Summary of the Stock Assessments for Gambian Sole: 2008, 2011, 2012, 2013

DECEMBER 2013

USAID FROM THE AMERICAN PEOPLE

REPUBLIC OF THE GAMBIA

COASTAL RESOURCES CENTER
University of Rhode Island

WWF

The work herein was supported by the USAID funded Gambia-Senegal Sustainable FisheriesProject (BaNafaa). The BaNafaa project is implemented by the Coastal Resources Center of the Graduate School of Oceanography at the University of Rhode Island and the World Wide Fund for Nature-West Africa Marine Program Office (WWF-WAMPO) in partnership with the Department of Fisheries and the Ministry of Fisheries and Water Resources.

Cover Photo: USAID/BaNafaa project/World Wide Fund for Nature-West Africa Marine Program Office (WWF-WAMPO).

Table of Contents

Summary of the Stock Assessments for the Gambian Sole: 2008, 2011, 2012, 2013.................... 2

Description of the Gambia Tiger (black) and Red Sole Stock Assessment by Medley (2008) .. 4

Description of the Gambia Black and Red Sole Stock Assessment by DeAlteris et al, 2012 8

Description of the Gambia Black and Red Sole Stock Assessment by Ceesay, Jallow, Sanyang, Parkins and Castro... 13

Description of the Gambia Black and Red Sole Stock Assessment by Jallow, Ceesay and Castro 17

Conclusion 23

References... 25

Summary of the Stock Assessments for the Gambian Sole: 2008, 2011, 2012, 2013

There have been four stock assessments conducted for the Gambian sole species. The first was associated with the pre-audit activities for Marine Stewardship Council (MSC) certification by Paul Medley et al., in 2008 using compiled export weights from the processing sector (Atlantic Seafood); the second was conducted by DeAlteris et al (2012) using length-weight data from the Atlantic Seafood and length frequency measurements on landings; the third was conducted by Ceesay et al (2013) using monthly length frequency data from Atlantic Seafood collected over the full year; and the last was conducted using research data on length frequency collected in a gillnet study over a one month period (Jallow et al.,2013). All assessments concentrate on estimation of fishing mortality rather than biomass. There are no fishery independent sources of data available to calculate biomass.

As each assessment has been conducted, the information has become more detailed. Medley et al combined both species whereas DeAlteris et al, Cessay et al., and Jallow et al., were able to separate red and black sole (*Cynoglossus senegalensis* and *Synaptura cadenati*). The conclusions for each assessment are unique to each and care must be used to determine the status of the stock based on these assessments. Each one is a significant improvement in obtaining much needed information in a data limited fishery.

Study	**Additional Analysis**	**Conclusion**
Medley et al		Not recruitment overfishing
DeAlteris et al	CPUE	Overfishing both species

Ceesay et al	Condition Index	Red Sole: Not growth overfishing but recruitment overfishing (F_{30}); Black Sole: growth and recruitment overfishing
Jallow et al		Red Sole: Not growth overfished, but recruitment overfished (F_{30}) Black Sole: Growth and recruitment overfished

Each assessment has used the same methodology. Fish length is converted to age, and numbers of each age are used to calculate the decline over time establishing a total mortality (Z) estimate. Natural mortality is estimated and subtracted to give fishing mortality (F). Reference points are established using a Yield per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBPR) model. Observed F is compared to F_{max} or $F_{20\%}$ or $F_{30\%}$ and a conclusion is reached.

Each study has varied in the use of parameters for these models:

Parameter	**Medley**	**DeAlteris**	**Ceesay and Jallow**
Natural Mortality	0.7	0.5	0.4
L_{max}	60	57	65 red sole 60 black sole
maturity	Knife edge	Linear between age 1 and 2	Linear between age 1 and 2
Vulnerability to gear	Knife edge	Linear between age 1 and 2	Linear between age 1 and 2
K	0.34	0.35	0.35
Wa	0.014	0.00001	Red: 0.1 Black: 0.02
Wb	2.75	3	Red:2.14 Black:2.76

The following highlights the results of each stock assessment.

Description of the Gambia Tiger (black) and Red Sole Stock Assessment by Medley (2008)

This first assessment essentially compares the results of Yield per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBPR) analysis to establish overfishing reference points to the results of a length-based catch curve (LCCA) and Length-based Cohort Analysis (LCA) to estimate the fishing mortality rate. The analysis was only completed for the red sole.

All data used in this analysis was obtained from Atlantic Seafood. Specifically the LW relationship was obtained using a limited data set collected for the purposes of the assessment. The remainder of the data used was from the processer records of export by weight category.

PROCEDURES AND RESULTS OF THE YPR-SSBPR ANALYSES

Procedures:

1. As there is little known about the life history characteristics of red sole in the Gambia, values for the input parameters for the model must be taken from the literature or estimated.

    a. The value of M, the instantaneous natural mortality coefficient was estimated using Pauly's relationship

$$\ln M = -0.0152 - 0.279 * \ln L_{\infty} + 0.6543 * \ln K + 0.463 * \ln T$$

Based on the following parameters, M was estimated to be 0.726.

Growth Parameters	
L0	0
K	0.34
Linf	60
Average Seawater Temperature	28

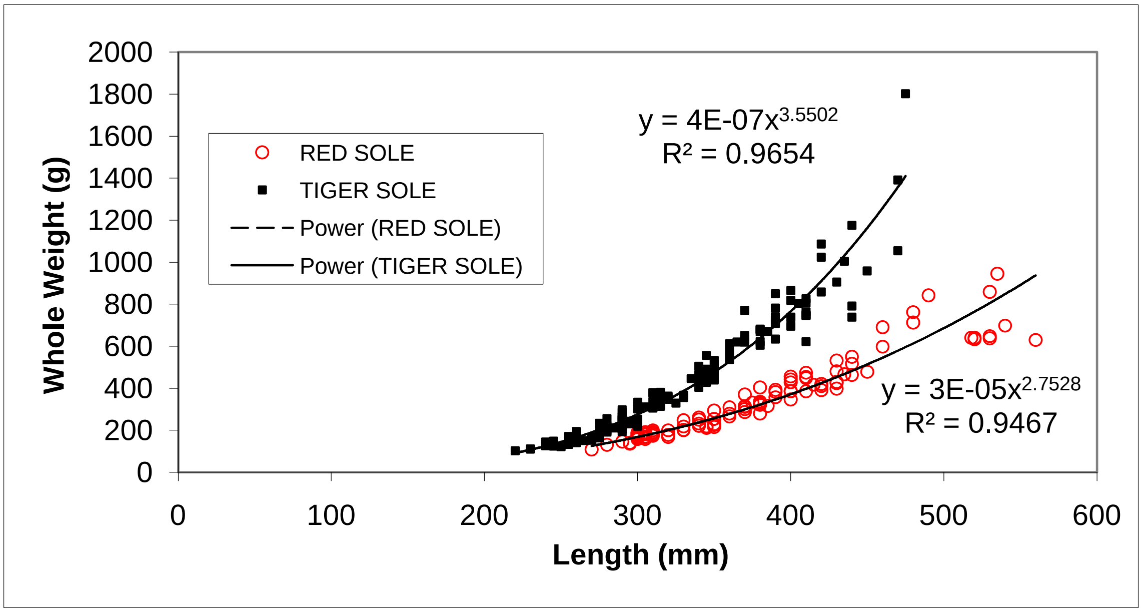
    b. The input maturity function was logistic with a slope of 1.0 and assumed a length at 50% maturity of 30 cm.

    c. The fish are assumed to instantaneously recruit to the fishery at 27 cm.

e. The a and b parameters of the Length-Weight function are:

W_a	0.014
W_b	2.753

These were estimated based on data collected at Atlantic Seafood. The length-weight relationship for the red and tiger (black) sole was estimated for the full range of the samples, from 100 to 1000 grams weight. The data were fit to the power model, $W=aL^b$, estimating the parameters a and b.



f. The model was run at two K values (0.34 and 0.10) and several Linf values(60, 66 and 72 cm) to investigate the sensitivity of the recruitment overfishing reference points to the input parameters.

Results:

Parameter	Estimates			
K (/year)	0.34	0.10	0.34	0.34
Linf (cm)	60.00	60.00	66.00	72.00
SPR40%	0.83	0.37	0.79	0.80
SPR30%	1.23	0.56	1.17	1.18
SPR20%	1.99	0.94	1.85	1.87

PROCEDURES AND RESULTS OF THE LCCA ANALYSES

Procedures:

1. Estimate the mean weight of the samples for the following market weight categories in grams: 100/200, 200/300, 300/400, 400/600, 600/700, 700/1000. Using the derived W-L relationship, then estimate the length at those mean weights.

Market Wt category (g)	Mean Wt (g)	Mean Length
100/200	169	30.06
200/300	250	34.65
300/400	350	39.15
400/600	500	44.57
600/700	650	49.03
700/1000	850	54.05

2. Based on published life history characteristics for black sole, estimate the age for the lengths at the mean weights for the market categories using the von Bertalanffy growth equation. The von Bertalanffy equations is:

$$Lt = L\infty * (1 - e^{(K*T)})$$

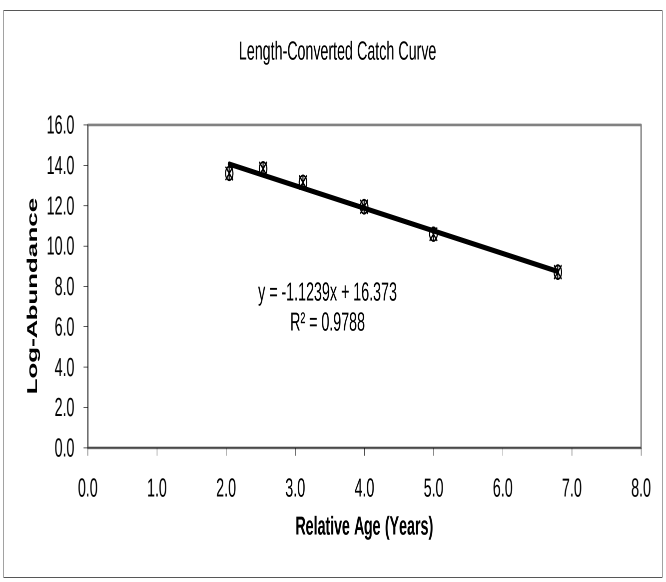
Market Wt category (g)	Mean Wt (g)	Mean Length	Mean Age
100/200	169	30.06	2.0
200/300	250	34.65	2.5
300/400	350	39.15	3.1
400/600	500	44.57	4.0
600/700	650	49.03	5.0
700/1000	850	54.05	6.8

3. Summarize the total landings for the year by weight category, and based on the mean weight in each of the weight categories, estimate the number in the catch at each weight category by dividing the total weight by the mean individual weight.

Market Wt category (g)	Mean Wt (g)	Mean Length	Mean Age	Total Export (Kg)	Estimated Numbers
100/200	169	30.06	2.0	136870	809881.7
200/300	250	34.65	2.5	254797	1019188.0
300/400	350	39.15	3.1	180360	515314.3
400/600	500	44.57	4.0	77964	155928.0
600/700	650	49.03	5.0	25885	39823.1
700/1000	850	54.05	6.8	5181	6095.3

4. Using the estimated numbers in each weight category, take the natural log of those numbers, and plot the Ln (N) against the age, and the slope of the linear regression line is the total mortality Z.

Estimated Numbers	Ln(Numbers)
9881.7	13.6
1019188.0	13.8
515314.3	13.2
155928.0	12.0
39823.1	10.6
6095.3	8.7



Results:

The slope of the linear regression of Ln (catch) versus the Age is 1.124, and M is estimated at 0.726, therefore, F is estimated to be 0.449.

		Estimate		Current
Linf	K	Z	M	F
60	0.34	1.124	0.726	0.449

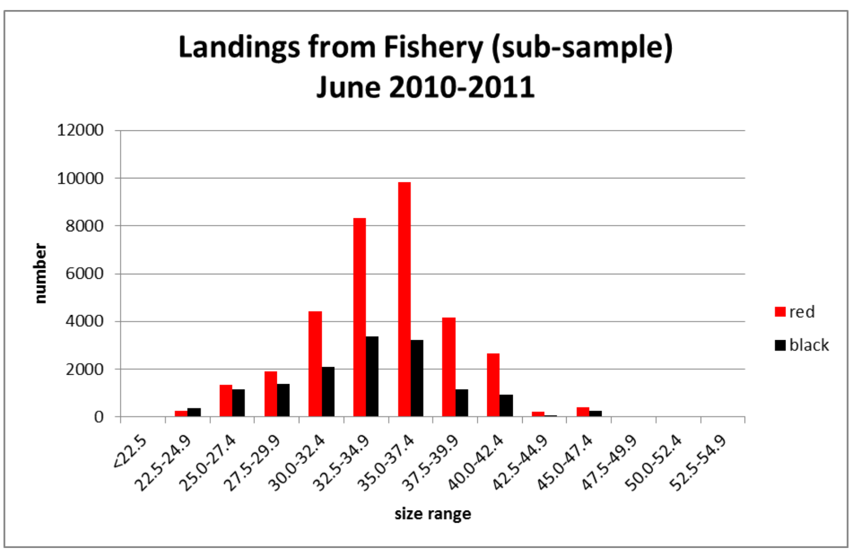
Conclusion:

Based on the LCCA, the red sole stock is not experiencing recruitment overfishing as the estimated F is less than F 40% from the SSBPR analysis. No conclusion is given for growth overfishing.

Description of the Gambia Black and Red Sole Stock Assessment by DeAlteris et al, 2012

The assessment essentially compares the results of Yield per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBPR) analysis to establish overfishing reference points to the results of a length-based catch curve (LCCA) to estimate the fishing mortality rate. The analysis is completed for the red sole and black sole.

The date used in this assessment was from the length frequency data collection of the Department of Fisheries (DOFISH) sponsored by the USAID/Ba Nafaa project at 4 landing sites between June 2010 and May 2011. A total of 33,626 red sole and a total of 14,059 black sole were measured.



PROCEDURES AND RESULTS OF THE YPR-SSBPR ANALYSES

Procedures:

M was re-adjusted to be more realistic at 0.5. A sensitivity analysis was done to see effects of M on final results.

Growth Parameters	
L0	0
K	0.35
Linf	57

The input maturity function was linear between age 1 and 2 with all year 2 and older fish being classified as mature.

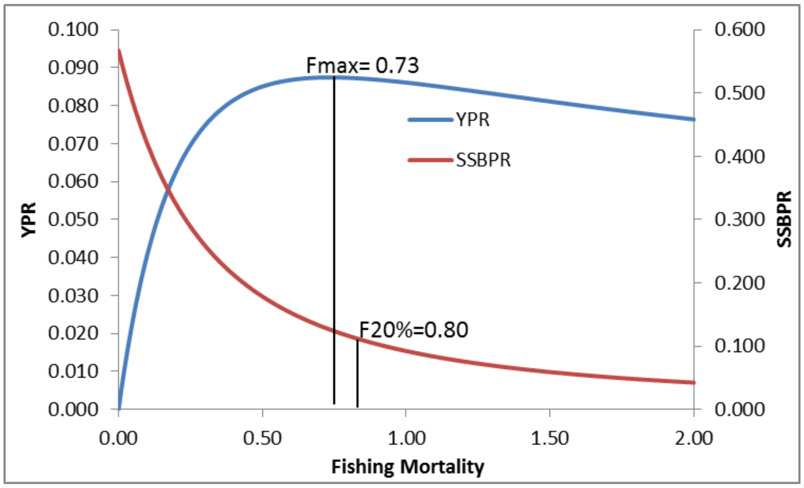
The fish are assumed to recruit in a linear manner from Age 1 to Age 2 with all fish 28.7 cm and above are assumed to be retained by the gear 100%.

A and b parameters of the Length-Weight function were determined to be:

a	0.00001
b	3.00

Data from the Atlantic Seafood was used to generate the l-w relationship. The data were fit to the power model, $W=aL^b$, estimating the parameters a and b.

The model was run at two K values (0.3-0.4) and several Linf values (53-65 cm) to investigate the sensitivity of the recruitment overfishing reference points to the input parameters.



Results:

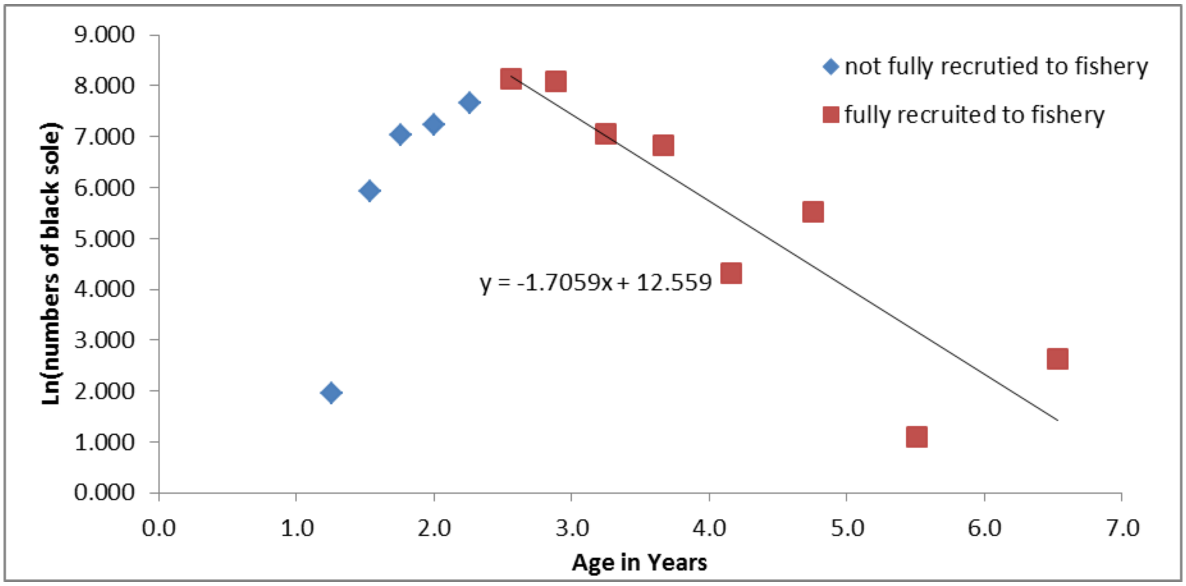
Procedures and results of the LCCA analyses

Based on life history characteristics chosen for sole, estimates for the age for the lengths at the mean weights for the market categories used the von Bertalanffy growth equation. The von Bertalanffy equations is:

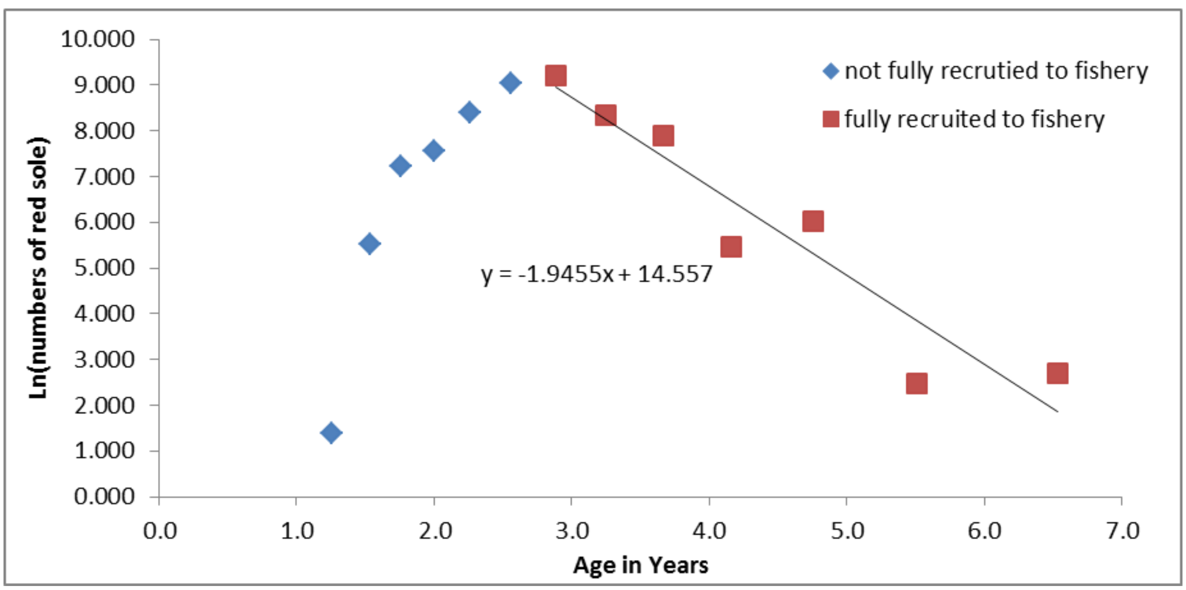
$$Lt = L\infty * (1 - e^{(K*T)})$$

mid-range L	mid-range t Age	Numbers Black Sole	Numbers Red Sole
20.3	1.3	7	4
23.7	1.5	375	253
26.2	1.8	1139	1358
28.7	2.0	1385	1909
31.2	2.3	2102	4428
33.7	2.6	3391	8329
36.2	2.9	3216	9849
38.7	3.2	1172	4155
41.2	3.7	930	2662
43.7	4.2	74	235
46.2	4.8	251	417
48.7	5.5	3	12
51.2	6.5	14	15
53.7	8.1	0	0

Black Sole



Red Sole



Results:

Black sole summary									
Linf=	65.0	65.0	60.0	60.0	57.0	55.0	55.0	55.0	53.0
K=	0.40	0.35	0.40	0.35	0.35	0.35	0.35	0.30	0.30
M=	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Z=	3.4	3.0	2.5	2.1	1.7	1.4	1.4	1.2	0.8
F=	3.0	2.6	2.0	1.7	1.2	0.9	0.8	0.6	0.2
	Risk Adverse	→			Best	→			Risk Prone

Red sole summary									
Linf=	65.0	65.0	60.0	60.0	57.0	55.0	55.0	55.0	53.0
K=	0.40	0.35	0.40	0.35	0.35	0.35	0.35	0.30	0.30
M=	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Z=	3.9	3.4	2.9	2.5	2.0	1.6	1.6	1.3	0.9
F=	3.5	3.0	2.4	2.0	1.2	1.1	1.0	0.7	0.3
	Risk Adverse	→			Best	→			Risk Prone

Conclusion:

The results of the LCCA analysis suggests that the best estimate of fishing mortality (F) for red and black sole is 1.5 and 1.2, respectively, based on L_{inf} , K and M values of 57 cm, 0.35 and 0.5, for both species.

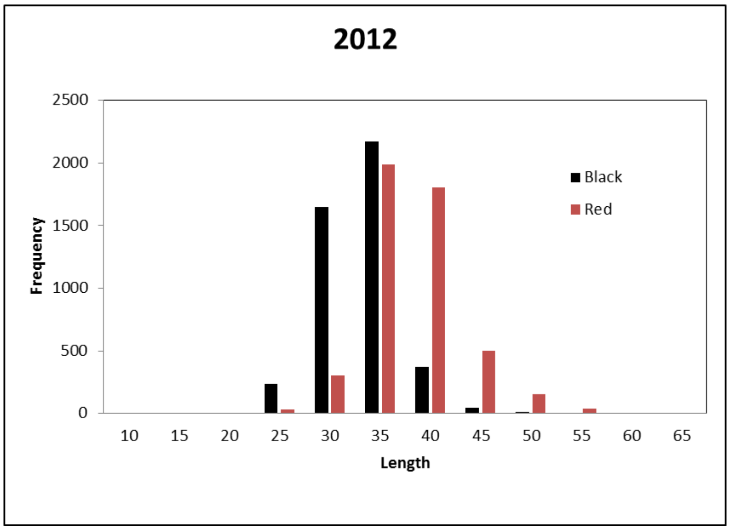
The reference points for growth and recruitment overfishing, Fmax and F20%, for combined red and black sole are 0.73 and 0.80, respectively.

Comparing the results of the LCCA to the reference points estimated in the YPR and SSBPR analysis, both red sole and black sole were experiencing growth and recruitment overfishing in 2010-2011.

Description of the Gambia Black and Red Sole Stock Assessment by Ceesay, Jallow, Sanyang, Parkins and Castro

The assessment compares the results of Yield per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBPR) analysis to establish overfishing reference points to the results of a length-based catch curve (LCCA)) o estimate the fishing mortality rate.

The Atlantic Seafood Company provided the information for length-weight and a subsample of length frequency for the period Jan-Dec 2012. There were no data collected by DOFISH at the beach. A total of 4487 black sole and 4832 red sole were sampled.



Procedures and results of the YPR-SSBR analyses

Procedures:

The researchers decided to use an M of 0.4 in a more risk-averse approach. Information on growth was obtained for both species separately.

Growth Parameters-Black	
L0	0
K	0.35
Linf	55

Growth Parameters-Red	
L0	0
K	0.35
Linf	65

A different L_{inf} was used in this assessment because the researchers saw fish larger than the size used in the last assessment in the sample.

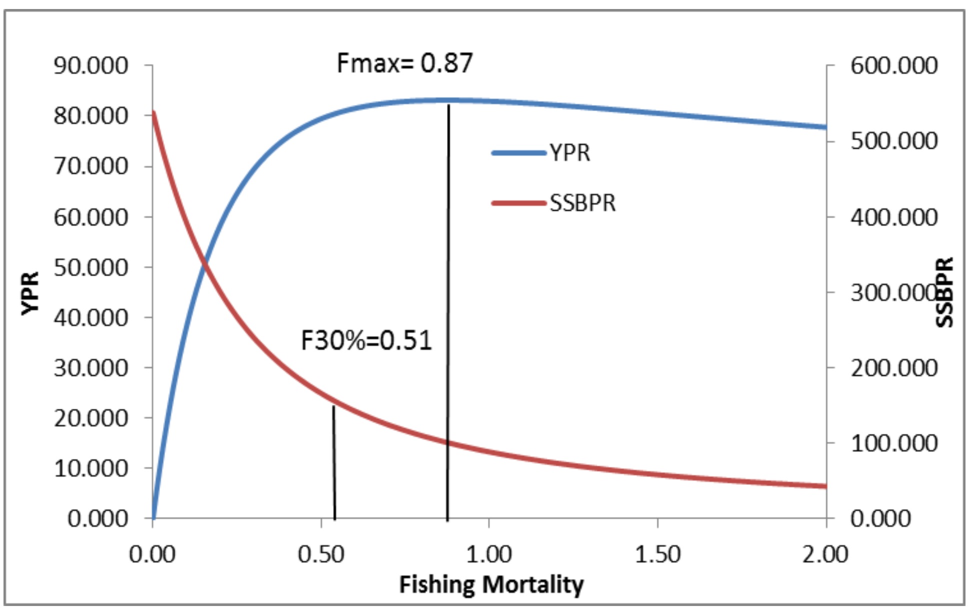
- The input maturity function was linear between age 1 and 2 with all year 2 and older fish being classified as mature.
- The fish are assumed to recruit in a linear manner from Age 1 to Age 2 with all fish 28.7 cm and above are assumed to be retained by the gear 100%.

A and b parameters of the Length-Weight function are:

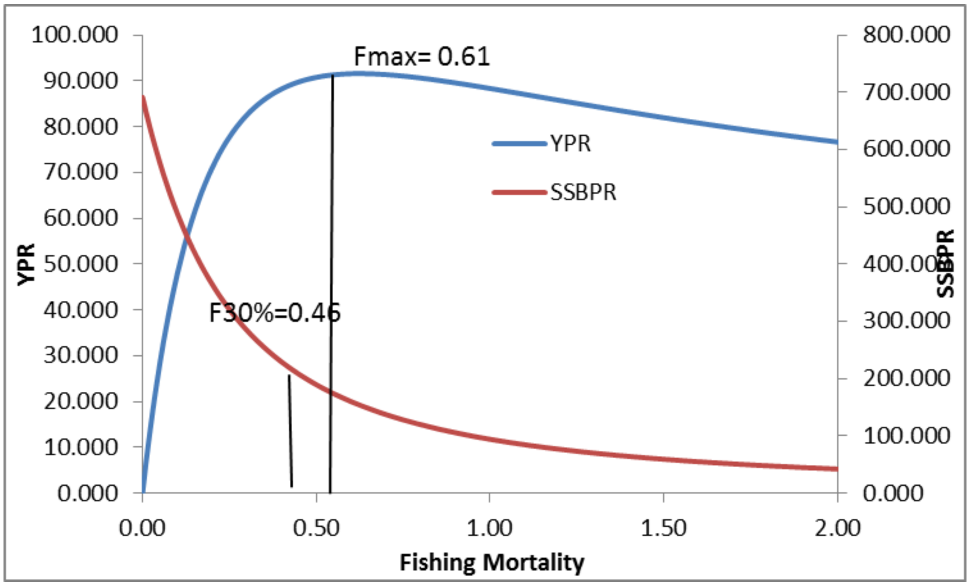
W_a RED	0.11
W_b RED	2.14
W_a BLACK	0.02
W_b BLACK	2.76

The data were fit to the power model, $W=aL^b$, estimating the parameters a and b.

Results:



Red Sole



Black Sole

Procedures and Results of the LCCA Analyses

Procedures:

5. Estimate the age for the lengths at the mean weights for the market categories using the von Bertalanffy growth equation. The von Bertalanffy equations is:
   $Lt = L\infty * (1 - e^{(K*T)})$

Red sole

Lt	**Age(t)**	***Number***
20	1.050642	5
25	1.387165	37
30	1.768683	303
35	2.209114	1815
40	2.730033	1532
45	3.367586	452
50	4.189534	145
55	5.348006	30

Lt	Age (t)	*Number*
20	1.291386	6
25	1.731817	237
30	2.252735	1503
35	2.890288	1903
40	3.712237	353
45	4.870709	43
50	6.851129	9

Using the estimated numbers in each weight category, take the natural log of those numbers, and plot the Ln (N) against the age, and the slope of the linear regression line is the total mortality Z.

Red Sole

Black sole

Results:

The results of the length-base Catch Curve Analysis of the red and black sole indicated that the slope of the linear regression of the natural log of numbers versus the age, the total mortality was 1.2 for red sole and 1.3 for black sole. Based on the formula to estimate the fishing mortality F=

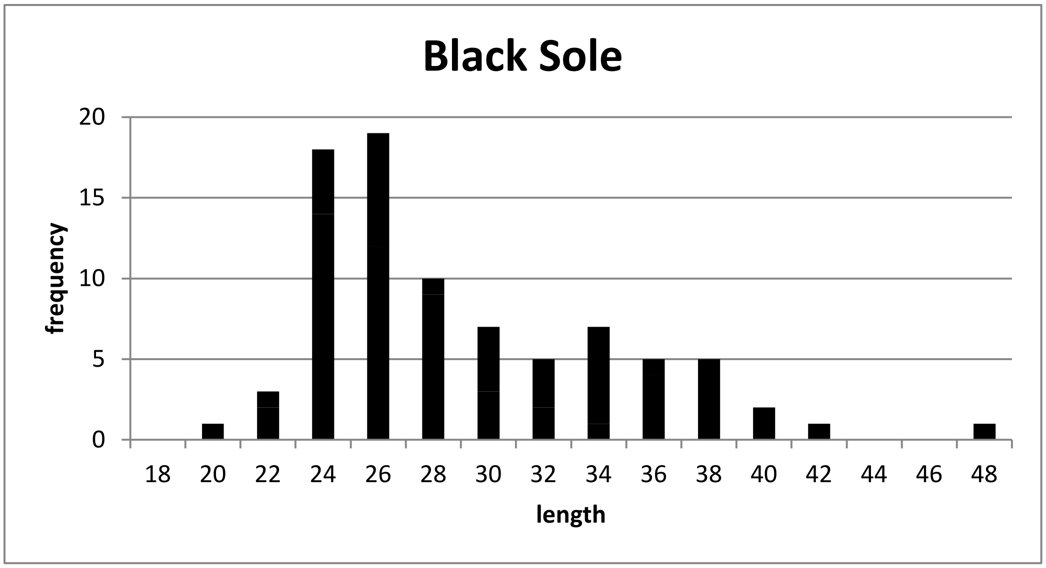
(Z-M), Red sole was 0.8 and black sole 0.9. This analysis was based on the following parameters for the life history characteristics:

Linf= 65 cm, K= 0.35 and M= 0.4 for red sole and Linf= 55 cm, k=0.35 and M=0.4 for black sole.

Based on the recalculated reference points, for red sole, the calculated fishing mortality is slightly lower than F_{max}. Recruitment overfishing is occurring. Care should be taken to ensure fishing pressure does not increase; black sole is experiencing both recruitment and growth overfishing.

Description of the Gambia Black and Red Sole Stock Assessment by Jallow, Ceesay and Castro

The assessment compares the results of Yield per Recruit (YPR) and Spawning Stock Biomass per Recruit (SSBPR) analysis to establish overfishing reference points to the results of a length-based catch curve (LCCA) to estimate the fishing mortality rate.



A research project examining catch composition in the sole bottom gillnet fishery collected length-weight for the period May-June 2013. A total of 84 black sole and 42 red sole were sampled.

Growth Parameters-Black	
L0	0
K	0.35
Linf	55

Growth Parameters-Red	
L0	0
K	0.35
Linf	65

PROCEDURES AND RESULTS OF THE YPR-SSBPR ANALYSES

Procedures:

The input maturity function was linear between age 1 and 2 with all year 2 and older fish being classified as mature.

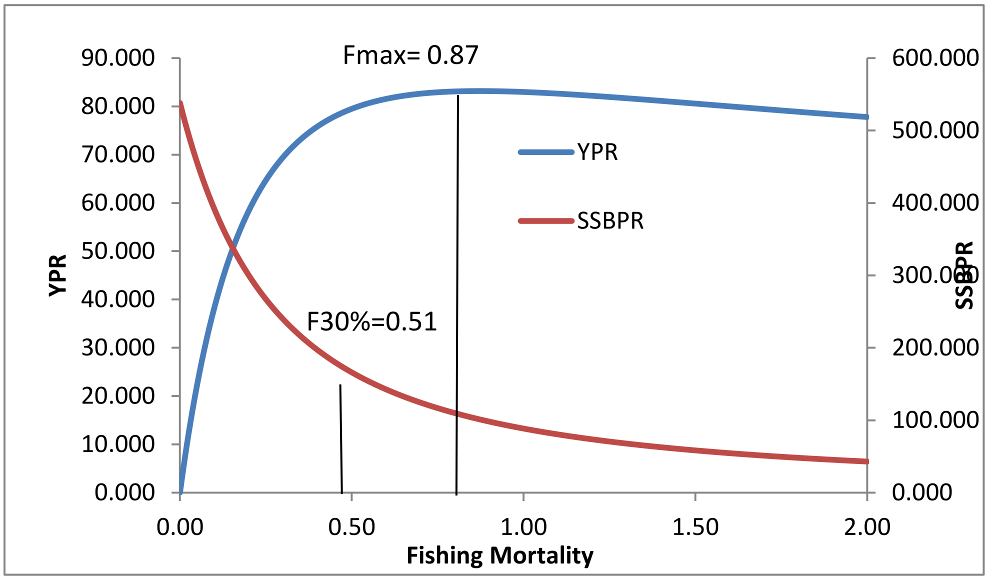
The fish are assumed to recruit in a linear manner from Age 1 to Age 2 with all fish 28.7 cm and above are assumed to be retained by the gear 100%.

A and b parameters of the Length-Weight function are:

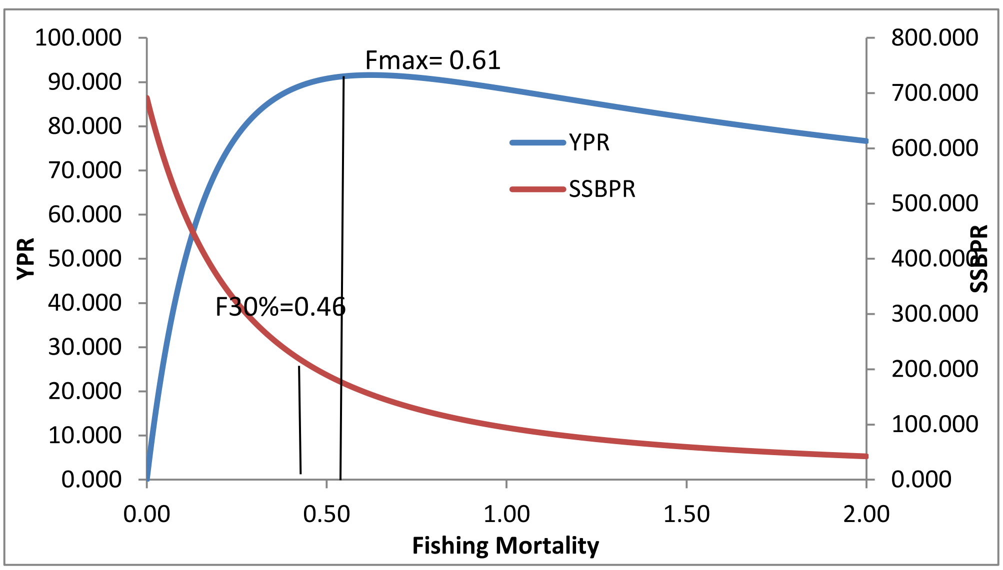
W_a RED	0.11
W_b RED	2.14
W_a BLACK	0.02
W_b BLACK	2.76

The data were fit to the power model, $W=aL^b$, estimating the parameters a and b.

Red Sole



Black Sole



Procedures and results of the LCCA analysis

Procedures:

Estimate the age for the lengths at the mean weights for the market categories using the von Bertalanffy growth equation. The von Bertalanffy equations is:

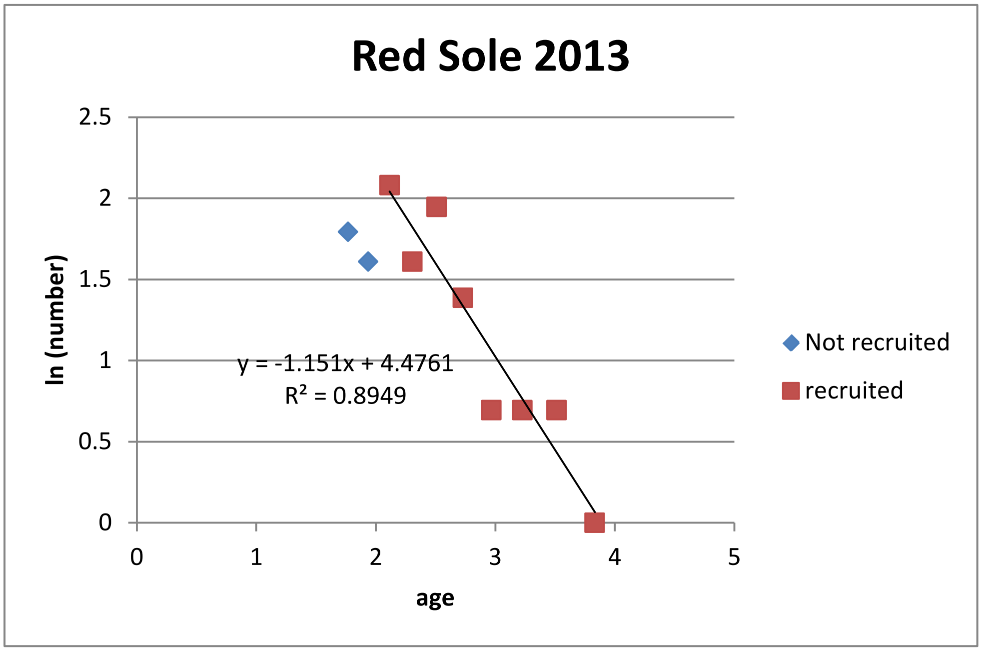
$$Lt = L\infty * (1 - e^{(K*T)})$$

Black Sole

ln(number)	Age(t)
0	1.291386
1.098612	1.459502
2.890372	1.638131
2.944439	1.828678
2.302585	2.032847
1.94591	2.252735
1.609438	2.490968
1.94591	2.750888
1.609438	3.036841
1.609438	3.354628
0.693147	3.712237
0	4.121097

Red Sole

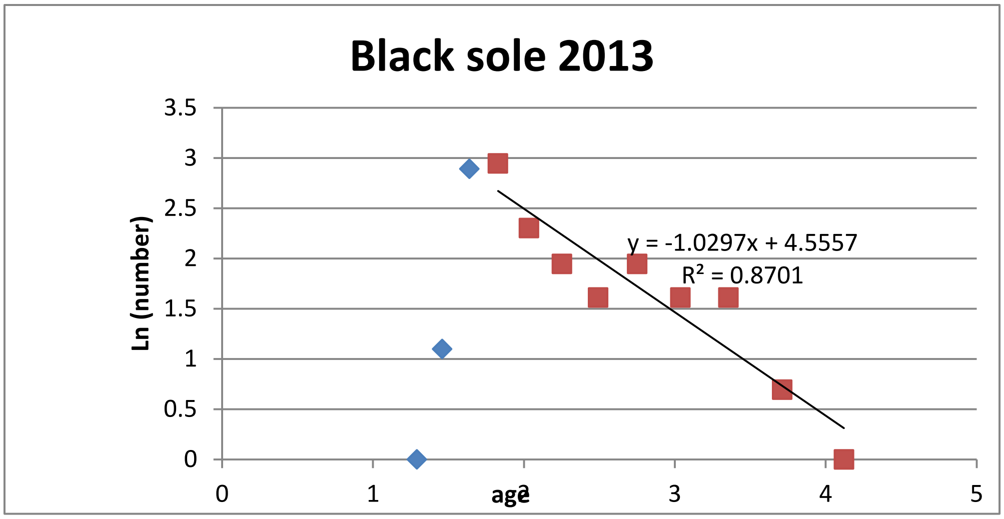
In number	Age
1.791759	1.768683
1.609438	1.936799
2.079442	2.115429
1.609438	2.305976
1.94591	2.510144
1.386294	2.730033
0.693147	2.968266
0.693147	3.228185
0.693147	3.514138
0	3.831926



Red Sole

Using the estimated numbers in each weight category, take the natural log of those numbers, and plot the Ln (N) against the age, and the slope of the linear regression line is the total mortality Z.

Black Sole



Results:

The results of the length-base Catch Curve Analysis of the red and black sole indicated that the slope of the linear regression of the natural log of numbers versus the age, the total mortality was 1.15 for red sole and 1.03 for black sole. Based on the formula to estimate the fishing mortality F= (Z-M), Red sole was 0.75 and black sole 0.63. This analysis was based on the following parameters for the life history characteristics:

Linf= 65 cm, K= 0.35 and M= 0.4 for red sole and Linf= 55 cm, k=0.35 and M=0.4 for black sole.

Based on the recalculated reference points, for red sole, the fishing mortality is essentially at F_{max}. Recruitment overfishing is occurring (using reference point at $F_{30\%}$). Care should be taken to ensure fishing pressure does not increase; black sole is experiencing both recruitment and growth overfishing.

Conclusion

Each stock assessment has been able to utilize existing data sets and try to improve on the estimates of the parameters used in the models. However, there needs to be a consistent data set from the landing sites collected by the DOFISH to be combined with information from the processing sector. Estimates of maturity can be improved with directed research and some progress has been made on aging black sole using otoliths.

There is consistency in some of the data on sole that has emerged from these studies. Sole species are known to travel inshore for spawning and growth is assumed to be rapid during the first year. The variability in the length-weight relationships continues to be large and creates uncertainty in the growth parameters. The condition index may indicate changes during spawning season that change the ratio of length to weight. Black sole grows at a faster rate than red sole.

The National Sole Fishery Co-Management Committee (NASCOM) has adopted the precautionary approach for management of these species because of the lack of consistency in data collection. Although this is an excellent way to reduce overfishing, it may result in lost yield to the fishery and income to the fishermen due to under-harvesting. In the future, a data collection program needs to be in place that combines the beach landings information with the processer information.

Atlantic Seafood will continue to provide length frequency by month data to the DOFISH and NASCOM for analysis. However it is suggested that a landing site survey would be important to verify any biases in this data. At minimum, one sampling conducted over a month in 4 landing sites (minimum of 500 fish) would assist in this analysis. If done in April before the spawning area is closed and again in November when the fishing area reopens, we might obtain additional information on the results of the closed area in terms of fishing mortality reductions.

Ideally fisheries independent surveys could be added that would allow for estimates of biomass to be obtained that would assist the managers with their decision making. Ideally, a trawl survey that is standardized, with small mesh and conducted several times a year would be the best approach. This would need to be coordinated with the artisanal fishery as the area sampled would cover inshore fishing areas and could entangle gear resulting in substantial friction between fishermen and managers. However, estimates of species biomass are a critical first step in utilizing output controls such as quotas.

Although these stock assessments are producing rough estimates of fishing mortality over the years in a data poor fishery, it is clear that conservation measures must be taken to ensure the long term sustainability of the resources for the Gambia. The closure of the coastal waters out to 1 nm will help to protect the fish during their vulnerable spawning season, especially the males that are mouth brooding the young. This will be difficult to measure in terms of effectiveness of effort reduction but biologically it makes sense. The increase of mesh size for the bottom gillnets (92 mm) will also help to ensure that immature fish are not harvested. The new research on the long line hook selection will allow for decisions to be made to bring impactful conservation measures for this component of the fishery as well. This will need to be monitored and changes made as often as needed, especially for the vulnerable bycatch species.

Applied research on aspects of the species and the fisheries is critical for the development of meaningful long term management decisions. A bilateral approach between The Gambia and Senegal would be useful for sharing data, research tasks and conclusions. Access to universities and third party funding would enhance the scope and the quality of the research. Collaborative research using fishermen and fishing vessels is key to obtaining useful results.

However, the issues surrounding the open entry for both Gambian and Senegalese fishermen will need to be addressed in the near future. Discussions to produce meaningful bilateral agreements are ongoing on capping effort and include joint vessel registration and fishermen licensing agreements. With the possible acquiring of an MSC label for sole, demand for the product will increase. It is absolutely imperative that discussions now include effort restrictions and possibly even fishing or export quotas to ensure the sustainability and profitability of this fishery.

References

Cessay, S., Jallow, A.,Sanyang, L, Parkins, C and K. Castro. 2013. Description and analysis of the Gambia sole stock assessment- 2012. Coastal Resources Center, GSO, URI.

DeAlteris, J. Cessay, S. and A. Jallow. 2012. Final report: the Gambian Sole Stock Assessment. CRC, URI. PP 20.

Medley, P. C. Carleton, T. Southall, B. Keus, J. Ndenn, and M. McFadden. 2008. MSC Sustainable Fisheries Certification, the Gambia small-scale artisanal fishery for sole. Food Certification International. 68.ES