Appendix B1: Term of Reference 6

Evaluate the magnitude, trends and uncertainty of predator consumptive removals on butterfish and associated predation mortality estimates and, if feasible, incorporate said mortality predation estimates into models of population dynamics.

Introduction

Food habits were evaluated for a wide range of butterfish predators. The total amount of food eaten and the type of food eaten were the primary food habits data examined. From these basic food habits data, diet composition of butterfish, per capita consumption, total consumption, and the amount of butterfish removed by these butterfish predators were calculated. Combined with abundance estimates of these predators, when summed the total amount of butterfish removed by predators was calculated. Contrasts to estimates of landings (see above) were conducted to place this source of mortality into context and to fully address the Term of Reference.

Methods

Every predator that contained butterfish was identified from the NEFSC Food Habits Database System (FHDBS). From that original list, a subset of predators was analyzed to elucidate which predators consistently ate butterfish with a diet composition of >1% for any five year block. The consistent butterfish predators are listed in Table B.6.1.

Estimates were calculated on a seasonal basis (two 6 month periods) for each predator species, summed for each annum. Although the food habits data collections started quantitatively in 1973, not all species of butterfish predators were sampled during the full extent of this sampling program. For more details on the food habits sampling protocols and approaches, see Link and Almeida (2000). This sampling program was a part of the NEFSC bottom trawl survey program; for background and context, further details of the survey program can be found in Azarovitz (1981) and NEFC (1988).

This approach followed previously established and described methods for estimating consumption, using an evacuation rate model methodology. For further details, see Durbin et al. (1983), Ursin et al. (1985), Pennington (1985), Overholtz et al. (1991, 1999, 2000, 2008), Tsou & Collie (2001a, 2001b), Link & Garrison (2002), Link et al. (2002, 2006, 2008, 2009), Methratta & Link (2006), Link & Sosebee (2008), Overholtz & Link (2006, 2007), Tyrrell et al. (2007, 2009), Link and Idoine (2009), Moustahfid et al. (2009a, 2009b), and NEFSC (2006, 2007a, 2007b, 2008). The main data inputs are mean stomach contents (S_i) for each butterfish predator i, diet composition (D_{ij}) where j is the specific prey butterfish, and T is the bottom temperature taken from the bottom trawl surveys (Taylor et al. 2005). Estimates of variance about all these variables (data inputs) were calculated. Further particulars of these estimators can be found in Link and Almeida (2000). Units for stomach estimates are in g.

As noted, to estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There has been copious experience in this region using these models (see references listed above). The two main parameters, α and β, were set to 0.004 and 0.11 respectively based upon prior studies and sensitivity

analyses (NEFSC 2007a, 2007b). The exception is that α was set to 0.002 for elasmobranch predators to reflect their slightly lower metabolism than teleost fishes.

Once daily per capita consumption rates were estimated for each butterfish predator those estimates were then scaled up to a seasonal estimate by multiplying the number days in each half year, which were then multiplied by the diet composition D_{ij} that was butterfish, to estimate the seasonal per capita consumption of butterfish, which were then summed to provide an annual estimate, which were then scaled by the total stock abundance of each predator to estimate a total amount of butterfish (*j)* removed by any predator *i*, where either the swept area estimate of abundance or stock assessment value for each predator for each year were used, with a cutoff of 20 cm to exclude predators incapable of consuming butterfish. These predator species-specific consumptions were then summed across all *i* predators to estimate a total amount of butterfish removed by all consistent butterfish predators.

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Results

Total consumptive removals by all consistent butterfish predators exhibited two increasing trends, one in the early to mid 1980s and another more recently (Figure B.6.1.a). These estimates have averaged around 4-6 MT yr^{-1}. When examining only the amount of consumptive removals by age class, the same trends and patterns follow, with most of the consumption being on adults (~80%) (Figure B.6.1.a). For more explicit presentation of the step-by-step consumptive removal results, please contact the working group, as has been done in prior assessments (NEFSC 2007a, 2007b).

When comparing the total amount of butterfish consumed by all predators to landings (Figure B.6.1.b), landings dominated earlier in the time series (1970s), but some of the same patterns (or at least magnitudes) were seen in the 1980s for both estimates. Finally, since the early 2000s consumptive removals are a much larger source of removals than are landings.

Sources of Uncertainty

1. Minimum swept area estimates for some predator abundance does not account for q for all predators; these are likely lower estimates of predator abundance and thus these consumption estimates should be viewed as conservative estimates.
2. Size cutoffs to allocate between juvenile and adult butterfish assumed fixed and consistent sizes across predators and time; they may be more dynamic.
3. Is the α too low compared to literature? These too may be somewhat conservative, but are within the range of those generally reported.
4. Some fish predators that did not consistently eat butterfish (e.g. pollock) were dropped.
5. Also, these estimates did not include a wide range of other (non-fish) predators known to consume butterfish (e.g., seabirds, squids, marine mammals). Collectively this relatively limited set of predators thus may result in these being fairly conservative estimates of overall predatory removals of butterfish.
6. Spatio-temporal overlap considerations between predators and butterfish were not taken into account fully.
7. Diet compositions of butterfish in these predators amount to a relatively small amount. Thus these estimates may either be an underestimate of diet composition

contributed by butterfish or reflective of non-preference by predators for butterfish.

Summary

1. Total consumption of butterfish is on the same order of magnitude as estimates of butterfish stock landings.
2. Total consumption of butterfish exhibits similar trends as landings estimates, until recent years.
3. Butterfish were usually coincident with squid in the diets of these predators (not shown).
4. Variances about these estimates (available, not shown) have CVs on the order of 0.5 to 1, often much tighter than estimates of butterfish discard/bycatch (see above).
5. Instead of increasing uncertainty, incorporating information on consumption of butterfish may actually help to better inform and improve model fitting.
6. It is feasible to calculate M in this context
7. Ignoring some form of dynamic M may provide misleading BRPs, or least result in incorrectly scaled model results (estimates of B, F, etc.).

Recommendations

1. At the least, consumptive removals should be able to be used as a qualitative index in butterfish assessment, providing context.
2. These results provide further justification for modifying M (to be dynamic) in the assessment model, which should be modeled explicitly.
3. Consumptive removals may be able to be included as a covariate to a dynamically modeled M.
4. Even a simple ratio of Consumptive Removals/Biomass can be used to scale, inform and approximate M used in the model apart from a separate estimation procedure for M.
5. The Consumptive removals are able to be incorporated as a separate "fleet" a la Overholtz et al., Moustahfid et al., etc., and this should be done.
6. Incorporating Consumptive removals should help to stabilize, inform and otherwise improve the KLAMS model as an ESAM.
7. Partitioning total mortality into Z and M2 (with some minimal assumed M1) will have implications for projections and BRPs, but it is feasible.
8. Extant Multispecies models should also be considered to provide further context; although not shown, they confirm these general consumptive removal results.
9. Given the high co-occurrence of butterfish with squids-- in time, space, and the fishery-- future assessments should consider a joint assessment of these species using some form of MS model. Such models are extant and have been reviewed, albeit not for this particular application.

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