well be conferring some other benefit within the ecosystem.

### Maybe a quick point in the discussion….

1. CA-I was formerly a large year-round closure on GB, it was not directly included in this analysis because of changes in the size and management of the are over time. It is currently a seasonal spawning closure with a much larger footprint than the closure implemented in 1994. Approximately 50% of the original closure is found within the domain of this study. The core area for both species has declined substantially within the portion of CA-I in this study, in line with the overall declines observed outside of CA-II on GB. The changes in the size of core-area can be found in our dashboard.