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A PRE-META-ANALYSIS OF STOCK RECRUITMENT DATA FOR SCOMBRIDAE, ISTIOPHORIDAE AND XIPHIIDAE

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SUMMARY

In this study we present a pre-meta-analysis of stock recruitment data for pelagic species from a variety of oceans. The intention is to screen these data in order to specify a stock recruitment meta- analysis for Scombridae, Istiophoridae and Xiphiidae. A common stock recruitment relationship (i.e., Beverton and Holt) was fitted to all the data to allow a comparison of diagnostics in order to identify potential problems.

RÉSUMÉ

Dans cette étude, nous présentons une méta-analyse préalable des données de recrutement des stocks pour les espèces pélagiques provenant de divers océans. L'intention est de filtrer ces données afin de spécifier une méta-analyse de recrutement des stocks pour les Scombridae, Istiophoridae et Xiphiidae. Une relation stock-recrutement commune (c.-à-d. Beverton et Holt) a été ajustée à toutes les données pour permettre une comparaison des diagnostics en vue d'identifier les problèmes potentiels.

RESUMEN

En este estudio se presenta un meta análisis previo de los datos de reclutamiento de stocks de especies pelágicas de varios océanos. La intención es filtrar estos datos para especificar un meta-análisis de la relación stock-reclutamiento para Scombridae, Istiophoridae *y* Xiphiidae. *Se ajustó una relación stock-reclutamiento común (a saber, Beverton-Holt) a todos los datos para poder comparar los diagnósticos con el fin de identificar problemas potenciales.*

KEYWORDS

Stock Recruitment, Meta Analysis, Scombridae, Istiophoridae, Xiphiidae, Beverton Holt

1. Introduction

The main management objective of ICCAT is to maintain the populations of tuna and tuna-like fishes at levels which will permit the maximum sustainable catch. Scientific advice within ICCAT is therefore based on maximum sustainable yield (MSY) and associated reference points; i.e. the biomass or spawning stock biomass (BM SY) and fishing mortality (FM SY) that will provide MSY. Advice in order to achieve MSY is provided in the form of the Kobe II strategy matrix (K2SM). Where the probability of being above B_{MSY} and below F_{MSY} is summarized for different catch levels (or other management options) by year. In line with the Precautionary Approach (PA), management advice must explicitly consider uncertainty and the risk of achieving or not achieving management objectives. Therefore in order to develop a management framework based on best science consistent with the PA KOBE III recommendation (K3- REC-A) under Science included:

> *Emphasizing the potential of the K2SM to communicate efficiently among all stake- holders and to assist in the decision-making process according to different levels of risk, but also recognizing that substantial uncertainties still remain in the assessments, Kobe III participants recommended that the Scientific Committees and Bodies of the tRF- MOs develop research activities to better quantify the uncertainty and understand how this uncertainty is reflected in the risk assessment inherent in the K2SM.*

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Reducing uncertainty about MSY is of key importance when providing scientific management advice to the Commission. Most estimates of MSY and related benchmarks provided by tuna Regional Fisheries Management Organizations (tRFMOs) are calculated by combining yield-per-recruit and spawner-per-recruit and stock-recruitment relationship (SRR) Anonymous (2011). However, in most stock assessments, the SRR is notoriously difficult to estimate and requires fixing parameters. Therefore meta- analyses of stock and recruitment data have received much recent attention Dorn (2002) Michielsens et al. (2006) Forrest et al. (2010) and Hillary et al where the results from several studies are combined.

Advantages of Meta Analysis include the ability to generalize to the population of studies, control for between-study variation and higher statistical power to detect an effect than from a single study. However weaknesses include that fact that such analyses do not follow the rules of hard science, for example by proposing a way to falsify the hypothesis in question, sources of bias are not controlled, a good meta-analysis of badly designed studies will still result in bad statistics, heavy reliance on published studies and Simpsons Paradox Simpson (1951) i.e. where two smaller studies may point in one direction, while a combined study may point in another.

Therefore in this study we collate stock recruit data (S-R) from a variety of pelagic stocks and conduct a preliminary analysis in order to evaluate their appropriateness for meta-analyses.

2. Material and Methods

2.1 Data

Data used were for Scombridae from the Atlantic, Indian, Pacific and Southern Oceans and swordfish from the Atlantic and Mediterranean. These comprised estimates of recruits and spawning reproductive potential (SRP) estimated as spawning stock biomass (SSB, i.e. the sum over age of the numbers, proportion mature and mass). Estimates were derived from a variety of age based assessments.

2.2 Analysis

An unconstrained Beverton and Holt stock recruitment relationship Beverton and Holt (1993) was fitted to all stocks separately. A Beverton and Holt SRR was chosen since there is no evidence of over depensation which might suggest a Ricker SRR would be appropriate (Ricker, 1954).

Non-parameteric relationships were explored to help evaluate the appropriate functional form of the SRR and to test whether covariates other than SBB influence recruitment. Finally a time series analysis was conducted on recruits and SBB to look at variability in these quantities.

Two dimensional confidence intervals for steepness and virgin biomass were estimated from the SRR fits using the Chi-Squared distribution to define lines of equal probability. Finally a spectral analysis Jenkins and Watts (1968) was conducted to explore variability in recruitment and SSB. This is a graphical technique for examining cyclic structure in the frequency domain, based on the Fourier transform which decomposes a signal into the sum of a number of sine waves of different frequency components. The spectrum is then the representation of the signal in the frequency domain, i.e. a plot of intensity or magnitude of the signal against frequency. Trends were first removed from the time series using a lowess smoother before applying the spectral analysis to the residuals. Frequency was measured in cycles per year, so a frequency of 0.5 corresponds to two years and frequency of 0 to an infinite cycle.

Run sequence plots, where the times series were standardized and the 1st point in the times series subtracted from the entire time series, were used to summarize the S-R data in the time domain. These show how a signal changes over time, whereas the spectral analysis in the frequency-domain graph shows how much of the signal lies within each the given frequency bands over a range of frequencies.

3. Results

The unconstrained Beverton and Holt fits to the data are shown in **Figure 1** along with a loess smoother, parameter estimates are shown in **Table 1**. Steepness is dimensionless and so is comparable across stocks. However virgin biomass is stock specific and so for ease of comparison, virgin biomass was scaled so the maximum value was 1. From the plots it can be seen that for 10 stocks recruit increases as stock size declines (i.e steepness¿1), while for 10 stocks recruitment declines with SSB. The parameters estimates are compared in **Table 1.**

Goodness of fit diagnostics are plotted in **Figures 2 to 6**. In **Figure 2** the residuals plotted against SSB to evaluate whether the model is a reasonable fit to the data. Systematic patterns are seen in the residuals implying that either the model choice was wrong or that recruitment is also driven by factors other than SSB. Therefore in **Figure 3** the residuals were plotted against year and the residual deviances compared in **Table 2,** in most cases year explains more of the variance than SSB. The residuals are plotted against the fitted values in **Figure 4** as a check of the variance. **Figure 5** plots residuals by quantile against their expected quantiles, if they come from a normal distribution, any systematic departure from the straight line indicates a violation of the assumptions, i.e. skewness or over or under dispersion. The final diagnostic in **Figure 6** are plots of the residuals with a lag of 1 to identify autocorrelation.

Problems with fitting occur if there is strong correlation between explanatory variables or because the likelihood is virtually flat at the maximum. A check for this is to profile the likelihood, i.e. **Figure 8** where the likelihood was estimated for steepness and virgin biomass. The plots measure the uncertainty associated with a parameter estimate and evaluate how well a parameter can be estimated from the data. They also allow confidence intervals to be estimated.

Recruitment by year, along with loess smoothers are presented in **Figure 9**, while time series are presented in figures 9 for SSB and recruitment as run sequence plots and the spectral analysis is presented in Figures 11 and 10. These show that annual variability independent of SSB is be important, that recruitment is more variable between years than SSB.

4. Discussion and Conclusions

It has been known for almost a century Hjort (1926) that fish stocks can fluctuate extensively over a large range of spatial and temporal scales independent of human exploitation. Many studies have also shown that most exploited marine populations are not stationary, but display strong natural spatial and temporal variations Hjort (1926), Cushing and Dickson (1976), Walters (1987), Ottersen and Sunbdy (1995), Schwartzlose et al. (1999), Ravier and Fromentin (2001) and Dorner et al. (2008).

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Table 1. A comparison of model fits.

Stock	*Steepness*	*SE*	*Virgin*	*spr0*	*lambda*
ALB north Atlantic	1.54	0.00	94424.80	0.01	-11.43
ALB north Pacific	1.28	0.17	240272.91	0.01	-18.32
ALB south Atlantic	0.69	0.00	239187.96	0.02	8.90
ALB south Pacific	0.36	0.00	264451.74	0.01	2.26
BET Atlantic	0.60	0.00	1173301.13	0.02	6.10
BET east Pacific	2.00	0.00	201107.98	0.02	-8.00
BET Indian	0.98	0.00	1116683.22	0.01	206.76
BET west Pacific	1.70	0.00	582464.03	0.26	-9.73
BFT east Atlantic	1.15	0.03	305223.77	0.14	-30.72
BFT west Atlantic	0.22	0.00	8443.01	0.17	1.11
KGM west Atlantic	2.00	449648.84	898.19	0.00	-8.00
MAC NE Atlantic	1.97	6989.57	5363929.41	1.75	-8.11
MAS NE Pacific	0.27	0.00	157478.17	0.25	1.46
PBF Pacific	0.81	0.00	41497.05	0.00	16.59
SBF southern	0.61	0.00	911195.35	0.13	6.22
SSM GulfMexico Atlantic	2.00	3161.09	5901.34	0.00	-8.00
SSM west Atlantic	0.69	0.00	5049.74	0.00	8.89
SWO Mediterranean	0.20		394316240.16	167.68	1.00
SWO north Atlantic	0.93		43264046.26	78.01	51.34
YFT Atlantic	1.11	0.00	750068.18	0.01	-38.95
YFT east Pacific	0.34	0.00	170749.42	0.00	2.03
YFT Indian	1.44	0.04	2757078.57	0.04	-13.00
YFT west Pacific	0.57	0.00	2430577.67	0.02	5.35

Table 2. A comparison of deviances for lowess fits to stock recruit data with year or SSB as a covariate.

	Residual Deviance			
Stock	*Year*		*SSB*	
ALB north Atlantic	57.18	***	61.01	**
ALB north Pacific	25.62	**	36.66	
ALB south Atlantic	13.91	***	16.92	***
ALB south Pacific	35.31	**	37.43	*
BET Atlantic	13.66	***	19.32	**
BET east Pacific	18.95	***	20.88	**
BET Indian	55.29		54.69	
BET west Pacific	28.56	***	31.51	***
BFT east Atlantic	9.43	***	20.01	***
BFT west Atlantic	11.23	***	11.92	***
KGM west Atlantic	14.47		14.86	
MAC NE Atlantic	32.84		31.35	
MAS NE Pacific	40.16	***	36.11	***
PBF Pacific	43.76	.	47.62	
SBF southern	24.18	***	26.51	***
SSM GulfMexico Atlantic	10.93		9.56	.
SSM west Atlantic	9.78	*	9.27	*
YFT Atlantic	14.60	***	25.84	*
YFT east Pacific	17.15	***	21.40	**
YFT Indian	26.41	*	29.40	
YFT west Pacific	47.12		50.08	
SWO north Atlantic	16.01	***	20.23	*
SWO Mediterranean	19.56		17.52	

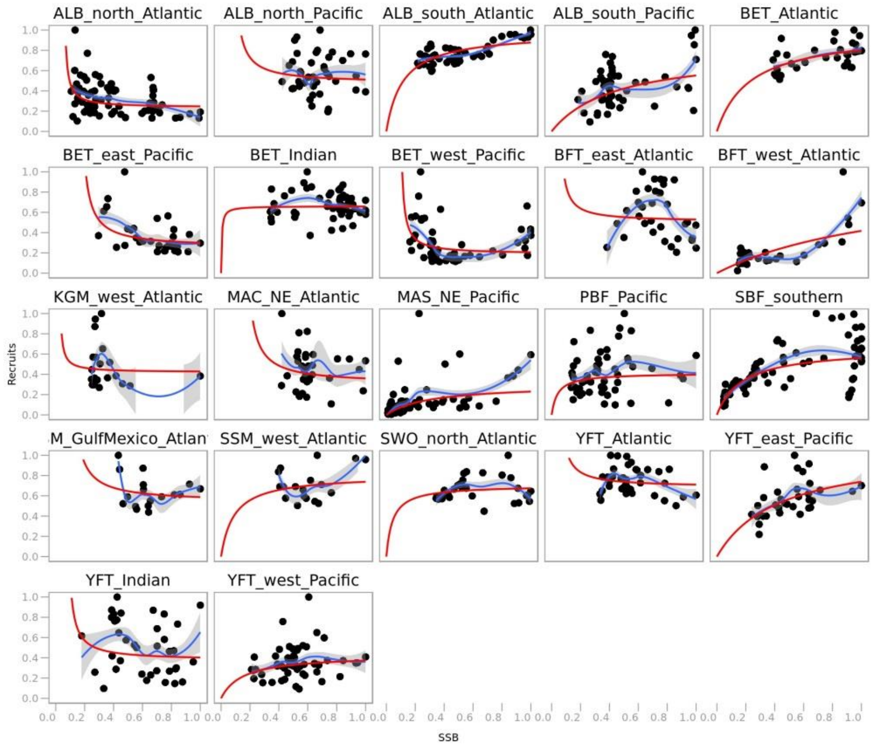

Figure 1. Recruitment verses spawning stock biomass with fitted Beverton and Holt stock recruitment relationships; SSB is scaled so maximum observed value is 1.

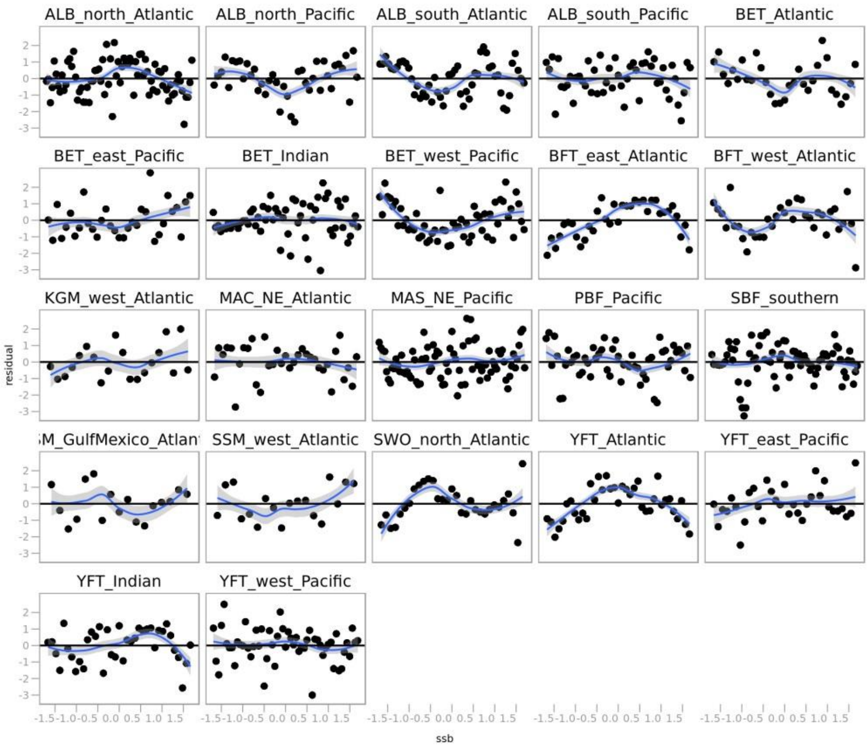

Figure 2. Residuals from the Beverton and Holt fits plotted against SSB by stock.

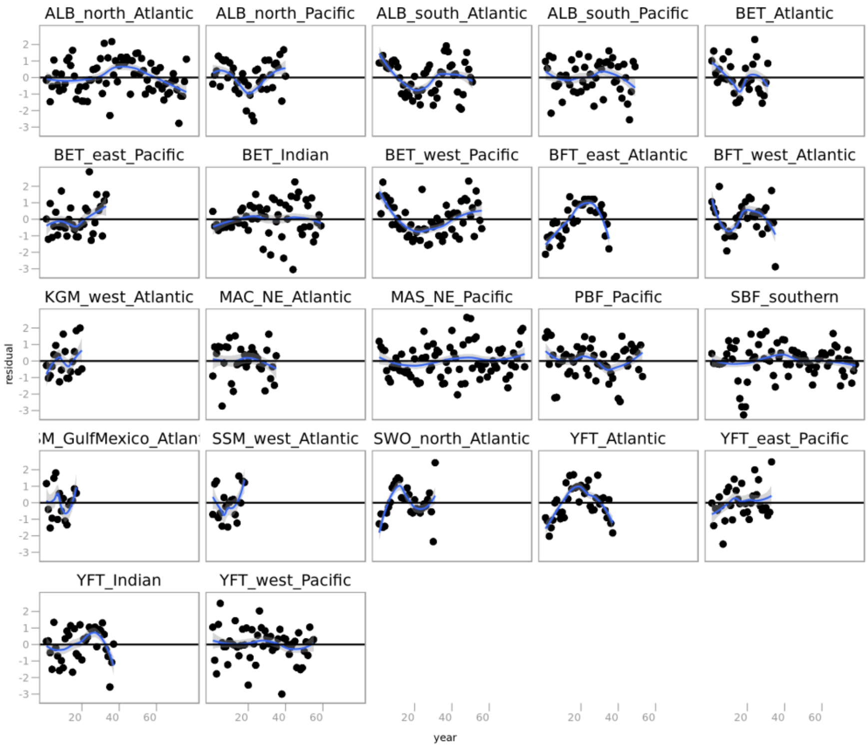

Figure 3. Residuals from the Beverton and Holt fits plotted against Year by stock.

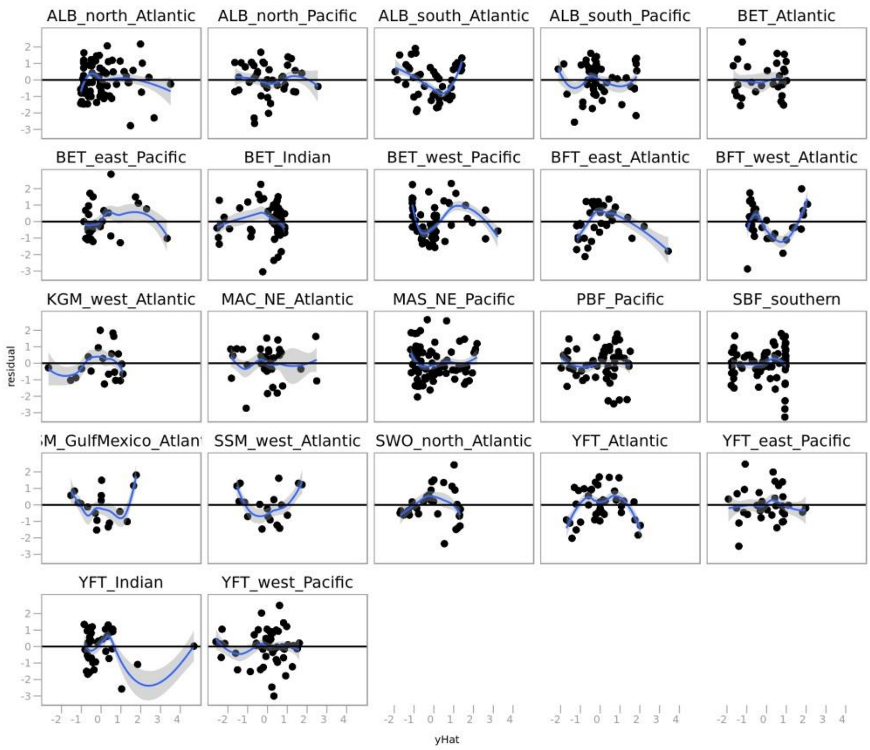

Figure 4. Residuals from the Beverton and Holt fits plotted against predicted recruitment by stock.

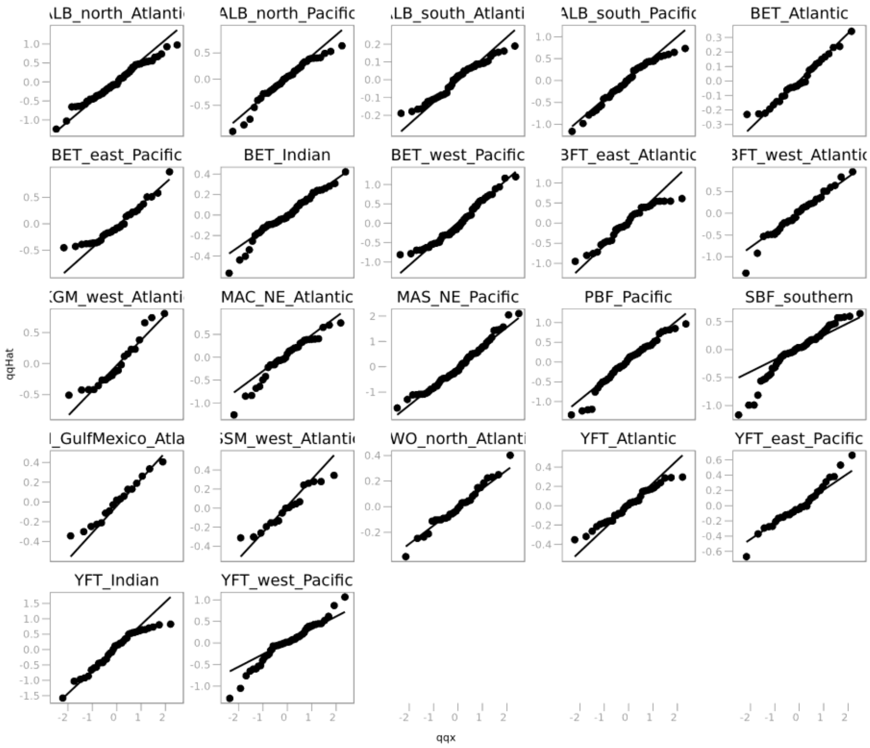

Figure 5. Quantile-quantile plots by stock.

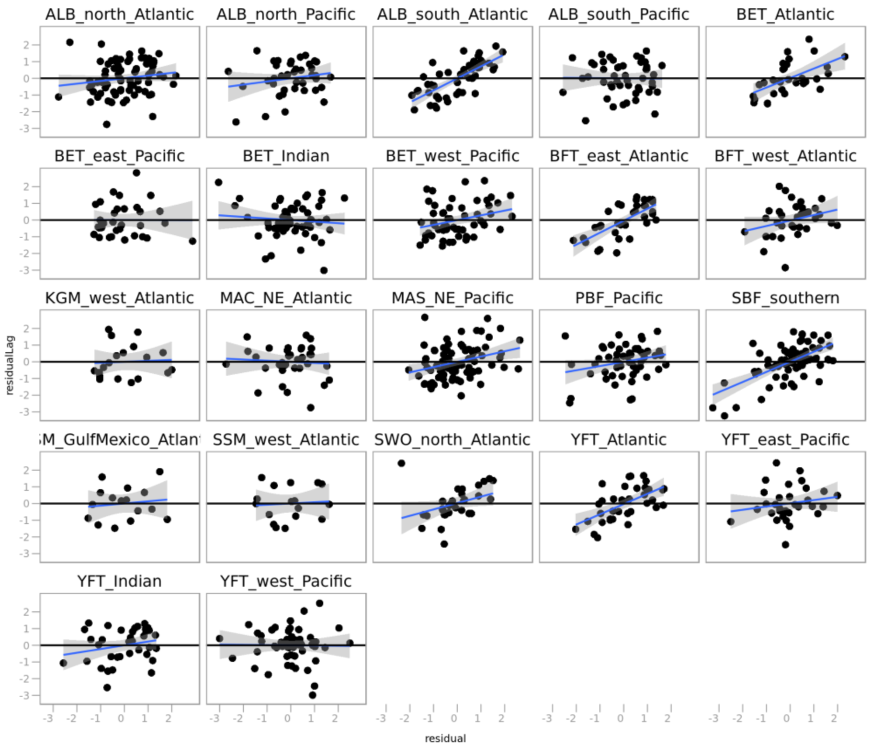

Figure 6. Residuals from the Beverton and Holt fits plotted against residuals with a lag of 1 by stock.

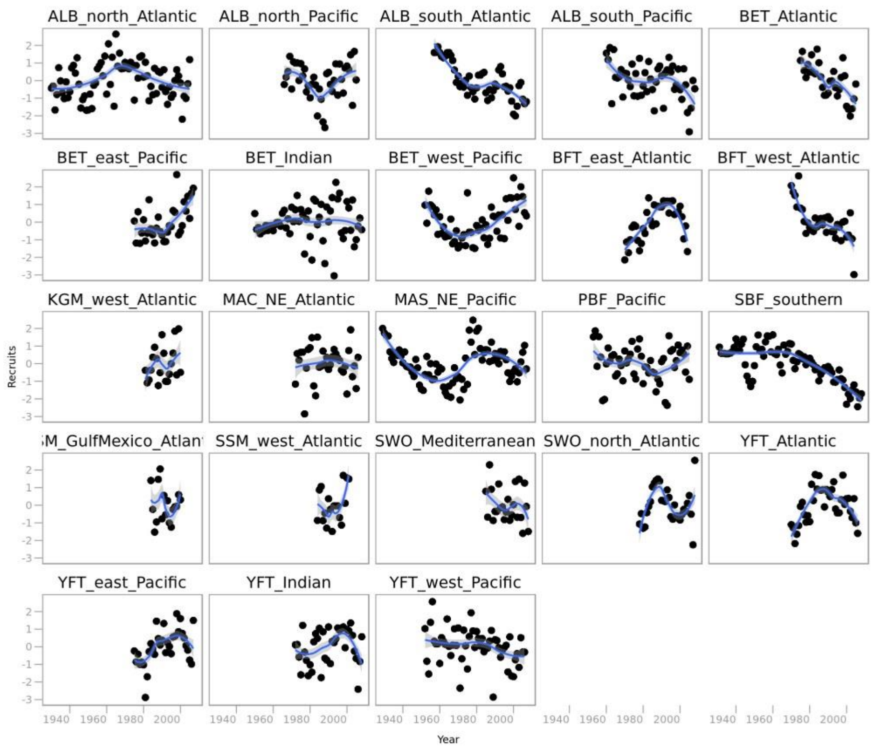

Figure 7. Recruitment verses year with lowess smoothers; SSB is scaled so maximum ob served value is 1**.**

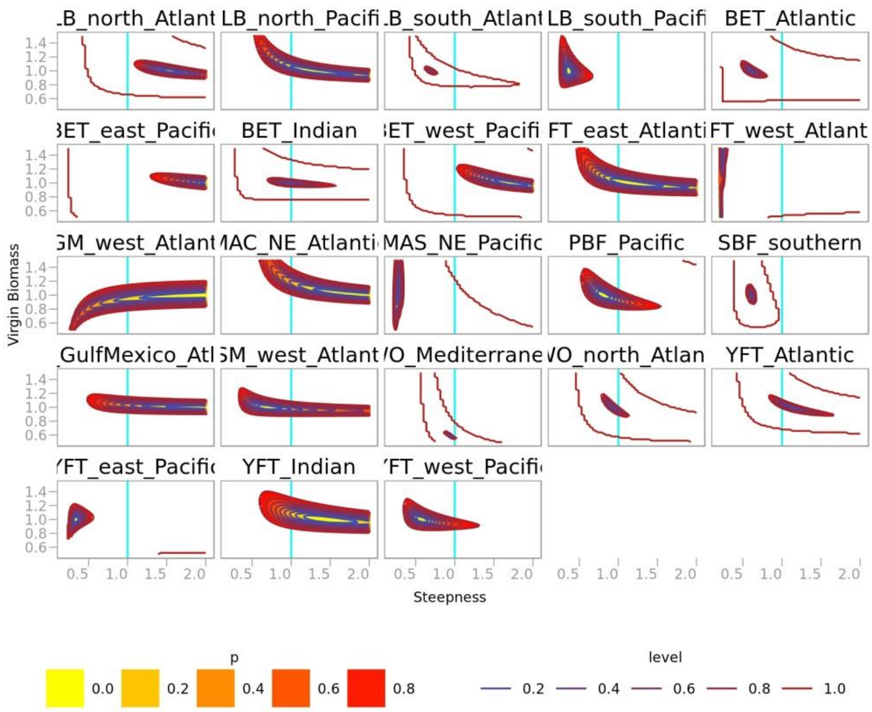

Figure 8. Confidence regions for Beverton and Holt stock recruitment relationships, contours and colours correspond to probability levels.

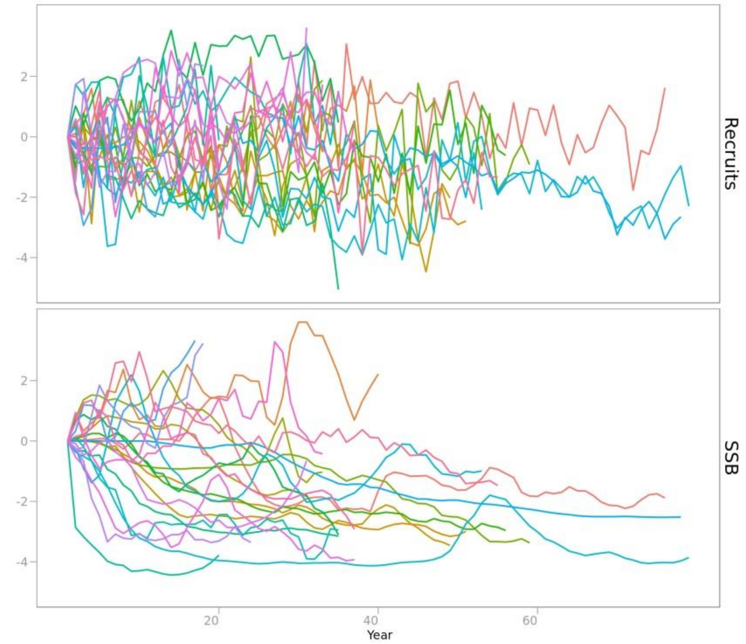

Figure 9. Run sequence plots, for SSB and recruits, time series are standardised and the 1st value in each series set to 0.

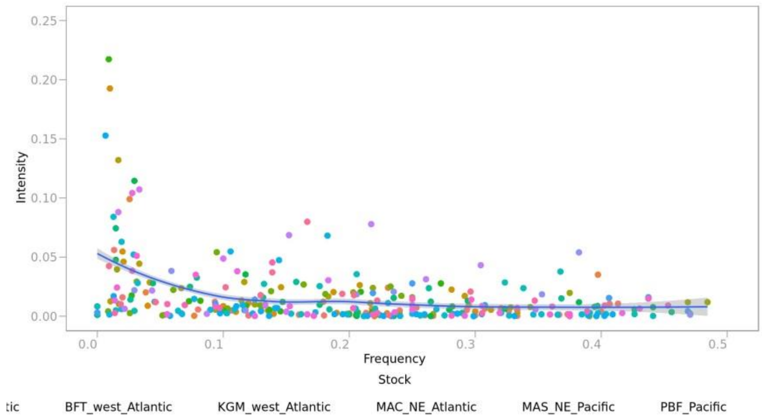

Figure 10. Spectral plot for recruitment for all stocks with smoother, showing intensity against frequency; a frequency of 0 corresponds to an infinite cycle while a frequency of 0.5 corresponds to a cycle of 2 years.

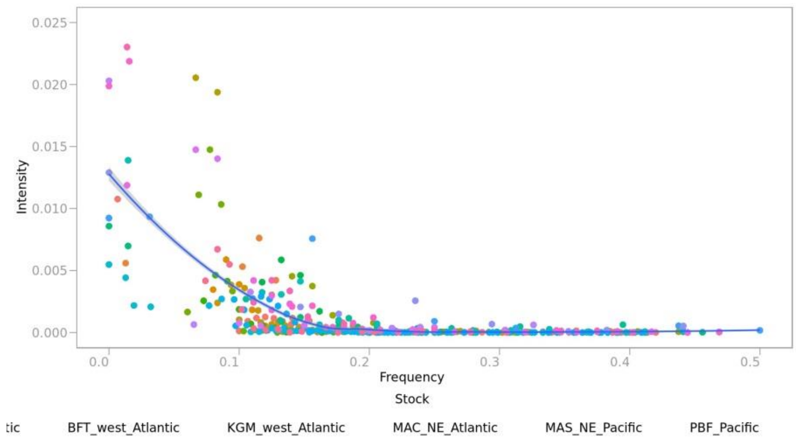

Figure 11. Spectral plot for SSB for all stocks with smoother, showing intensity against frequency; a frequency of 0 corresponds to an infinite cycle while a frequency of 0.5 corre- sponds to a cycle of 2 years.