WCPFC-SC1 **ME-WP-3**

Western and Central Pacific Fisheries Commission

1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission
WCPFC–SC1
Noumea, New Caledonia
8–19 August 2005

Why are there still large pelagic predators in the oceans? Evidence of severe hyper-depletion in longline catch-per-effort.

Robert Ahrens and Carl Walters

Fisheries Center
University of British Columbia

2259 Lower Mall
Vancouver, B.C. V6T 1Z4
ahrens@zoology.ubc.ca

August 2005

Abstract

Industrial catch-per-effort (cpue) data are used as an indicator of population abundance and, contrary to strong cautions of potential biases, are often used without regard for spatial interactions as the only data source from which inferences are made. Recent controversy surrounding the status of large predatory pelagic communities has resulted from varying interpretations of the Japanese longline cpue data. Contrary to many stock assessments on the major tuna species, ratio and fished-area-only cpue estimators for specific regions of the world oceans indicate that large pelagic predator biomass has declined to 10% of pre-industrialized fishing levels, with large declines occurring in the first few years of fishing. We have re-examined the SPC public domain longline 5°x5° global data set, correcting for errors that result from utilizing ratio cpue estimators, to see if such spatially corrected cpue data provide a more reliable indicator of population abundance.

Although spatially corrected cpue time series indicate depletion more in line with current stock assessments, there is evidence of severe hyper-depletion even in the corrected data. For several species, estimates of recruitment (to size classes fished by longlining) based on catch and cpue would indicate linear stock recruitment relationships. Such relationships are contrary to current assessments and are expected under declining catchability (q) over time. When recruitment is assumed stable (utilizing compensation observed over most species) q is calculated to decline rapidly over the initial years of the fishery. Other, more complex assessments utilizing recruitment and abundance estimates from catch composition data also estimate declining q even after the period of early cpue decline. Apparent fishing mortality rates (F) required to produce the initial declines in ratio cpue with 20-30% of the maximum effort observed later, imply substantially higher F in later periods if q is assumed constant. Such an effect is also observed in the analysis of 5°x5° cell specific depletion models. Such high fishing mortality rates are inconsistent with current estimates from stock assessment, and with size composition of catches; yield per recruit analysis indicates that such Fs would have resulted in greater declines in mean weights than observed in the catch. Such observations can be explained by hyperdepletion in the early cpue data and further investigation into the early spatial distribution of fishing effort is required to determine if effort was initially targeted at localized spatial aggregations or alternately if longline effort initially removed more active and susceptible components of the population.

Introduction

The utility of catch-per-effort (cpue) data for the development of population trend indices and the construction historical recruitment pattern is central in stock assessment. Often, more detailed stock composition data is unavailable for the early year of a fishery and cpue information is utilized in order to more fully capture fishery impacts upon a stock, determine recruitment relationships, potential non-stationarity in such relationship as well as explore potential trophic interactions. However, industrial catch-per-effort (cpue) data are used as an indicator of population abundance and, contrary to strong cautions of potential biases, are often used without regard for spatial interactions as the only data source from which inferences are made. Recent controversy surrounding the status of large predatory pelagic communities has resulted from varying interpretations of the

Japanese longline cpue data. Contrary to many stock assessments on the major tuna species, simple ratio and fished-area-only cpue estimators for specific regions of the world oceans indicate that biomass has declined to 10% of pre-industrialized fishing levels, with large declines occurring in the first few years of fishing. We have re-examined the SPC public domain longline 5°x5° global data set, correcting for errors that result from utilizing ratio cpue estimators (Walters 2003), to see if such spatially corrected cpue data provide a more reliable indicator of population abundance. These indices are then utilized to reconstruct historical recruitment patterns utilizing a methodology similar to that proposed by Schaefer for the estimation of surplus production.

Spatial Analysis of Catch-per-Effort

The need for spatial catch-per-effort indices of population abundance was clearly outlined by Walters (2003). To prevent introducing hyperstability or hyperdepletion due to the spatial interaction of fishing effort and population distribution as well as the error of placing more weight on those areas that received more effort and assuming unfished areas behaved similarly to fish areas we have attempted to reconstruct the cpue time series for each of the 5ºx5º cells available in the SPC longline public domain data set for the major tuna and billfish species for 1950-2001. These cell specific temporal reconstructions are then utilized to develop a population cpue index (eq. 1) Where *i* is the cell stratum, y is the ratio estimator and w is the physical stratum size divided by the sum of the stratum sizes.

(1) $\bar{y} = \sum_{i} y_i w_i$

It is important to note that we are assuming that effort 5ºx5º is sufficiently random to assume the cell specific ratio estimator reflects population abundance. Secondly we assume that over the time period catchability does not change. Given the changes in gear configuration and fishing practices (Ward and Myers 2005, Bigelow et al 2002) such an assumption is unrealistic and we therefore restrict our recruitment analysis prior to 1970 before the major changes in fishing practices. It is also necessary to make assumptions about cpue for those cells in which no effort was realized. We are therefore forced to make our best estimate of the catch rate for those cells we have no measurement. For result presented in this paper we have assumed a catch rate prior to first fishing equal to the mean of the first 3 years of fishing and a catch rate for those years after in which fishing did not occur set to the catch rate observed in the last year fished.

One may argue that such assumptions are unnecessary given the potential movement rates of large pelagic predators and even though fishing effort is localized, mixing as a result of movement will cause the effect of fishing to impact throughout the population range. Utilizing movement rates observed from tagging studies we developed a simulation in which each 5ºx5º cell is modeled as a separate population with mixing between adjacent cells using eq.2. where R is the cell specific recruitment calculated utilizing observed catch and catch-per-recruit estimates, N is the cell population, v is the instantaneous cross cell emigration rate and $\overline{N}$ is the mean density of the 4 surrounding cells.

(2) $$\frac{dN}{dt} = R - ZN - 4vN + 4v\overline{N}$$

Simulations (Fig. 1) indicate that even with substantially higher movement rate that indicated from tagging, the effect of depletion due to fishing is not observed as a significant effect in cells fished later.

Figure 2 present the spatially calculated cpue indices for the large pelagic species in the SPC 5ºx5º public domain database. Trends are presented for quarterly data and all quarters combined. Although there is some variation in the trends depending on quarter for each species indicating potential changes in catchability or recruitment between quarters the overall trends are similar. Figure 3 contrasts the spatial estimator with a mean fished area only estimator. It is evident that substantial differences with regard to population abundance trends and potential trophic interactions would be made given the estimator used. The effect of ignoring unfished cells is evident as the mean fish area only estimators indicate unrealistic population increased and declines. If the initial declines of the estimators are assumed to be the result of fishing then an estimate of species specific catchability can be obtained. If this estimate of q is assumed constant over time the apparent fishing mortality rates implied by the mean fished area only estimator (fig. 4) are substantially higher than those currently estimated in current stock assessments.

Recruitment Reconstruction

Recruitment reconstruction was done following a Schaefer like approach outlined in Walters and Hilborn (in press) utilizing the spatial catch-effort-estimator as an index of abundance. Recruitment is calculated using eq. 3 where y_t is the relative abundance, q is and estimated catchability, C_t is the observed catch and M is the mortality rate.

(3) $$R_t = \left[\frac{y_t}{q} - \frac{y_{t-1}}{q} e^{-M}\right]\left[\frac{M}{\left(1 - e^{-M}\right)}\right] + C_t$$

The difficulty with such a method is that the estimation of recruitment depends on assumptions about q and some methods of reducing the noise in cpue. Waters and Hilborn indicate that a simple 3 year moving average of cpue performs adequately when compared to more complex linear smoothers. The difficulty lies in the estimation of q. It is perhaps more suitable to present recruitment results from a range of fishing mortality (F) estimates or derive q from tagging based studies. In this paper we have opted to calculate q utilizing estimates of F from current stock assessment reports.

Apparent stock-recruit (recruitment to sizes vulnerable to longline gear) relationships (fig.5) for 1950-1970 for many species estimated to be linear with the catch component of the recruitment estimation not contributing to the observed trend. The resulting recruitment relationships are sensitive to assumptions about q which effect the relative catch contribution within the estimation procedure. However, over the range of fishing mortalities estimated in current stock assessments the observed linear relationships are still evident. Assuming recruitment was stable over the initial years of the fishery (compensation observed in almost all fisheries) catchability for those species with apparent linear recruitment relationships is calculated to have declined (fig. 6). If is possible that apparent decline in recruitment during the initial years of the fishery are also a result of changes in productivity and further investigation is required to discriminate between changes due to productivity and those due to catchability.

Evidence of Hyperdepletion

For several species, estimates of recruitment (to size classes fished by longlining) based on catch and cpue would indicate linear stock recruitment relationships even after cpue estimated spatially to remove potential non-linearity between cpue and population abundance . Such relationships are contrary to current assessments and are expected under declining catchability (q) over time. When recruitment is assumed stable (utilizing compensation observed over most species) q is calculated to decline rapidly over the initial years of the fishery. Other, more complex assessments utilizing recruitment and abundance estimates from catch composition data also estimate declining q even after the period of early cpue decline. When using simple ratio catch-per-effort estimators. apparent fishing mortality rates (F) required to produce the initial declines in cpue with 20-30% of the maximum effort observed later, imply substantially higher F in later periods if q is assumed constant. Such high fishing mortality rates are inconsistent with current estimates from stock assessment, and with size composition of catches; yield per recruit analysis indicates that such Fs would have resulted in greater declines in mean weights than observed in the catch. Although not presented in this paper, estimates of recruitment at the 5ºx5º cells scale utilizing catch data and estimates of catch-per-recruit result in apparent negative recruitment in the early years of the fishery as cpue drops off faster than can be explained by the catches. Such observations can be explained by hyperdepletion in the cpue data.

Potential Mechanisms

Although there is evidence that catchability declined during the initial years of the longline the mechanism which resulted in apparent hyperdepletion is unclear. There are a number of potential mechanisms that can explain the observed patters.

1) Effort within 5ºx5º cells was not random particularly over the first few years an area was fished. Thus cell specific catch rate data is not proportional to abundance resulting in apparent hyperdepletion at the 5ºx5º cell scale.
2) Longlining initially removed an accumulation of more susceptible individuals resulting and a change in catchability as a result of selection for less vulnerable

individuals. Therefore the longline catch rate data is measuring only a particular component of the population.

3) Apparent linear recruitment patterns may be explained utilizing a chain linked recruitment model with a “self-seeding” core area and recruitment in subsequent areas depending on the previous in the chain.

References

Bigelow, K.A., J. Hampton, and N. Miyabe. 2002. Application of a habitat-based model to estimate effective longline fishing effort and relative abundance of Pacific bigeye tuna (Thunnus obesus). Fish. Oceanogr. 11:3, 143–155.

Myers, R.A. and B. Worm 2003. Rapid worldwide depletion of predatory fish communities. Nature 425, 280-283

Walters, C. 2003. Folly and fantasy in the analysis of spatial catch rate data. Can. J. Fish. Aquat. Sci. 60:1433-1436.

Ward, P and R.A. Myers. 2005. Inferring the depth distribution of catchability for pelagic fishes and correcting for variations in the depth of longline fishing gear. Can. J. Fish. Aquat. Sci. 62: 1130–1142

Figure 1.

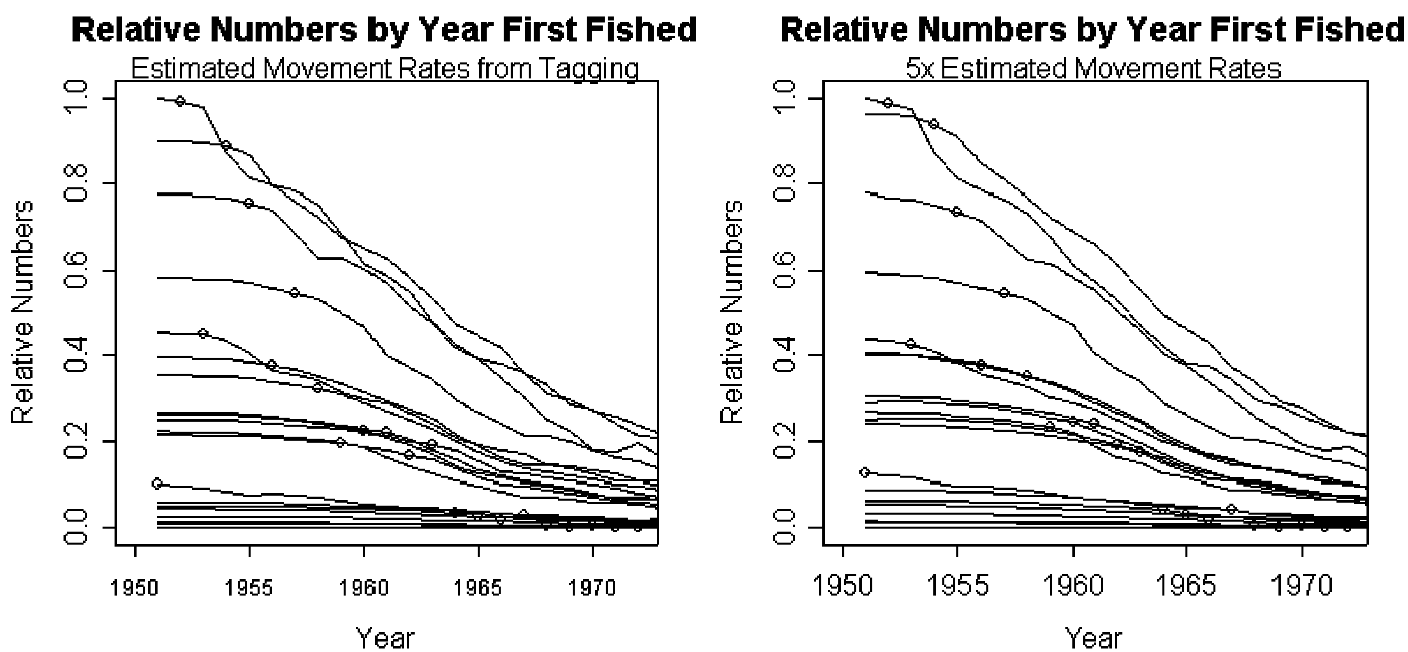
Relative Numbers by Year First Fished
Estimated Movement Rates from Tagging
Relative Numbers
0.0
0.2
0.4
0.6
0.8
1.0
1950
1955
1960
1965
1970
Year
Relative Numbers by Year First Fished
5x Estimated Movement Rates
Relative Numbers
0.0
0.2
0.4
0.6
0.8
1.0
1950
1955
1960
1965
1970
Year

Figure 2

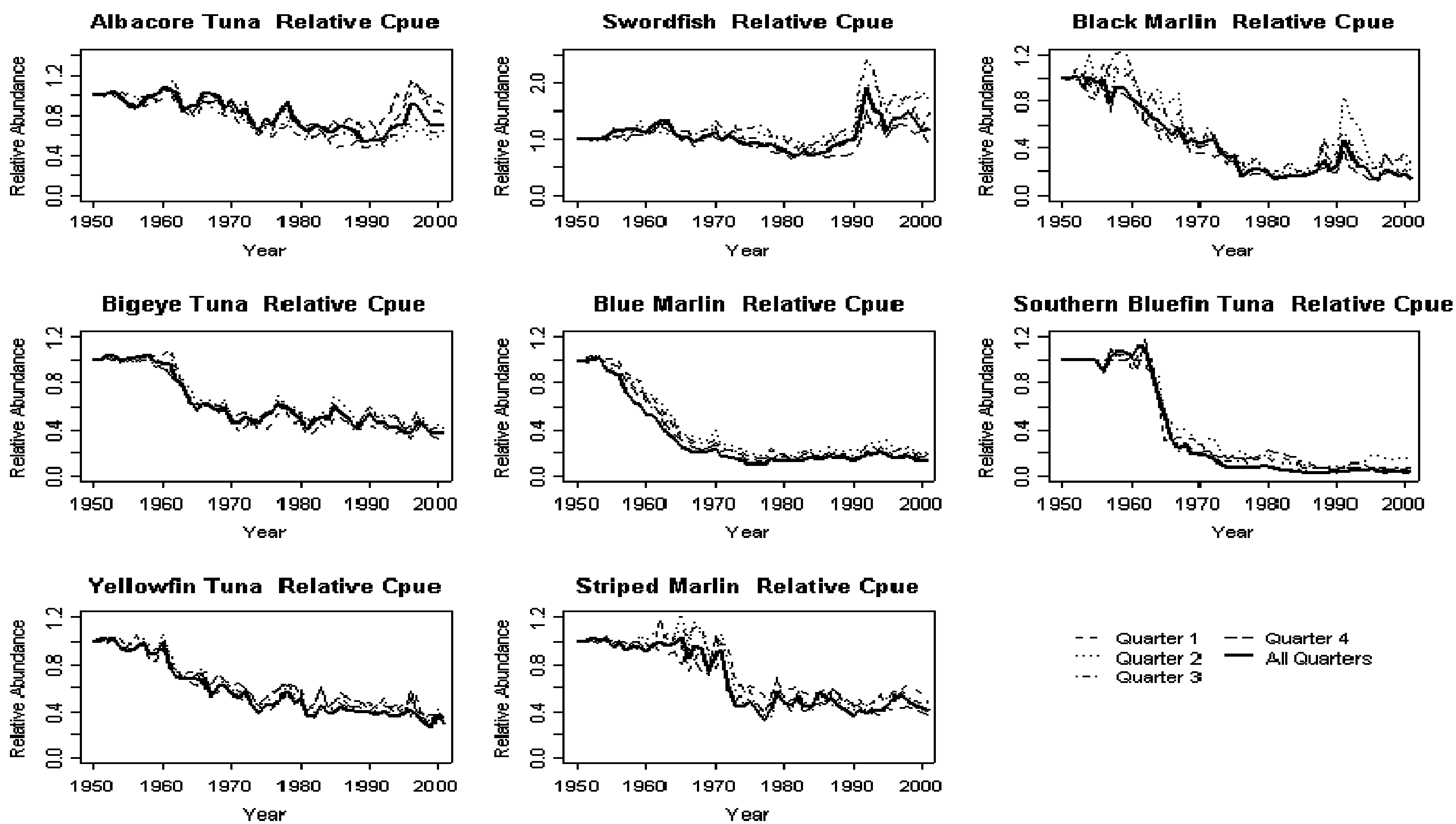
Albacore Tuna Relative Cpue
Swordfish Relative Cpue
Black Marlin Relative Cpue
Bigeye Tuna Relative Cpue
Blue Marlin Relative Cpue
Southern Bluefin Tuna Relative Cpue
Yellowfin Tuna Relative Cpue
Striped Marlin Relative Cpue
Relative Abundance
Year
1950 1960 1970 1980 1990 2000
Quarter 1
Quarter 2
Quarter 3
Quarter 4
All Quarters

Figure 3.

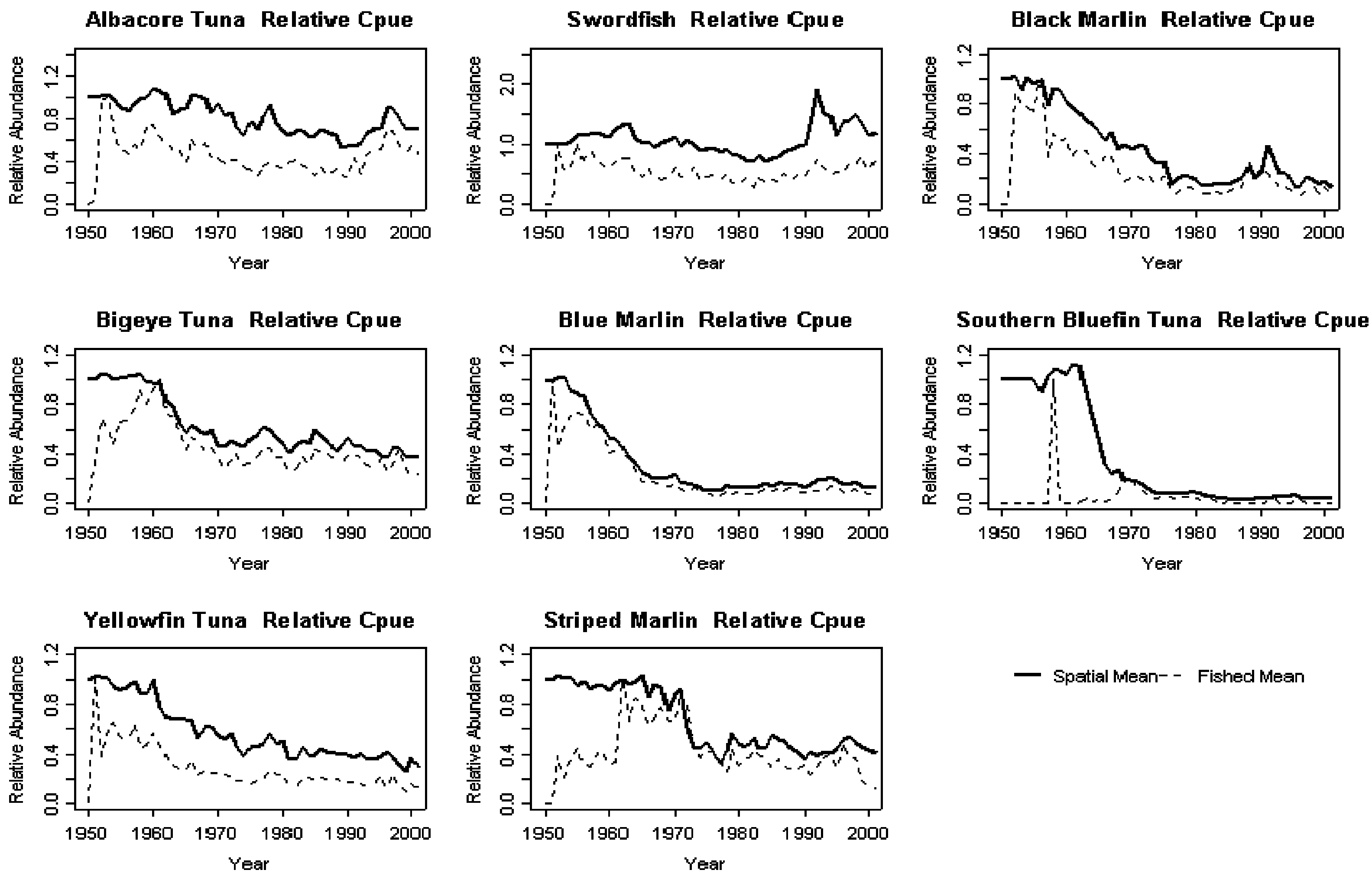
Albacore Tuna Relative Cpue
Swordfish Relative Cpue
Black Marlin Relative Cpue
Bigeye Tuna Relative Cpue
Blue Marlin Relative Cpue
Southern Bluefin Tuna Relative Cpue
Yellowfin Tuna Relative Cpue
Striped Marlin Relative Cpue
Relative Abundance
Year
1950 1960 1970 1980 1990 2000
0.0 0.4 0.8 1.2
0.0 1.0 2.0
Spatial Mean
Fished Mean

Figure 4.

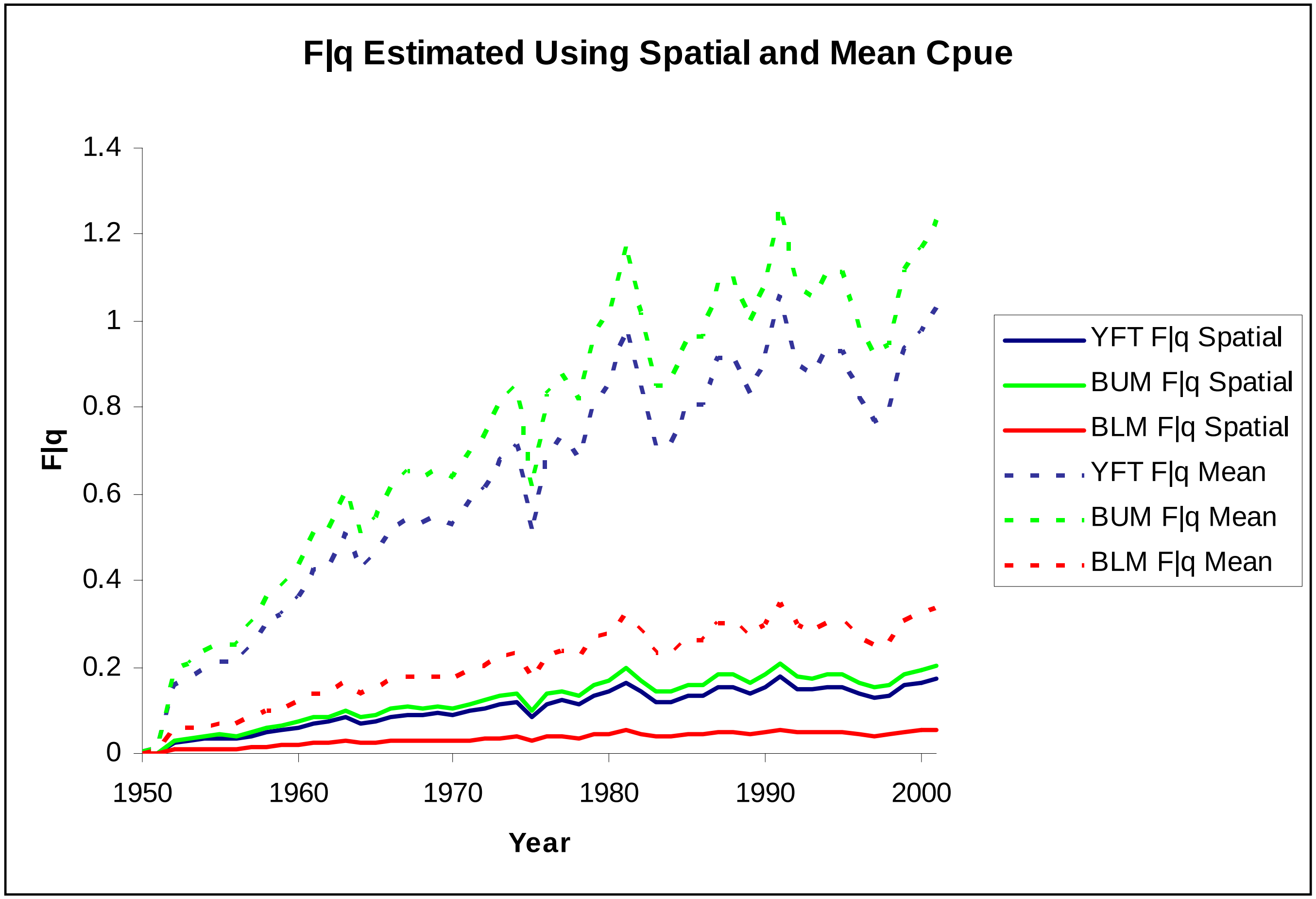
F|q Estimated Using Spatial and Mean Cpue
1.4
1.2
1
0.8
0.6
0.4
0.2
0
F|q
1950
1960
1970
1980
1990
2000
Year
YFT F|q Spatial
BUM F|q Spatial
BLM F|q Spatial
YFT F|q Mean
BUM F|q Mean
BLM F|q Mean

Figure 5.

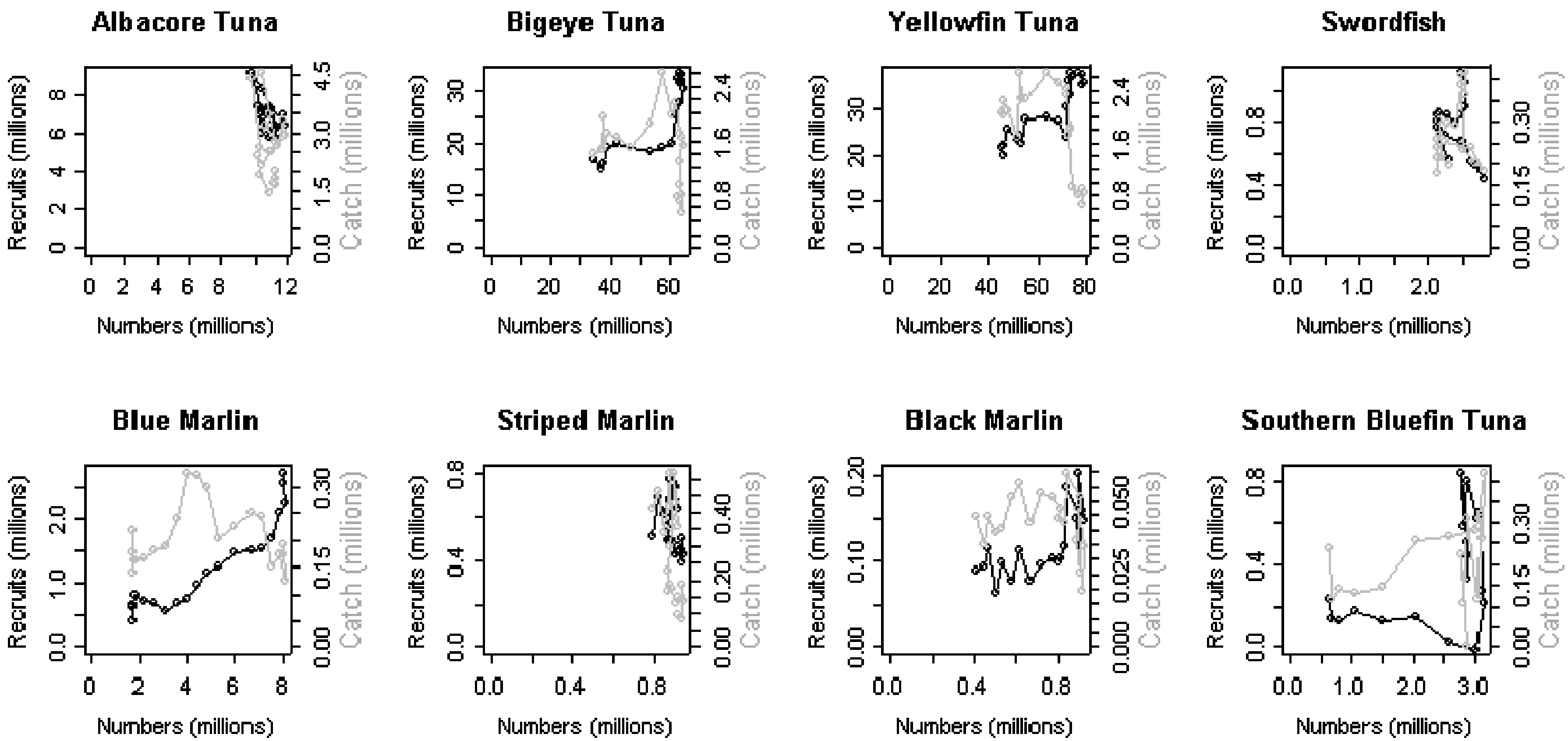
Albacore Tuna
Bigeye Tuna
Yellowfin Tuna
Swordfish
Blue Marlin
Striped Marlin
Black Marlin
Southern Bluefin Tuna
Recruits (millions)
Catch (millions)
Numbers (millions)

Figure 6.

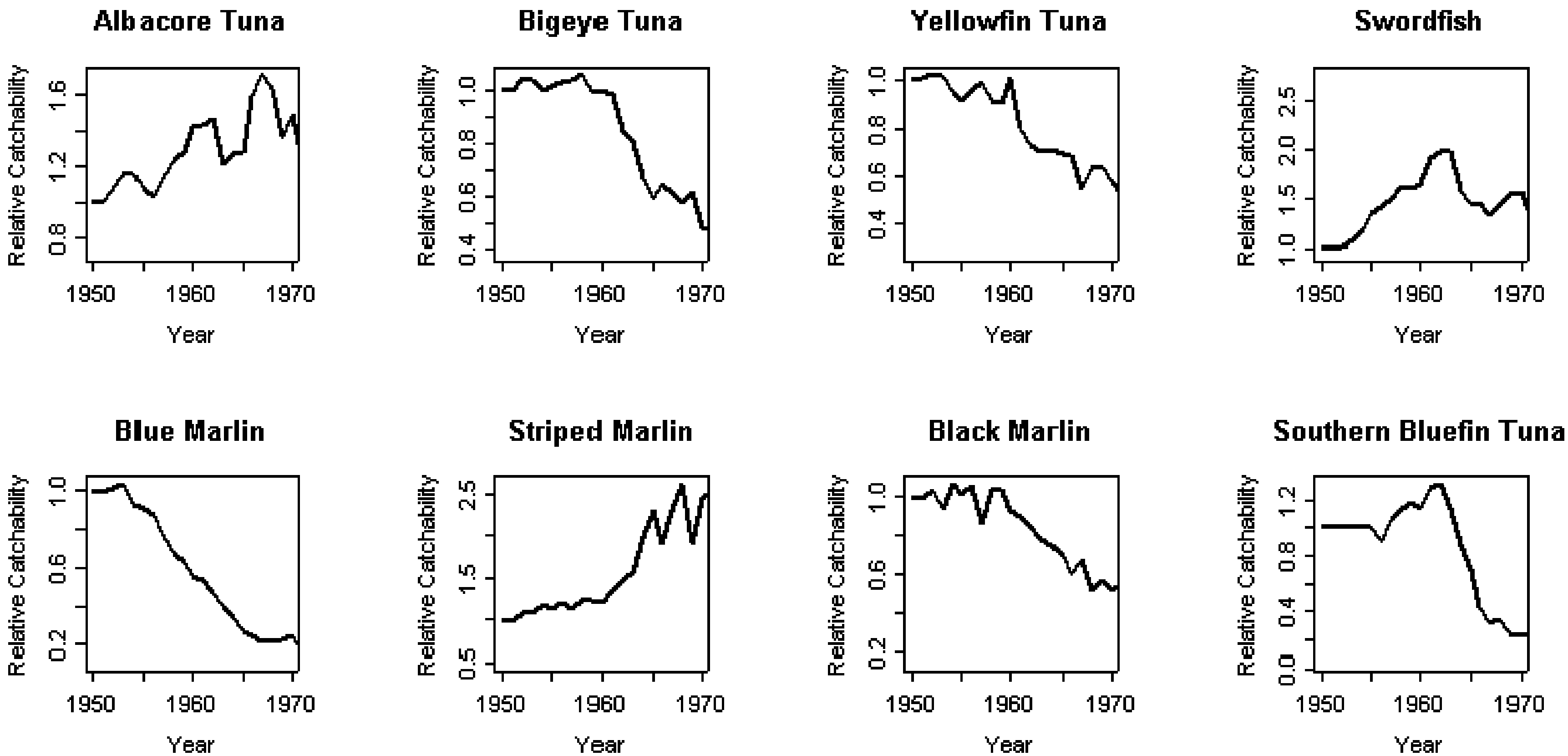
Albacore Tuna
Bigeye Tuna
Yellowfin Tuna
Swordfish
Blue Marlin
Striped Marlin
Black Marlin
Southern Bluefin Tuna
Relative Catchability
Year
1950
1960
1970
0.8
1.2
1.6
0.4
0.6
0.8
1.0
0.4
0.6
0.8
1.0
1.0
1.5
2.0
2.5
0.2
0.6
1.0
0.5
1.5
2.5
0.2
0.6
1.0
0.0
0.4
0.8
1.2

Figure Captions

Figure 1. Effect of fishing by cells clusters as first year fished on areas fished later in time under observed movement rates from tagging and a 5x increase in movement rate. Circles indicate the year in which a cell cluster was first fished.

Figure 2. Spatially derived cpue indices for major tuna and billfish species utilizing quarterly and all quarter catch effort data.

Figure 3. Spatial and mean area fished cpue indices for major tuna species all quarters combined.

Figure 4. Estimates of fishing mortality rate on yellowfin tuna (YFT) blue marlin (BUM) and black marlin (BLM) for spatial (solid lines) and mean fished area only (dashed lines) estimators assuming q calculated from initial decline is constant over time.

Figure 5. Apparent stock recruitment relationships for the major tuna and billfish species (black line) and the associated catch component of the relationship (grey line).

Figure 6. Estimated changes in catchability for the major tuna and marlin stocks assuming stable recruitment over the initial years of the fishery.