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Relative impacts of FAD and free-school purse seine fishing on skipjack tuna stock status, incorporating non-linear purse seine CPUE/abundance dynamics and effort creep

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Graham Pilling, Robert Scott and John Hampton[1]

[1] SPC-OFP

Relative impacts of FAD and free-school purse seine fishing on skipjack tuna stock status

Abstract

Advice has previously been presented on the relative impact on yellowfin and skipjack tuna stock status of different ratios of purse seine set types, i.e. FAD or associated sets versus free-school or unassociated sets. SC11 requested the analysis be extended to examine the implications of potential non-linear purse seine CPUE/abundance relationships ('hyperstability') for skipjack tuna on those results, along with those of effort creep in the purse seine fishery. We undertook deterministic stock projections using the 2014 skipjack tuna assessment assuming 2010-2012 average purse seine effort, and either catch or effort by non-purse seine gears. Separate projections were run using different proportions (0%, 20%, 40%, 60%, 80% and 100%) of the total tropical purse seine effort (in assessment model regions 2 to 5) being attributed to associated sets and the complementary percentage to unassociated sets. These projections were run under three alternative assumptions: assuming a linear relationship between purse seine CPUE and abundance (no hyperstability - the 'standard' assumption within WCPO projections); where a relatively high level of 'hyperstability' was assumed; and under a high level of 'hyperstability' and effort creep within the tropical purse seine fishery at 2% per year.

Three stock status indicators were examined:

1. spawning biomass at the end of the projection period in relation to the average unexploited spawning biomass in 2002-2011;
2. spawning biomass at the end of the projection period in relation to the spawning biomass at MSY; and
3. fishing mortality at the end of the projection period in relation to the fishing mortality at MSY.

All three were relatively insensitive to changes in the set type composition of tropical purse seine effort. For example, the range of $SB/SB_{F=0}$ was 0.44-0.50. Slightly better stock status – higher spawning biomass indicators and lower fishing mortality – and higher maximum sustainable yield occurred for purse seine effort compositions favouring unassociated sets. The extreme hyperstability assumption provided similar results across the scenarios, while the differences between scenarios were slightly enhanced (range of $SB/SB_{F=0}$ was 0.44-0.52). The consequence of effort creep was reduced stock size and increased levels of fishing mortality relative to F_{MSY}, while the additional impact of hyperstability on the results under different set type combinations at those lower stock sizes remained relatively low (range of $SB/SB_{F=0}$ was 0.40-0.48). The results therefore remained relatively insensitive to the assumptions.

Introduction

Conservation and Management Measure (CMM) 2015-01 specifies a combination of seasonal closures for the use of fish aggregation devices (FADs) and FAD set limits by purse seiners to reduce fishing mortality on bigeye tuna. In addition to impacts on bigeye tuna, purse seine set type (FAD, or associated sets versus free-school or unassociated sets) could have impacts on other tuna species, as unassociated sets tend on average to catch larger tuna than associated sets (Figure 1). A paper was presented to SC10 on the relative impact on yellowfin catch and fishing mortality due to FAD set measures increasing the proportion of purse seine sets on unassociated schools (Hampton and Pilling, 2014). A follow up paper was presented to SC11 on a comparable analysis for skipjack tuna (Hampton and Pilling, 2015). SC11 noted that the analyses "had assumed a linear relationship between CPUE and stock abundance (potentially unrealistic in purse seine fisheries) and had not taken account of effort creep in purse-seine effort, for both associated and unassociated sets". SC11 recommended that "further analyses be undertaken taking into account the issues identified above" (para 82 of the SC11 report).

This paper provides SC12 with information on the relative average impact of different proportions of associated and unassociated purse seine sets on the skipjack tuna catch and various skipjack tuna stock status indicators, using the 2014 skipjack tuna reference case assessment, assuming two alternative forms of the purse seine CPUE/skipjack abundance relationship (linear and non-linear). It also examines the potential implications of effort creep within the purse seine fishery in combination with a non-linear CPUE abundance relationship.

Methods

The approach used for this evaluation was:

i. The 2014 skipjack tuna reference case assessment model (Rice et al. 2014) operating in projection mode was used as the basis of the evaluation for the 'linear' skipjack CPUE/abundance assumption.
ii. The approach used to capture potential non-linear purse seine CPUE/skipjack abundance is described in previous papers (Scott et al., 2015; OFP, 2015). In summary, the 2014 skipjack stock assessment model was refitted with an 'extremely hyperstable' purse seine CPUE/abundance relationship (Figure 2). For this scenario, the assessment model achieved a consistent fit to the data and the terminal estimates of abundance, fishing mortality and other model outputs were similar to those of the reference case assessment. This assessment was used as the basis of projections under the 'extreme hyperstability' assumption (k=-0.7).
iii. Effort creep was modelled as a year-on-year 2% increase in the effective effort within the tropical purse seine fishery. This was included within stock projections assuming extreme hyperstability only (see ii). The indicative value of effort creep for the purse seine fishery was taken from early estimates developed by Tidd et al. (2015). In the absence of knowledge on set-type specific differences, the same rate of effort creep was applied to both associated and unassociated effort levels.
iv. Deterministic projections were run over a 10-year period, 2013-2022, assuming future recruitment levels at the estimated average recruitment by model region for the period 2002-2011. Deterministic rather than stochastic projections were considered to be adequate for the purpose of this evaluation, since the objective is to provide advice on medium-term average impacts.
v. The base conditions for the projections were the 2010-2012 average catch and effort, by model fishery. All non-purse seine fisheries, and the domestic purse seine fisheries in Indonesia and Philippines, were projected using their average 2010-2012 catch or effort; purse seine fisheries were projected using effort (days).
vi. Separate projections were run using different proportions (0%, 20%, 40%, 60%, 80% and 100%) of the total tropical purse seine effort (regions 2 to 5 of the stock assessment model) being attributed to associated sets and the complementary percentage to unassociated sets. Within each run, the percentage of effort attributed to each set type was held constant. Total purse seine effort (i.e. the sum of associated and unassociated effort) was assumed to remain at the

2010-2012 average level throughout the projections. For reference, the average percentage of the total tropical purse seine effort attributed to associated sets for 2010-2012 was 42%.

vii. Three skipjack stock status indicators are monitored: the spawning biomass at the end of the projection period in relation to the average unexploited spawning biomass in 2002-2011 ($SB_{2022}/SB_{F=0,2002\text{-}2011}$); the spawning biomass at the end of the projection period in relation to the spawning biomass at MSY (SB_{2022}/SB_{MSY}); and the fishing mortality at the end of the projection period in relation to the fishing mortality at MSY (F_{2022}/F_{MSY}).

Results

The time-series plots of the three stock status indicators, for different proportions of associated sets, are shown in Figure 3. The recent historical estimates (2001-2012) from the skipjack tuna assessment are also plotted for reference. The indicators projected for 2022 (i.e. the terminal points of the trajectories in Figure 3) are shown in Figure 4.

Under the linear CPUE/abundance assumption, skipjack tuna stock status is slightly enhanced (i.e. higher spawning biomass and lower fishing mortality) by lower proportions of associated sets (and higher proportions of unassociated sets). However, the effect is relatively slight, for example $SB_{2022}/SB_{F=0,\ 2002\text{-}2011}$ ranges from a low of 0.44 if 100% of purse seine effort is on associated sets, to a high of 0.50 if there is zero associated sets and all purse seine effort is on unassociated sets (range of 6%). The MSY-based spawning biomass and fishing mortality indicators show similar changes between these extremes of possible purse seine set type proportions (range of 7% for F_{2022}/F_{MSY}, 12% for SB_{2022}/SB_{MSY}). Note that the variation in MSY-based indicators for the historical period evident in Figures 3b and c is in part due to variation in the proportion of associated and unassociated purse seine sets, which changes the overall fishery selectivity (age-specific pattern of fishing mortality) and in turn changes the MSY-based reference points.

Under the extreme hyperstability assumption, patterns are identical to those under the linear assumption, but differences between scenarios are slightly greater. Skipjack tuna stock status is again improved (i.e. higher spawning biomass and lower fishing mortality) by lower proportions of associated sets. While the assumption of hyperstability enhances this effect, the overall impact of different set type proportions remains relatively slight. For example $SB_{2022}/SB_{F=0,\ 2002\text{-}2011}$ ranges from a low of 0.44 if 100% of purse seine effort is associated sets, to a high of 0.52 if there are zero associated sets and all purse seine effort is on unassociated sets (range of 8%). The MSY-based spawning biomass and fishing mortality indicators showed similar changes between these extremes of possible purse seine set type proportions (range of 11% for F_{2022}/F_{MSY}, 20% for SB_{2022}/SB_{MSY}).

Inclusion of effort creep leads to notably lower stock status and increased fishing mortality in all scenarios. For example, $SB_{2022}/SB_{F=0}$ declined under effort creep for each scenario, to 0.40 if 100% of purse seine effort is associated sets, through to a high of 0.48 if all purse seine effort is on unassociated sets when compared to the run with assumed extreme hyperstability. The range of $SB_{2022}/SB_{F=0}$ estimates across scenarios increases very slightly to 9% (from 8%), suggesting that the additional impact of hyperstability at those lower stock sizes is relatively small. A similar pattern is seen in the MSY-based spawning biomass and fishing mortality indicators, with the range of results increasing to 14% (from 11%) and 22% (from 20%) respectively.

Conclusion

Skipjack tuna stock status is relatively insensitive to whether tropical purse seine effort is comprised mainly of associated sets or unassociated sets. Slightly better stock status (higher spawning biomass indicators and lower fishing mortality) occurred for tropical purse seine effort directed at unassociated sets. A similar pattern is found where extreme hyperstability is assumed, and the differences resulting from changes in the proportion of associated to unassociated sets are slightly enhanced. Inclusion of effort creep within the projections (at 2% per annum) led to lower stock status and higher fishing mortality levels, while the additional impact of hyperstability on the results under different set type combinations at those lower stock sizes remained relatively low. While effort creep was applied equally to associated and unassociated set effort here, there may be differential rates of creep between the two set types. This would influence the differences in stock status under different associated/unassociated set combinations.

References

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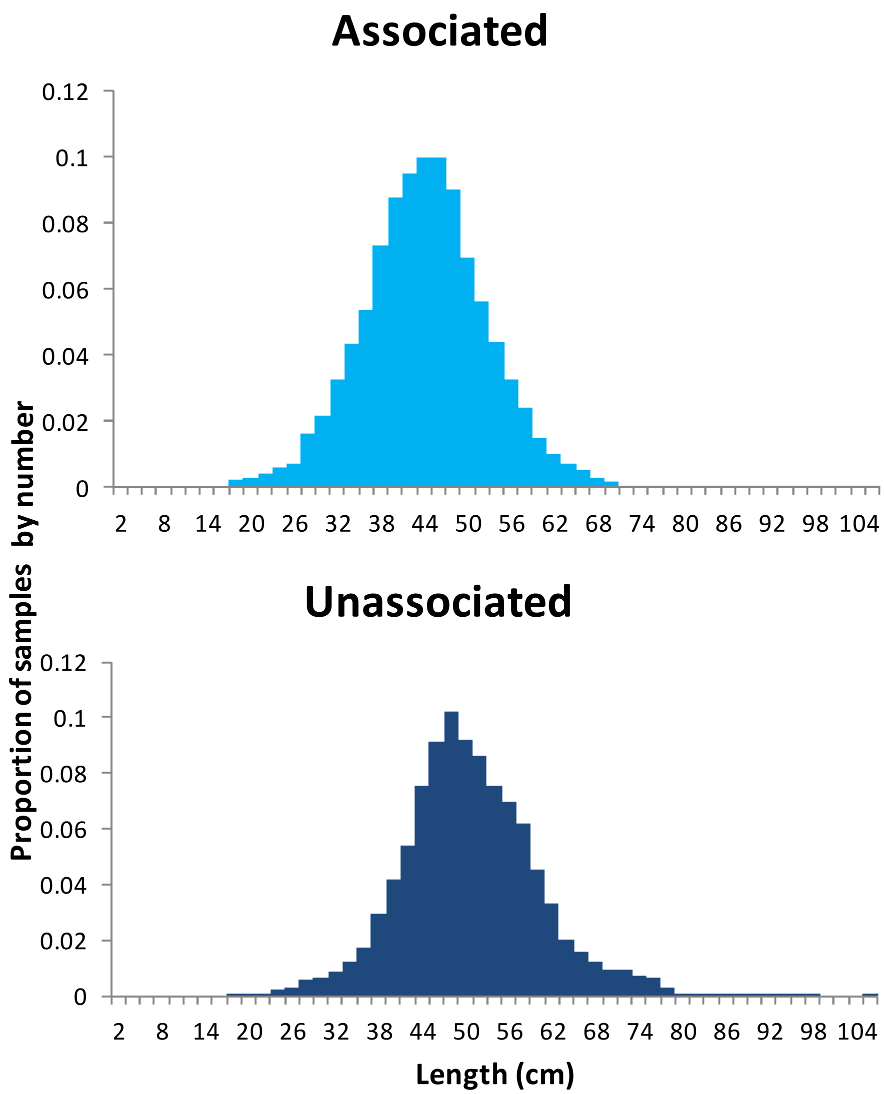

Figure 1. Size composition (by number) of skipjack tuna sampled in associated and unassociated sets, 2010-2012.

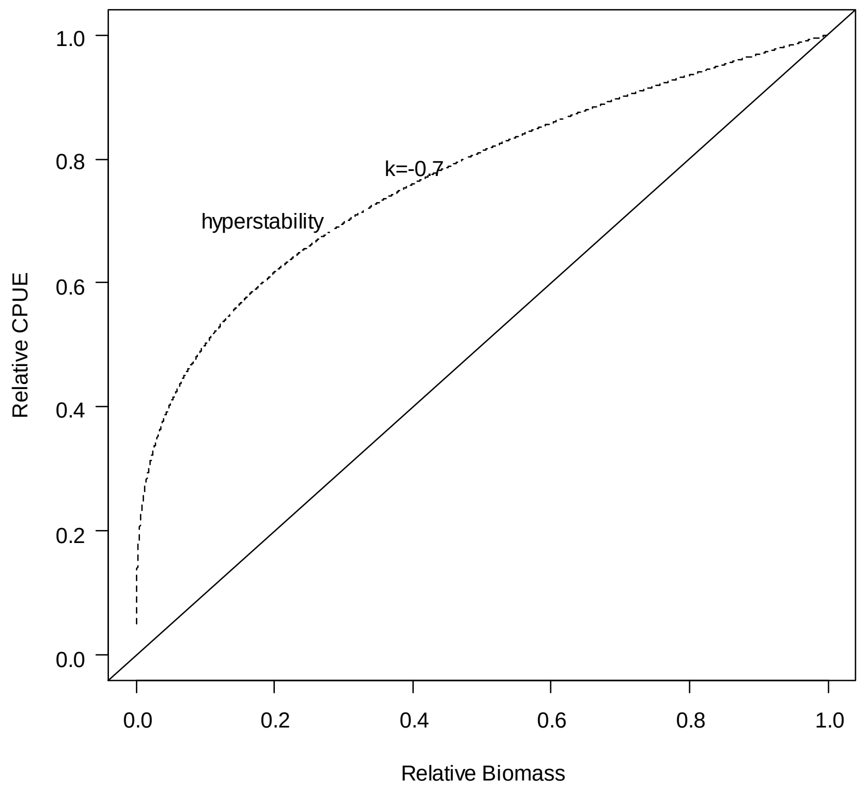

Figure 2. Conceptual plot of the assumed relationship between CPUE and stock abundance, for the two scenarios examined in this paper. Under extreme hyperstability (K=-0.7), CPUE remains at high levels with decreasing abundance, resulting in hyperstability in CPUE.

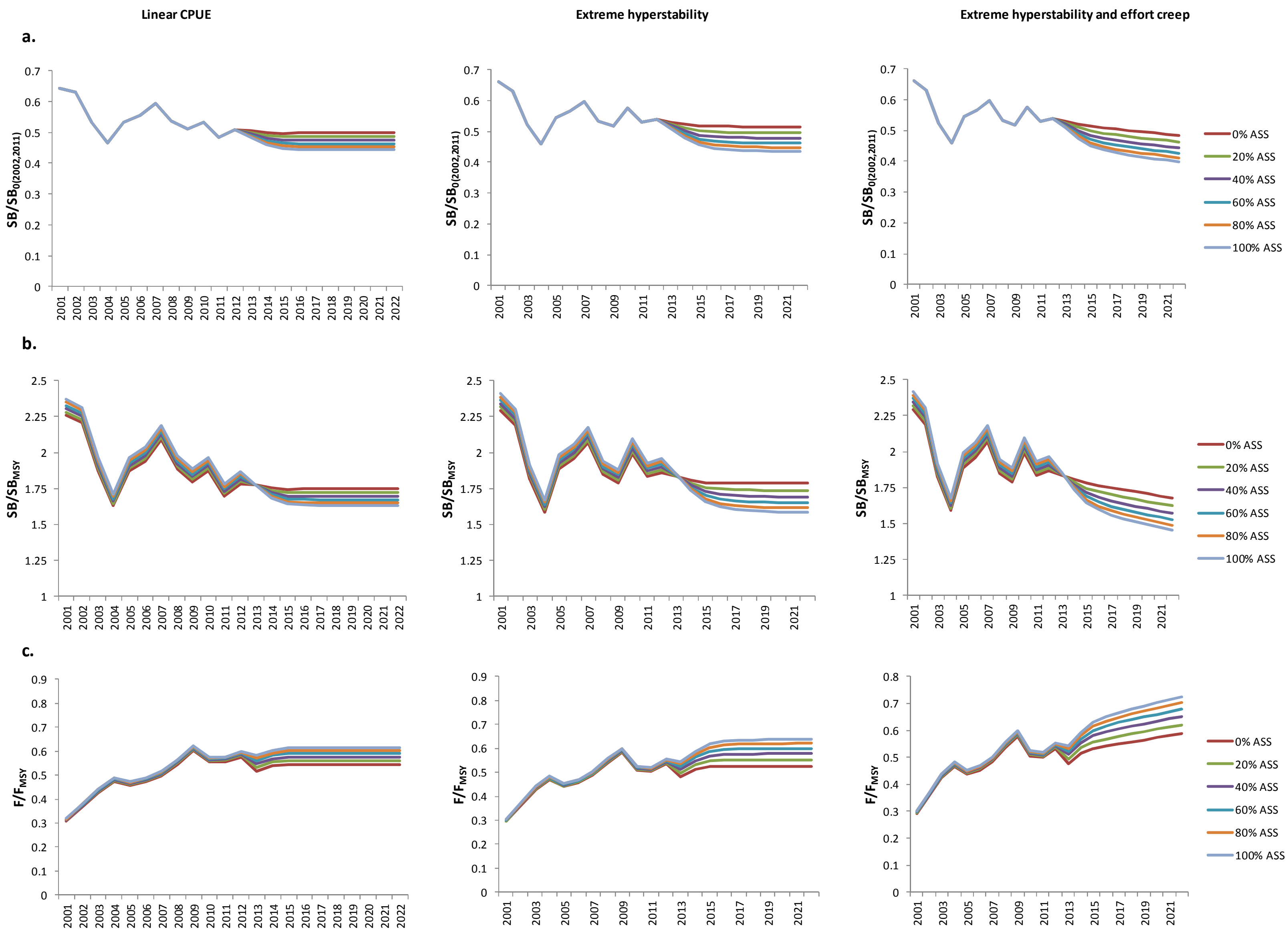

Figure 3. Projections of a) $SB/SB_{0\,(2002\text{-}2011)}$; b) SB/SB_{MSY}; and c) F/F_{MSY} with different proportions of total purse seine effort on associated (ASS) sets.

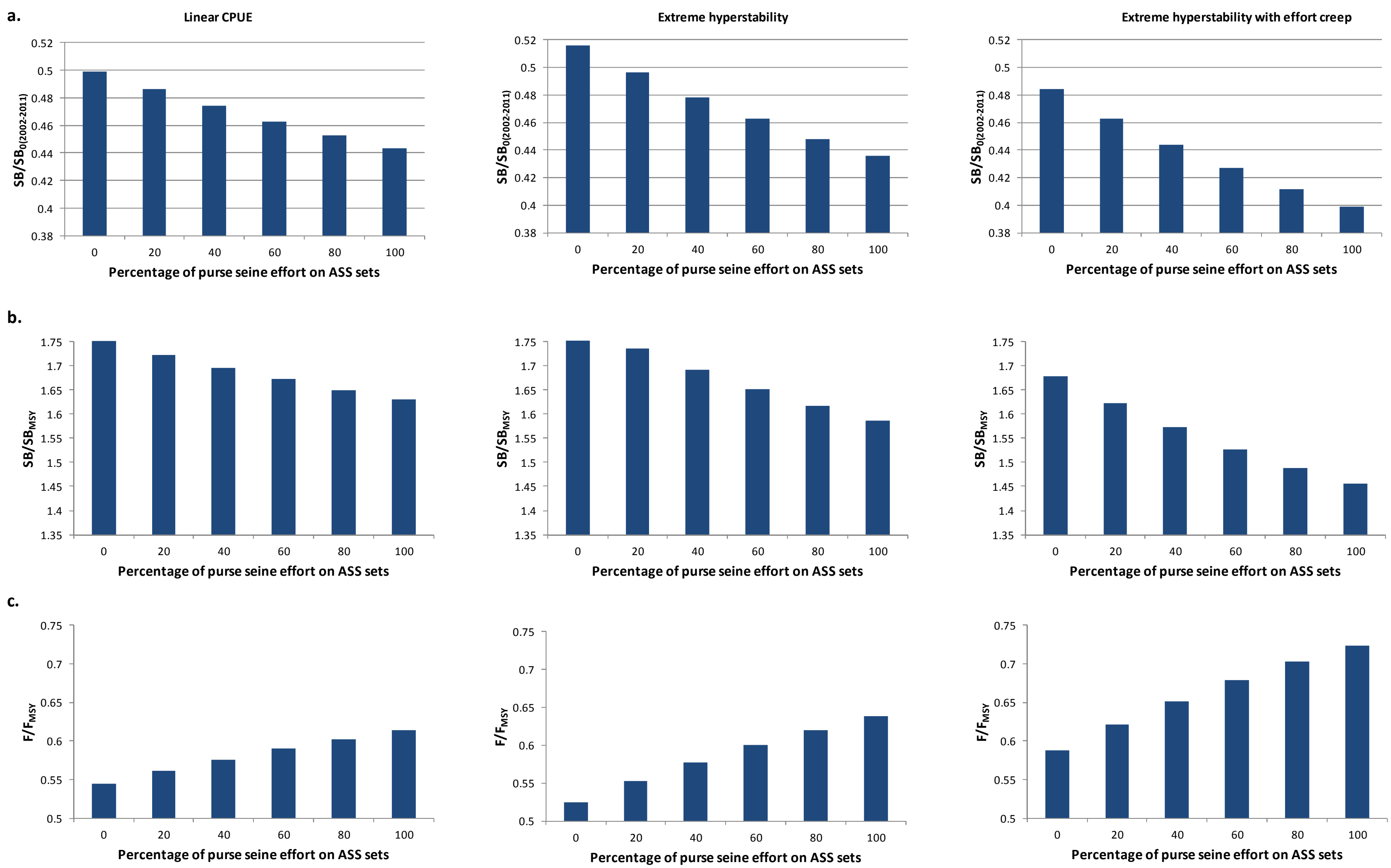

Figure 4. Response of stock status indicators a) $SB_{2022}/SB_{F=0\ (2002\text{-}2011)}$; b) SB_{2022}/SB_{MSY}; and c) F_{2022}/F_{MSY} to different proportions of total purse seine effort on associated (ASS) sets. NOTE: y-axis scales do not start at zero and hence differences are exaggerated.