REPORT OF THE 2009
ICCAT WORKING GROUP ON STOCK ASSESSMENT METHODS
(Madrid, March 11-14, 2009)

1. Opening, adoption of Agenda and meeting arrangements

Mr. Driss Meski, ICCAT Executive Secretary, opened the meeting and welcomed participants.

The meeting was chaired by Dr. Victor Restrepo. Dr. Restrepo welcomed the Working Group participants, reviewed the objectives of the meeting and proceeded to review the Agenda which was adopted with minor changes (**Appendix 1**).

The List of Participants is attached as **Appendix 2**.

The List of Documents presented at the meeting is attached as **Appendix 3**.

The following participants served as Rapporteurs for various sections of the report:

Section	*Rapporteurs*
1, 5, 7	P. Pallarés
2	V. Ortiz de Zárate and C. Minte-Vera
3	J. Neilson, M. Schirripa and E. Rodríquez-Marín
4	S. Cass-Calay, A. Di Natale and G. Scott
6	G. Scott

2. Manual for CPUE standardization

The Working Group Chair reminded the meeting participants that the outline of the ICCAT CPUE standardization manual has been available for some time (see Appendix 4 of Anon. 2008). However, the contents of the manual have not been drafted yet. In the *ICCAT Manual* available at the website, there is an introductory chapter on CPUE standardization to be used for ICCAT stock assessment.

During the meeting, several documents about CPUE standardization which were prepared for a workshop in the United States (SouthEast Data, Assessment, and Review process, SEDAR, http://www.sefsc.noaa.gov/sedar/) were presented as information documents. The Group found that the content of these documents (attached as **Appendix 4**) was very interesting and that the same material could potentially be used for the ICCAT manual on CPUE standardization. These scientists and others who are interested in collaborating on this effort were encouraged to work towards the completion of a first draft of the manual in time for the 2009 SCRS meeting.

3. Review of methods to address species targeting and gear/species overlap during CPUE standardization

The Group received three working papers that related to targeting in CPUE analyses. It should also be noted that recent reports of the Stock Assessment Working Group contain useful additional material relevant to this topic (Anon. 2001; Anon. 2004).

Simulation Testing

In SCRS/2009/028, the authors explored the effects of targeting, where fishing effort is directed towards one species as opposed to another, which can introduce bias into CPUE time series. In recognition of this fact, the ICCAT working group on assessment methods has recommended testing alternative standardization methods. Simulation techniques were shown to offer an objective and scientifically sound means to explore this problem. Data from simulations can subsequently be analyzed with any number of standardization methods to quantify the performance of each alternative. The authors presented a simple, two species-one gear approach that demonstrated a simple study design using simulated data. They then considered an arbitrary longline fleet catching yellowfin tuna and blue marlin whose distributions were assumed proportional to the annual average spatial distributions of catch per unit effort by month in the ICCAT longline data. The spatial distributions of otherwise arbitrary longline sets were input by year, month, latitude and longitude. Half of the simulations assumed no targeting, and the simulated effort was equally divided between areas of high yellowfin tuna and blue marlin catch rates. The other half of the simulations began with equal effort between the two species but targeted yellowfin tuna in the last half of the time series. The simulated population trajectories of the two species were either assumed to have no trend or to follow the trends estimated from the last assessments. Even with these relatively simple simulations, it was obvious that targeting substantially biased the CPUE time series. Such simulated data sets provide the opportunity to test alternative standardization methodologies to remove the biases introduced by species targeting. The simulation model employed, described as LLSIM at the end of this section, (a successor to the SEEPA program that is part of the ICCAT software library: http://www.iccat.int/en/AssessCatalog.htm) also provides for the evaluation of much more complicated problems. However, the authors proposed that studies progress from simple to more complex assumptions to minimize possible misinterpretation of results.

The paper SCRS/2009/028 pointed out some cases when the CPUE standardization was not able to recover the true simulated trend, even given perfect information on when the shifting in target was occurring during the time series. One possible explanation is that the software used to standardize the CPUEs might treat unbalanced designs in a different fashion. The Working Group decided that further exploration on the effect of software on the standardization of CPUE should be performed during this meeting. For this exploration, the simulated data used was that on blue marlin (hereafter BUM) generated when population trajectories were assumed to follow the trend estimated in the last stock assessment and the shift into targeting yellowfin tuna occurred in 1975. The delta-lognormal approach was computed in SAS (Shono, 2001) and compared to the original R results. Both standardizations were biased and produced higher relative CPUE then the true relative biomass before 1975 and lower after 1975. Although there could be some differences between the source code used in the two analyses, the Group concluded that the choice of statistical software was probably not responsible for the problem of biased representation of the trend in CPUE.

Another possible explanation for the bias was that the rareness of the blue marlin species was resulting in an empirical distribution of catch per set that could not be represented by a lognormal distribution even after the zeros are excluded (see Figure 4 lower panel in SCRS/2009/028). A more appropriate distribution to describe these data may be the Poisson distribution. Therefore the BUM data set was standardized using GLM procedure in R with the Poisson family. Two models were fit, with and without target as a factor explanatory variable. Similarly to the original models, both Poisson models had month and year as factors and latitude and longitude as continuous variables. The year effect estimates for both models differ only slightly between them and had the similar bias in trend that emerged when the delta-lognormal approach was used (**Figure 1**). The data might be more aggregated than expected by a Poisson distribution, and may be better described by other distributions. For future investigation of this issue, these data are available through the Secretariat. Also, a new data set should be produced with higher expected catches for blue marlin to explore whether the rareness of the species is the causing the bias.

Dynamic Factor Analysis (DFA)

In SCRS/2009/030, the author explored the usefulness of Dynamic Factor Analysis (DFA) to detect common patterns in the sets of CPUEs for Atlantic yellowfin (*Thunnus albacores*) and for eastern Atlantic skipjack (*Katsuwonus pelamis*), respectively. For yellowfin, the most appropriate model, in terms of AIC, identified two common trends. The 10 yellowfin CPUE series could be divided into three groups based on factor loadings. The grouping corresponds in part to the geographic location of the fisheries (i.e., the western Atlantic area for group 1 and the northeastern tropical Atlantic region for group 2). The fact that the first group is constituted by CPUEs obtained from three different fishing gears (pole and line, purse seine and longline), operating at different depth levels, suggests that the regional trend reflects more a sub-population response to a local exploitation rate than to environmental conditions. In light of the present results, the CPUEs should be combined respectively into two regional indices before performing a unique combined index. For skipjack, results are less conclusive and further studies with explanatory factors are required to account for the fact that this species is seldom targeted by the tuna fisheries.

The Group discussed the advantages and drawbacks of introducing increasing complexity into catch rate analyses. On the one hand, it was noted that more information and CPUE series is not always helpful, particularly when divergent and unexplained patterns are noted. On the other hand, it was pointed out that for spatially complex stocks, having discrete indicators of subpopulation exploitation rate can be very helpful, if sufficient data exist. The Group also commented that the reason that the skipjack results were less conclusive may be related to the impacts of FADs on catchability for this fishery. It was also noted that the various CPUE series could be targeting fish of different size.

An empirical approach

SCRS/2009/031 contained an examination of alternative methods to describe targeting in the Canadian pelagic longline fishery. Over the past decade, that fishery has evolved from a traditional swordfish fishery concentrated along the continental shelf edge to a more mixed fishery that targets swordfish and “other” tunas (albacore, bigeye and yellowfin). The spatial distribution of the fishery now also includes a higher proportion of trips made further offshore, in relatively warm Gulf Stream waters. A fishing trip is considered to be directed for swordfish if the total landed weight of swordfish exceeds that of tuna. Recent developments in the Canadian catch-effort database allow an examination of catch rates at the set level, thereby offering the potential for consideration of different target variables, such as bait type or sea surface temperature.

The authors concluded that all three potential targeting variables (proportion of swordfish catch weight, SST, and bait) gave plausible and generally comparable results for swordfish-targeted trips. However, the alternate target variables did not explain more of the observed variation in catch rates than the model which incorporated the traditional method used for targeting. Additionally, while it is evident that set-specific differences can exist within fishing trips, the number of trips including multiple bait types is relatively small. Set level detail is available only for the portion of the catch rate series since 1994, and in order to utilize set details in the standardization the early part of the time series (1988-1993) would have to be omitted. The authors therefore recommended that the current practice of using the traditional method of swordfish targeting be retained in the Canadian CPUE for the upcoming stock assessment.

The Group noted that including both bait and surface temperature together could be a useful approach, and could be investigated further.

Longline fishery simulator (LLSIM)

In addition to the three working papers described above, the Group received a presentation on a longline fishery simulator (LLSIM). The presentation noted that at the Assessment Methods Working Group Meeting in Shimizu, Japan in 2003 (Anon. 2004), the Working Group gave priority to use simulation to develop data sets for testing habitat standardization (HBS) versus GLM for standardizing CPUE for billfish caught on longlines. Initially the simulations were to use the same assumptions that were actually being used in the HBS for the Japanese longline data at the time. To accomplish this task, a longline data simulator (LLSIM) was developed. The first sets of simulated data from LLSIM were provided to the ICCAT Billfish species working group in preparation for its 2005 Data Preparatory Meeting in Natal, Brazil (Goodyear 2006a). The working group applied the available standardization methods to attempt to recover the “true” population trends from the simulated longline catch and effort data. None of the methods applied recovered the underlying true population trend. Subsequently, extensive analyses of the LLSIM code were performed as well as the inputs arising from the specifications adopted at the Shimizu meeting of the Methods Working Group. The results were presented at the September-October 2005 Madrid meeting of the ICCAT SCRS (Goodyear 2006b). The results implicated features of the Japanese data used in the simulations as major impediments to CPUE standardization in the simulated datasets.

Currently, the code is dimensioned for six species with up to four behaviorally different sex/age groups each, and up to 50 gear types. The spatial dimensions reflect the Atlantic Ocean at a scale of 1 degree latitude and longitude with 64 depth layers from the surface to 640 m depth. The model is flexible in that it can be used to test a number of different problems related to longline CPUE standardizations. It is anticipated that it will be applied to develop data sets to test the statistical habitat standardization method (StatHBS) and various alternatives for including species composition of the catch as a method to account for targeting effects in the standardization of CPUE.

The Group noted that as shown in SCRS/2009/028, LLSIM offers important capabilities for the investigations of catch rate standardizations, including targeting and gear/species overlap. To identify potential follow-up work from this meeting, the Group reviewed recent species stock assessments to identify priority problems involving catch rates and the impacts of targeting.

Future works

It was decided that the clustering methodology (Hazin *et al.* 2007a and Hazin *et al.* 2007b) used in the most recent swordfish assessment (Anon. 2007) would perhaps be a useful candidate. The group recognized a recommendation made during the review of that assessment:

Discussion of this approach resulted in a recommendation to investigate the method through simulation to permit evaluating the potential sources of bias in approach. Such simulations have been carried out for simpler methods which use catch of other species to index the degree of targeting (Anon. 2001). That set of simulations found that certain approaches using catch of other species could lead to serious bias in measures of relative abundance. The Group was concerned that the methods may have introduced a positive bias in the inferred relative abundance trend and believes that the pattern resulting may be an overly optimistic representation of the recent trend in southern Atlantic swordfish biomass.

Based on this recommendation the group set out to design a simulation study to test the veracity of the clustering methodology by evaluating (1) any potential biases inherent in this method, and (2) if any biases did exist how they would carry forward when including the clustering factor in the GLM standardization of the CPUE time series. The Group determined that a simulation employing six frequently encountered ICCAT species would be appropriate. Targeting would be simulated by assuming that fishers had accurate knowledge of the species geographic distribution and would change their target species by changing locations and directing more effort in those areas with known higher abundances. In an effort to begin with a simple design and to keep the results tenable, one gear configuration consistent over time would be used. The simulation results would be output such that the target species of each set would be known with certainty. While this feature needs yet to be implemented in the model, the author (Dr. Goodyear) assured the group that this could be done in a short time. Four simulations will be run, similar to those presented in SCRS/2009/028: (1) no trends in the simulated populations, (2) no targeting, (3) inconsistent trends in the population, (4) include targeting. The Group went on to discuss the various aspects of how targeting should be scheduled with regard to annual and/or monthly variation. This has yet to be worked out. The Group also agreed that the study should be conducted "blindly", which is to say that the analysts should not be provided the true targeting information during their analysis. Furthermore, the data sets should have reasonable degree of similarity to the actual practices of the fleet being simulated, but not so close as to make the nature of the targeting an already known quantity. Species will likely be referred to with generic names so as not to bias any results.

4. Influence of life history characteristics, environmental variability and gear selectivity on Status Determination with respect to the Convention objectives

Document SCRS/2009/29 described a framework for examining the influence of life history characteristics and other sources of variability on stock status determinations with respect to ICCAT Convention (or other) objectives. The authors point out excursions below the expected B_{MSY} can occur even in a fishery not undergoing overfishing (*e.g.* due to fluctuations in recruitment and other biological/environmental conditions). Therefore, it may be logical to define a "target" as a level that will accommodate natural variations of stock biomass without jeopardizing the health of the stock or the Convention objectives. If so, it may also be also useful to define a "limit" reference point less than the "target" benchmark, to use as a trigger for (accelerated) management actions. Under the current ICCAT convention fish stocks are managed with the objective of "maintaining the populations of these fishes at levels which will permit the maximum sustainable catch (MSY) for food and other purposes". This language could be interpreted that F_{MSY} is a "target" objective for each stock unit. Alternatively, more modern (than the ICCAT Convention) international instruments can be interpreted to mean MSY benchmarks should be treated as limit reference levels which should not be exceeded.

This simulation framework demonstrated in SCRS/2009/029 allowed evaluation of possible biomass limits (B_{lim}) in reference to whether the limit will likely trigger a ("false positive") response (indicating that the stock is overfished when it is simply undergoing "normal" variability in recruitment) or whether the limit will fail to trigger a response ("false negative") when the stock ***is*** being overfished and the limit is set too far away from the target to positively identify overfishing status. In the example given in the paper (loosely based on northern albacore) a notable result was the long recovery period required to rebuild SSB to a target level, even at relatively low levels of SSB depletion, making discrimination of overfishing effects from natural variation difficult unless the degree of overfishing (and subsequent depletion) is large.

The Working Group discussed the difficulty in evaluation of the appropriate limits and targets without some policy guidance on the tolerable level of risk of either a false positive or false negative response. While it is possible to select a biomass limit below B_{MSY} which offers low odds of 'false positives', this could be but at the expense of non-negligible odds of 'false negatives'. While SCRS/2009/029 did not conduct a statistical 'power analysis', the simulation framework used makes it possible to do such work and the Working Group recommended this be pursued through simulation to provide additional information for use in policy setting. One advantage of setting a target biomass above B_{MSY} is that such targets can be established at levels which simultaneously result in low odds of biomass excursions below B_{MSY} and low odds of 'false negatives'.

One result of the analysis provided in SCRS/2009/029 was the variability in SSB relative to the expected level of SSB_{MSY} was insensitive to the proxy F level used for MSY calculations and the selectivity pattern modeled. This result is similar to the finding in SCRS/1998/120. In view of this, the WG decided to examine the expected variability in SSB_{MSY} in ICCAT stocks for which recent age-based assessments were available (see **Appendix 5**). In the cases of stocks for which age-structured assessments are not the primary basis for management advice (*e.g*. N SWO, BET, BUM, WHM, *etc*.), it was recommended that the use of simulation methods following those described in Goodyear (1999) be applied to compare with the computations made by the Working Group at the meeting. The Working Group also decided to examine the variability in fishable biomass based on the age-structured analyses used for N SWO, BET and YFT to approximate the expected range of variability resulting from a lumped biomass form of assessment.

Table 1 and **Figure 2** show the results of the calculations carried out by the Working Group. These demonstrate that the probability of falling below expected biomass ratios less than about 0.8 due to natural (modeled) variability is low while fishing at an F_{MSY} (or proxy) level in most cases. On the other hand, the probability of falling below B_{MSY} while fishing at $.75F_{MSY}$ (**Table 2**) is exceedingly low (<<1%), with the added benefit of a substantial gain (~40%) in SSB, but only a marginal loss (~2%) in equilibrium yield compared an MSY proxy for the examples examined here.

The Working Group recommended that species groups apply similar methods to advise on a range of possible biomass limits and targets using an approach similar to this framework with each updated assessment. It would also be prudent for species groups to seek approaches to more fully characterize the overall uncertainty in assessments since these uncertainties likely have important impact on estimation of such targets and limits.

5. Other matters

Conveying stock status information

In the last years, the SCRS has introduced the "faces" plots as a method to convey the status of the ICCAT stocks. This graphic representation is considered a good method of conveying, especially to a non-scientific audience, complex situations such as what the state of the stock is. Nevertheless, the SCRS has used the more simple approach that is a three face design. With this method and other similar methods the user decides for him/herself which face is the most appropriate for the message they are trying to convey. If the possible outcomes are limited in number and defined by some type of objective function these plots are sufficient but if the outcomes are more complex these plots are not able to convey the overall picture.

Document SCRS/2009/027 presented an attempt of producing a community of faces to convey an overall picture of the condition of all ICCAT stocks relative to one another. Based on the potential of the "faces" plots method to convey multidimensional data, the authors developed series of faces (corresponding to points in a k-dimensional space) whose features, such as length of nose and curvature of mouth, correspond to components of the point. Those faces are formed from the data themselves and as such the user does not choose the face but rather the face is created from the actual data that is being conveyed. In this particular case, the authors integrated a variety of stock-specific data sources into a single face plot for each of the ICCAT stocks under consideration. In this way, faces conveying happiness would represent data rich situations and/or stocks that are being fished near their estimated optimal levels. Conversely, faces conveying sadness would represent data poor situations and/or stocks that are currently estimated to be overfished or experiencing overfishing. Factors used to represent the various facial expressions included such things as current yield, F/F_{MSY}, B/B_{MSY}, assessment category, and amount of Task I data.

The group recognized the limitation of the current approach to convey the complexity of the stock status and welcome the proposal of using a wider range of "faces". The advantages and disadvantages of using simple and complex face plots were also discussed. Simple face plots can easily convey a simple message with little room for misinterpretation, but the user must choose the correct face. More complex faces are useful for conveying more complex messages but the interpretation is not as straight forward but the face is an emergent property of the data and thus less subjective. The Group also discussed the possibility of using this method or additional graphical designs, such as arrows, to add a time component to the stock status representing the current situation in relation to the previous ones.

CPUE as a measure of abundance

Under this item the Group also considered that some CPUE series might be misleading, due to the characteristics of the fishery itself. As an example, the purse-seine or bait boat CPUEs need to be evaluated on a fishery-by-fishery base. It was noted that some series might not be able to represent trends in abundance since effort is not adequately described because it is difficult to account for the complexity of the fishing operations, the fishing patterns or the biology of species. The Group also raised the point of reviewing the CPUEs were only target species are considered, moving towards CPUEs where all the species in the fishery are taken into account, since targeting is quite frequently difficult to define.

Other issues

Other issues tabled during the meeting but not discussed in depth are included as **Appendix 6.**

6. Recommendations

One advantage of setting a target biomass above B_{MSY} is that such targets can be established at levels which simultaneously result in low odds of biomass excursions below B_{MSY} and low odds of ‘false negatives’, which is not the case if the limit is set below. While document SCRS/2009/029 did not conduct a statistical ‘power analysis’, the simulation framework used makes it possible to do such work. The Working Group recommended this be pursued through simulation to provide additional information for use in policy setting regarding limits and targets.

Uncertainties in life history characteristics are very relevant to the types of analysis discussed in Section 4 and they should be considered in future evaluations. A better use and exploitation of the available scientific literature might help in recovering useful information that could promote more fully capturing range of uncertainty in stock status evaluations.

Gear selectivity and targeting are important components influencing stock status evaluations. Appropriate methods to account for these effects are not fully developed, especially for cases wherein detailed information on gear, time/area/ and other features pertinent to the issue are unavailable. Methodological approaches using proxies such as proportion of different species in the catch have been implemented, but not rigorously tested. Testing of the different methods implemented should be conducted using simulated data sets such as available through the LLSIM model. In order to continue to address this, future work as outlined in Section 3 should be carried out.

7. Adoption of the report and closure

The report was adopted during the meeting.

The Chairman thanked the participants and the Secretariat for their hard work.

The meeting was adjourned.

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Table 4.1. Biomass ratios corresponding to indicated probabilities of falling below the indicated biomass ratio while fishing at two different target F's.

Spawning Biomass (SSB)	Fishing at F_{MSY} Proxy					
	Biomass Ratio Corresponding to Indicated Probability of falling below $E(SSB_{MSY})$					
Stock[1]	1%	5%	10%	15%	20%	25%
YFT	0.79	0.84	0.87	0.90	0.92	0.93
BET	0.86	0.90	0.92	0.93	0.95	0.96
N-SWO	0.88	0.92	0.93	0.95	0.96	0.96
W-BFT-R70+	0.66	0.75	0.80	0.83	0.86	0.88
E-BFT-R90+	0.91	0.94	0.96	0.97	0.97	0.98
N-ALB	0.72	0.80	0.84	0.87	0.89	0.91
E-BFT-R70+	0.83	0.88	0.91	0.92	0.94	0.95
W-BFT-R76+	0.86	0.90	0.92	0.94	0.95	0.96

Spawning Biomass (SSB)	Fishing at $.75*F_{MSY}$ Proxy					
	Biomass Ratio Corresponding to Indicated Probability of falling below $E(SSB_{MSY})$					
Stock[1]	1%	5%	10%	15%	20%	25%
YFT	1.14	1.21	1.26	1.29	1.31	1.33
BET	1.35	1.42	1.45	1.47	1.49	1.50
N-SWO	1.37	1.42	1.44	1.46	1.47	1.48
W-BFT-R70+	0.93	1.06	1.13	1.17	1.20	1.23
E-BFT-R90+	1.16	1.19	1.21	1.22	1.23	1.23
N-ALB	1.25	1.38	1.44	1.48	1.52	1.55
E-BFT-R70+	1.06	1.12	1.15	1.17	1.19	1.20
W-BFT-R76+	1.20	1.25	1.28	1.30	1.31	1.32

Fishable Biomass (FB)	Fishing at F_{MSY} Proxy					
	Biomass Ratio Corresponding to Indicated Probability of falling below $E(FB_{MSY})$					
Stock[1]	1%	5%	10%	15%	20%	25%
YFT	0.85	0.89	0.91	0.93	0.94	0.95
BET	0.88	0.91	0.93	0.95	0.96	0.96
N-SWO	0.91	0.94	0.95	0.96	0.97	0.97
W-BFT-R70+	0.73	0.81	0.86	0.89	0.90	0.92
E-BFT-R90+	0.92	0.95	0.96	0.97	0.97	0.98
N-ALB	0.76	0.83	0.86	0.89	0.91	0.92
E-BFT-R70+	0.84	0.89	0.91	0.93	0.94	0.95
W-BFT-R76+	0.90	0.93	0.95	0.96	0.97	0.97

Fishable Biomass (FB)	Fishing at $.75*F_{MSY}$ Proxy					
	Biomass Ratio Corresponding to Indicated Probability of falling below $E(FB_{MSY})$					
Stock[1]	1%	5%	10%	15%	20%	25%
YFT	1.10	1.16	1.19	1.21	1.23	1.24
BET	1.21	1.25	1.28	1.29	1.31	1.32
N-SWO	1.20	1.24	1.25	1.26	1.27	1.28
W-BFT-R70+	0.97	1.08	1.14	1.17	1.20	1.22
E-BFT-R90+	1.22	1.25	1.27	1.28	1.28	1.29
N-ALB	1.02	1.10	1.15	1.18	1.20	1.22
E-BFT-R70+	1.12	1.18	1.21	1.23	1.25	1.26
W-BFT-R76+	1.18	1.22	1.24	1.26	1.27	1.28

[1] Entries with –Rxx+ designations indicate the range of years of recruitment estimates considered in the analysis for the stocks indicated.

Table 4.2 Expected cost in equilibrium yield EY) and benefit in terms of SSB safety margin for setting target fishing mortality rate at 75% of $F_{MSY\ proxy}$ compared to fishing at F_{MSY} proxy.

	Fishing at .75*F_{MSY} Proxy	
Species	Gain in SSB	Loss in EY
YFT	42%	2%
BET	57%	2%
N-SWO	53%	2%
W-BFT-R70+	38%	2%
E-BFT-R90+	26%	1%
N-ALB	70%	2%
E-BFT-R70+	26%	1%
W-BFT-R76+	37%	2%

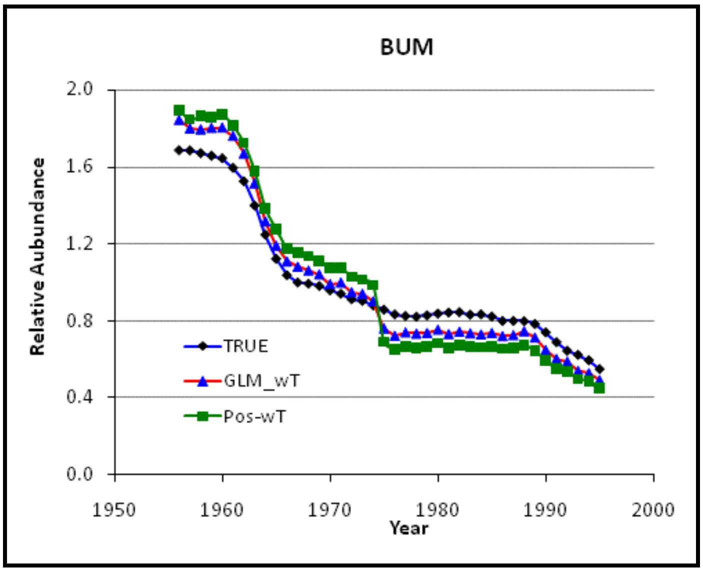

Figure 1. Standardized BUM CPUE using GLM procedure in R with the Poisson family. Two models were fit, with and without target as a factor explanatory variable. Both Poisson models had month and year as factors and latitude and longitude as continuous variables.

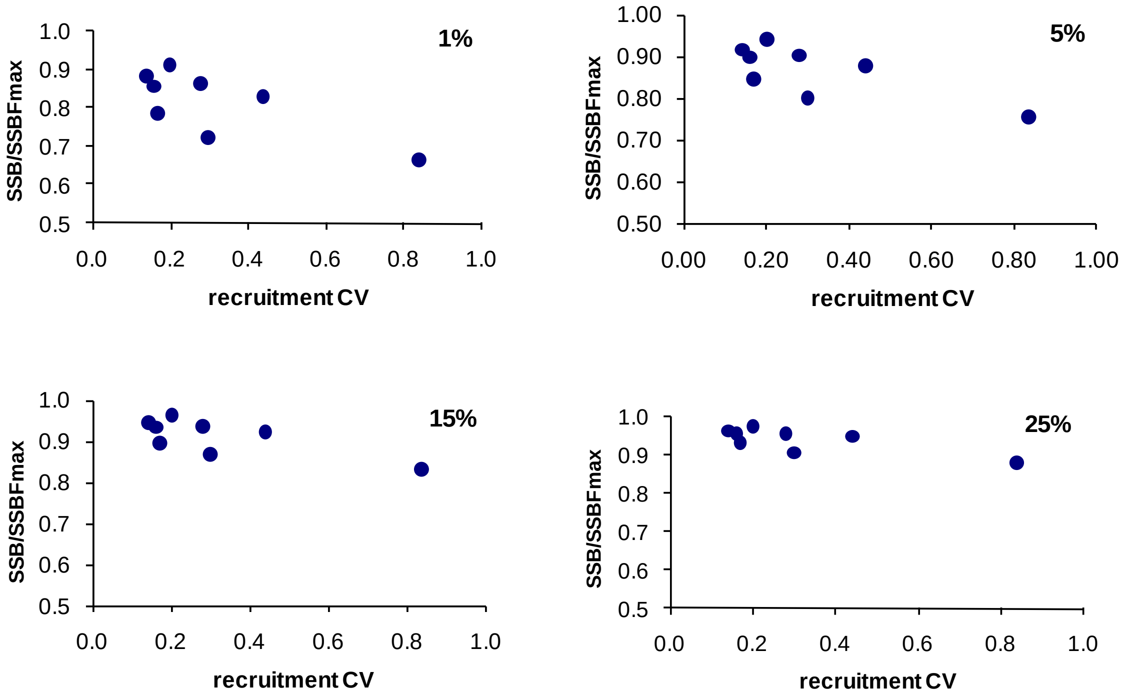

Figure 2. Biomass ratio corresponding to probability (1.5, 15 and 25%) of falling below E(SSB_{MSY}) as a function of the recruitment variability.