APPENDIX VII – Stock Status Report – Deep-sea red crab

STATUS REPORT

Chaceon erytheiae

Common Name: Deep-sea red crab

FAO-ASFIS Code: GER

2014

Updated: 9-Oct-14

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8. Description of the fishery

1.1 Description of fishing vessels and fishing gear

Data within the SEAFO database indicate that the deep-sea red crab (DSRC) resource has been utilized by two nations primarily, Namibia and Japan. The Namibian-flagged vessel, *FV Crab Queen 1*, known to fish crab in the SEAFO CA is a 49.61m, 1989-built steel vessel with an onboard holding capacity of 610m^3. The vessel can process on average 1200 traps (i.e. three sets with 400 traps each) per day.

During 2005 an older Japanese-flagged vessel, *FV Kinpo Maru no. 58*, conducted crab fishing activities in the SEAFO CA. This vessel was built in 1986, is 62.60m in length and has an onboard holding capacity of 648m^3. The *Kinpo Maru*, however, was replaced by the *FV Seiryo Maru* which is 37.06m in length, was built in 1987 and has an on-board holding capacity of 289 m^3.

The Namibian and Japanese vessels' gear setup (set deployment & design) are very similar. Both vessels use the same type of fishing gear – known as Japanese beehive pots (Fig. 1). The beehive pots are conical metal frames covered in fishing net with an inlet shoot (trap entrance – Fig. 1) on the upper side of the structure and a catch retention bag on its underside. When settled on the seabed the upper side of the trap are roughly 50cm above the ground ensuring easy access to the entrance of the trap. The trap entrance leads to the kitchen area of the trap – which is sealed off by a plastic shoot that ensures all crabs end up in the bottom of the trap.

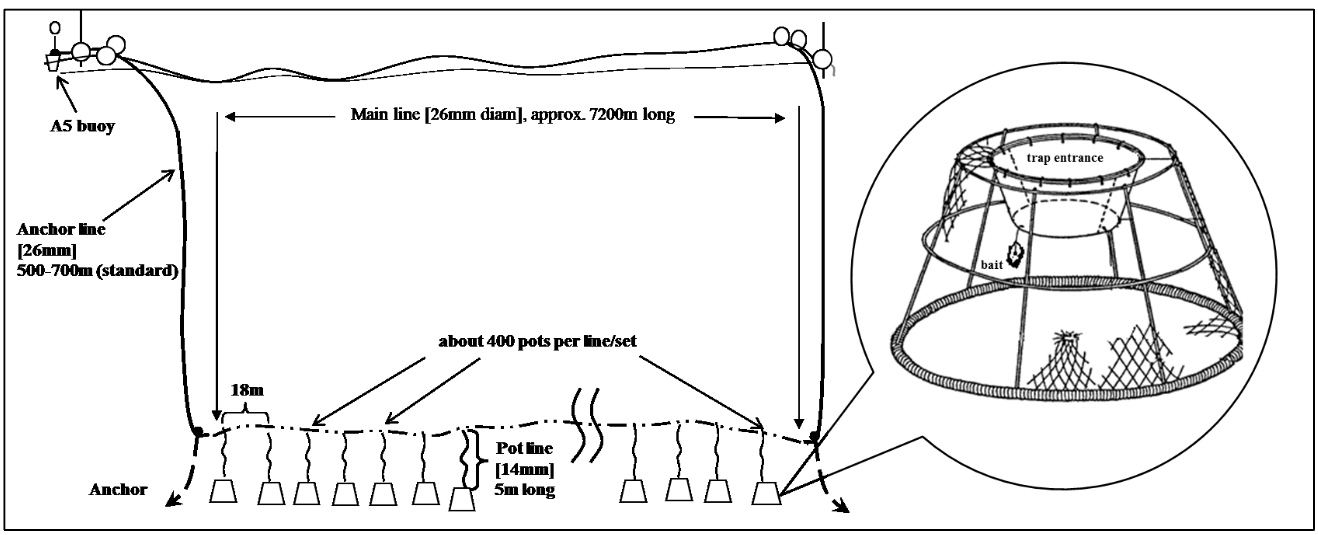

Figure 1: Deep-sea red crab fishing gear setup (set deployment and design) and illustration of a Japanese beehive pot (shown in enlarged form on the right).

One set or pot line consists of about 200-400 beehive pots, spaced roughly 18m apart, on a float line attached to two (start & end) anchors for keeping the gear in place on the seabed (Fig. 1). The start & end points of a set are clearly marked on the surface of the water with floats and one A5 buoy that denotes the start of a line. Under this setup (i.e. 400pots at 18m intervals) one crab fishing line covers a distance of roughly 7.2km (3.9nm) on the sea floor and sea surface.

1.2 Spatial and temporal distribution of fishing

In the SEAFO Convention Area fishing for deep-sea red crab is focussed mainly on *Chaceon erytheiae* on Valdivia Bank – a fairly extensive seamount that forms part of the Walvis Ridge (Fig. 2-6). This seamount is located in Division B1 of the SEAFO CA and has been the main fishing area of the crab fishery since 2005 when the resource was accessed by Japan. Records from the SEAFO database indicate that fishing for crab in this area occurred over a depth range of 280-1150m.

Table 1: The total number of sets from which deep-sea red crab catches were derived for the period 2010-2014.

2010	2011	2012	2013	2014
181	133	129	103	107

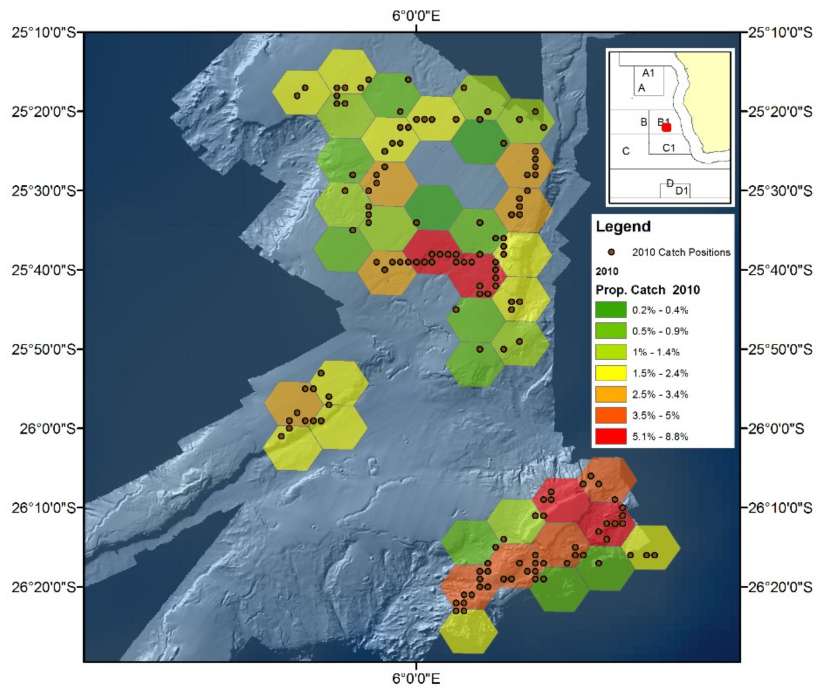

Figure 2: The 2010 catch distributions for deep-sea red crab in Division B1 aggregated to a 10 km^2 hexagonal area.

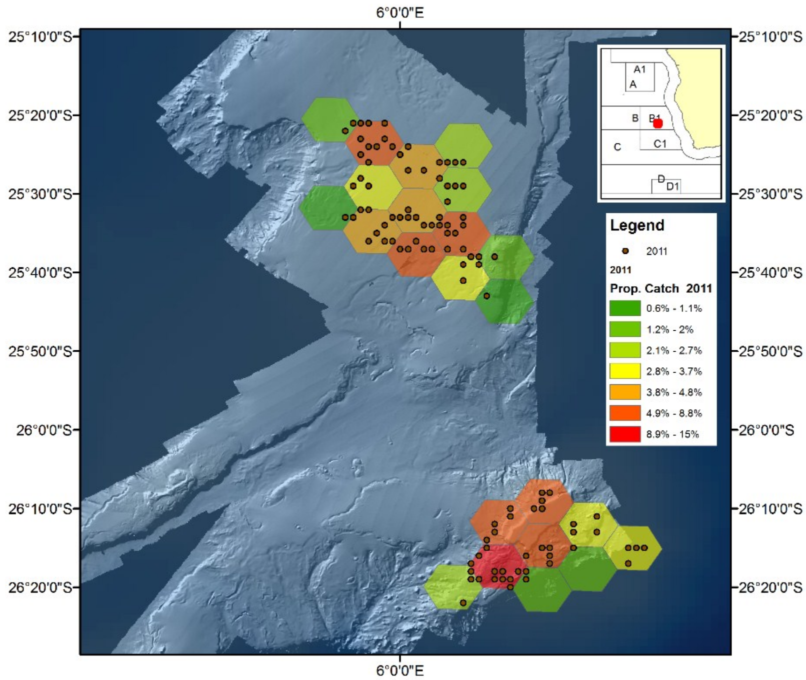

Figure 3: The 2011 catch distributions for deep-sea red crab in Division B1 aggregated to a 10 km^2 hexagonal area.

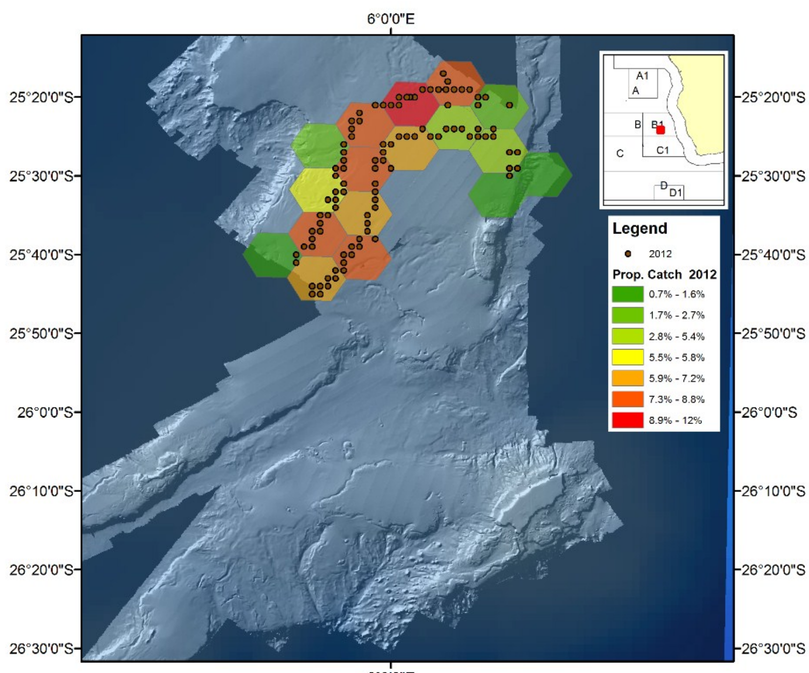

Figure 4: The 2012 catch distributions for deep-sea red crab in Division B1 aggregated to a 10 km^2 hexagonal area.

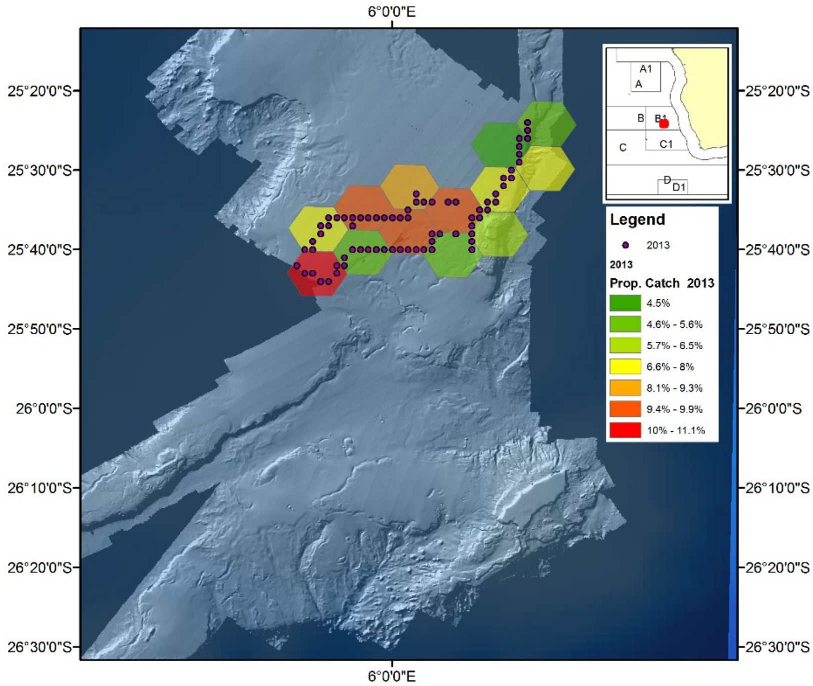

Figure 5: The 2013 catch distributions for deep-sea red crab in Division B1 aggregated to a 10 km^2 hexagonal area.

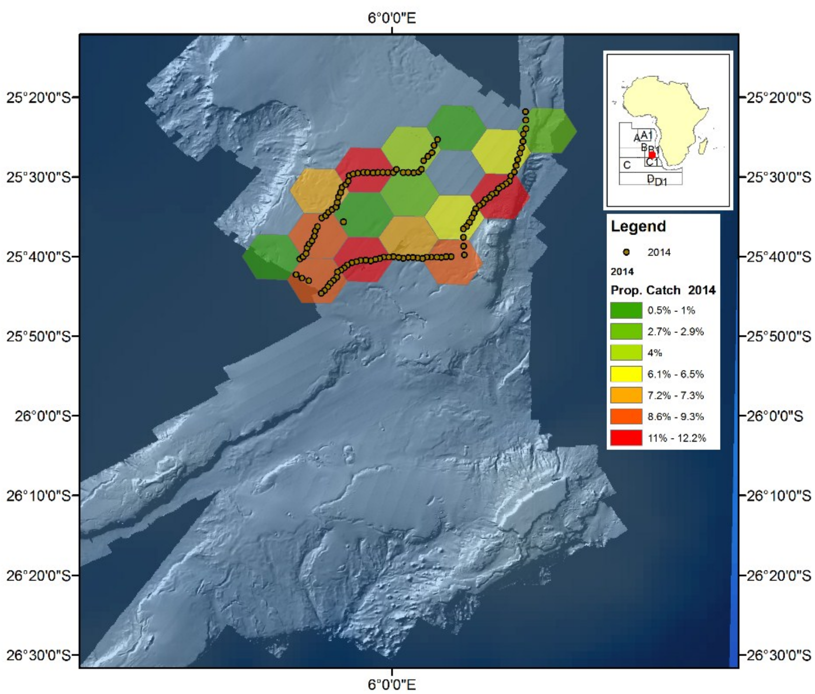

Figure 6: The 2014 catch distributions for deep-sea red crab in Division B1 aggregated to a 10 km^2 hexagonal area.

1.3 Reported landings and discards

Reported landings (Table 2) comprise catches made by Japanese, Namibian, Spanish and Portuguese-flagged vessels to date from 2003-2014. As is evident from Table 2 the two main players in the SEAFO crab fishery are Japan and Namibia, respectively, with Spanish and Portuguese vessels having only sporadically fished for crab in the SEAFO CA over the period 2003 to 2007. Spanish-flagged vessels actively fished for crab in the SEAFO CA during 2003 and 2004, whereas Portuguese-flagged vessels only fished for crab once during the 2007 season (Table 2).

Table 2: Catches (tonnes) of deep-sea red crab (Chaceon spp. – considered to be mostly *Chaceon erytheiae*).

Nation	**Japan**		**Namibia**		**Spain**		**Portugal**	
Fishing method	**Pots**		**Pots**		**Pots**		**Pots**	
Management Area	**B1**		**B1**		**UNK**		**A**	
Catch details (t)	**Retained**	**Discarded**	**Retained**	**Discarded**	**Retained**	**Discarded**	**Retained**	**Discarded**
2001					<1			
2002								
2003					5			
2004					24			
2005	253	0	54					
2006	389							
2007	770		3	0			35	
2008	39							
2009	196		N/F	N/F	N/F	N/F	N/F	N/F
2010	200	0			N/F			
2011	N/F	N/F	175	0	N/F	N/F	N/F	N/F
2012	N/F	N/F	198	0	N/F	N/F	N/F	N/F
2013	N/F	N/F	196	0	N/F	N/F	N/F	N/F
2014*	N/F	N/F	135	0	N/F	N/F	N/F	N/F

* Provisional (Aug 2014)
N/F = No Fishing.
Blank fields = No data available.
UNK = Unknown.

Being a pot fishery, the deep-sea red crab fishery has an almost negligible bycatch impact. To date only 5kg of teleost (Marine nei and European sprat) fish discards have been recorded, during 2010, from this fishery.

1.4 IUU catch

IUU fishing activity in the SEAFO CA has been reported to the Secretariat latest in 2012, but the extent of IUU fishing is at present unknown.

9. Stock distribution and identity

One species of deep-sea red crab has been recorded in Division B1, namely *Chaceon erytheiae* (López-Abellán *et al*. 2008), and is thus considered the target species of this fishery. Aside from the areas recorded in catch records the overall distribution of *Chaceon erytheiae* within the SEAFO CA is still unknown.

10. Data available for assessments, life history parameters and other population information

3.1 Fisheries and surveys data

Fishery-dependent data exist only for more recent years (2010-2014) of the SEAFO deep-sea red crab fishery (Fig. 7). Biological data from the fishery comprise gender-specific length-frequency, weight-at-length, female maturity and berry state data.

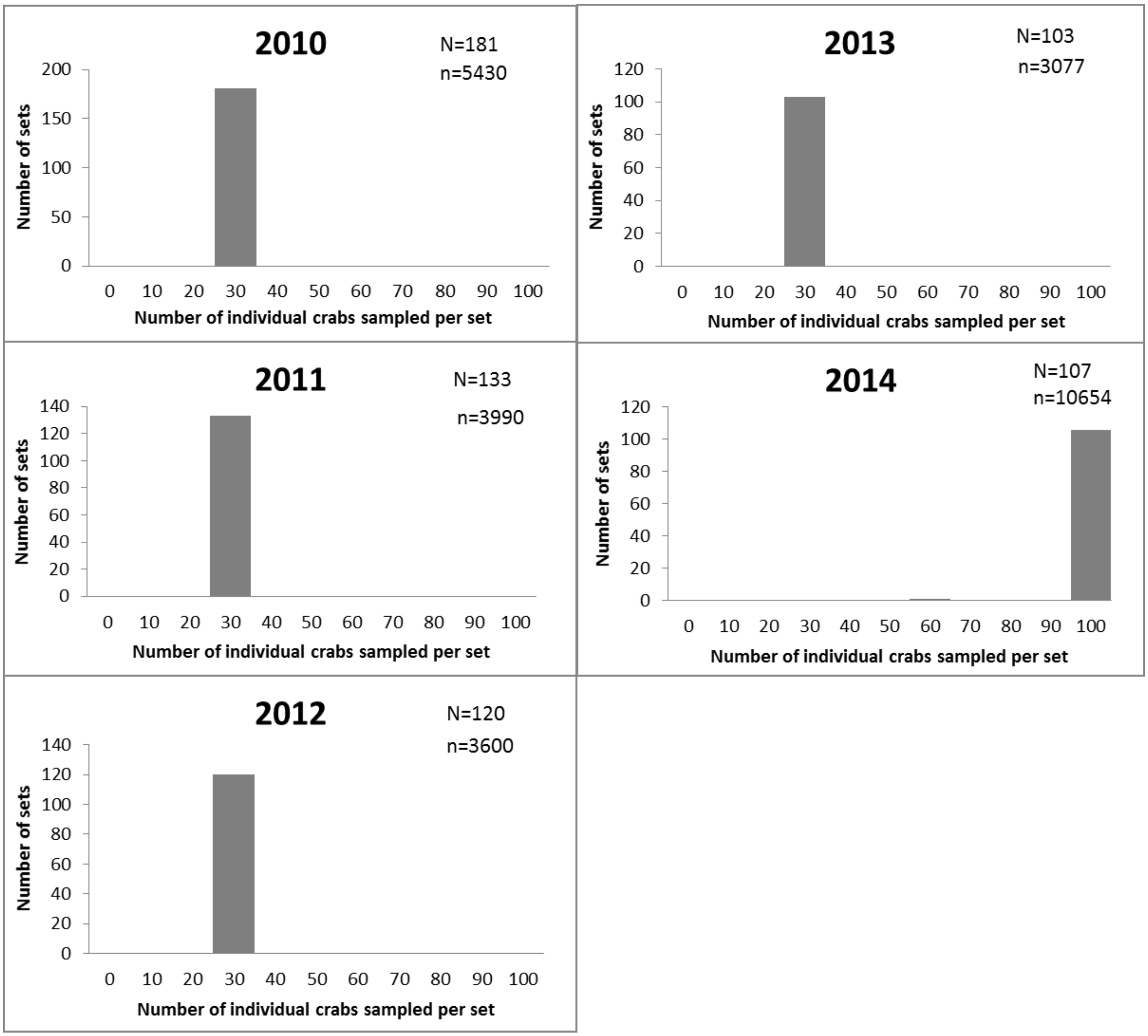

Figure 7: Illustration of sampling frequencies (2010-2014) from the deep-sea red crab commercial fleet within the SEAFO CA. Notes: N = total number of sets recorded per year; n = total number of crabs sampled.

Very limited fisheries-independent data on deep-sea red crabs exists for the SEAFO CA. A total of 479 deep-sea red crabs were sampled during the 2008 Spanish-Namibia survey on Valdivia Bank. The data was collected over a depth range of 867-1660m.

3.2 Length data and frequency distribution

Available length-frequency data for crabs caught in the SEAFO CA over the period 2010-2014 are presented in Figure 8. Length-frequency data from all areas sampled in Division B1 were pooled as no significant differences were detected between areas.

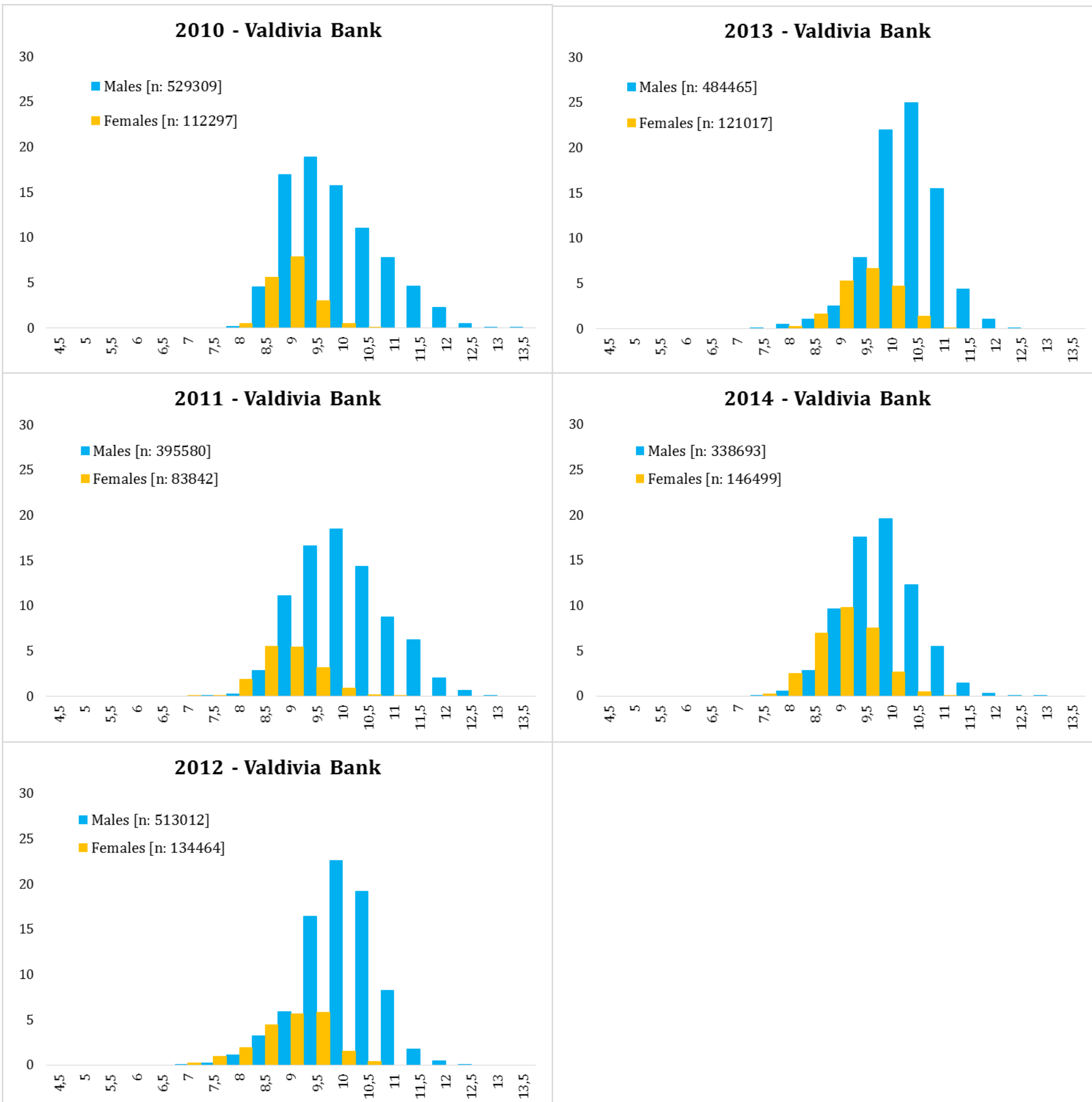

Figure 8: Length frequencies – raised to total catches – of crab caught on Valdivia Bank [2010-2014].

For the period 2010-2014 there have been no significant changes in the female crab size distribution (Fig. 8). The male crab size distribution changed from a wider size distribution in 2010 and 2011, where larger male crabs were recorded, to a slightly narrowed size distribution in 2012-2014 of smaller crabs. Sex ratio from crab commercial samples fluctuated around 4:1 in favour of male crabs – a well-known bias of the commercial traps used in this fishery.

3.3 Length-weight relationships

Length-weight relationship derived from catches on Valdivia Bank reveal the gender-specific growth disparity (Fig. 9). Male crabs grow at a faster rate than females and thus attain much larger sizes than female crabs. This species attribute, however, is not unique to *Chaceon erytheiae* and has been recorded for other crab species in the *Chaceon* genus (Le Roux 1997). Data from the 2008 survey show a much more coherent length-weight relation for both male and female crabs (Fig. 10).

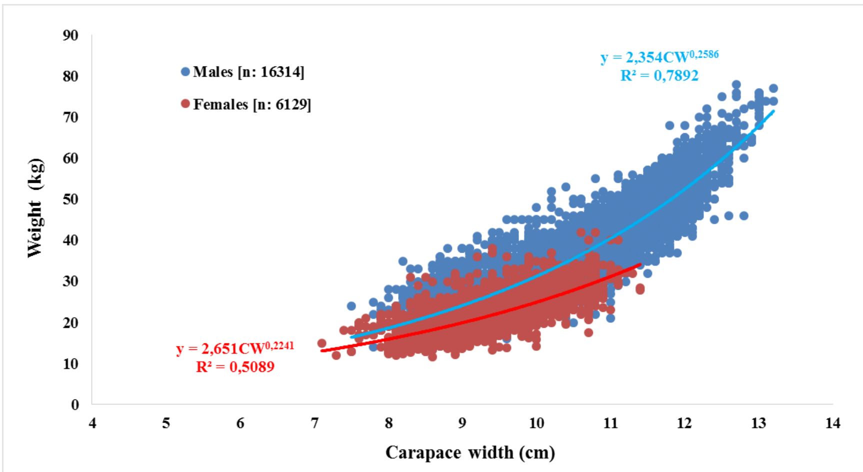

Figure 9: Length-at-weight data for *Chaceon erytheiae* as recorded from catches on Valdivia Bank (2008-2014). Red text show female length-weight relationship, blue text show male length-weight relationship.

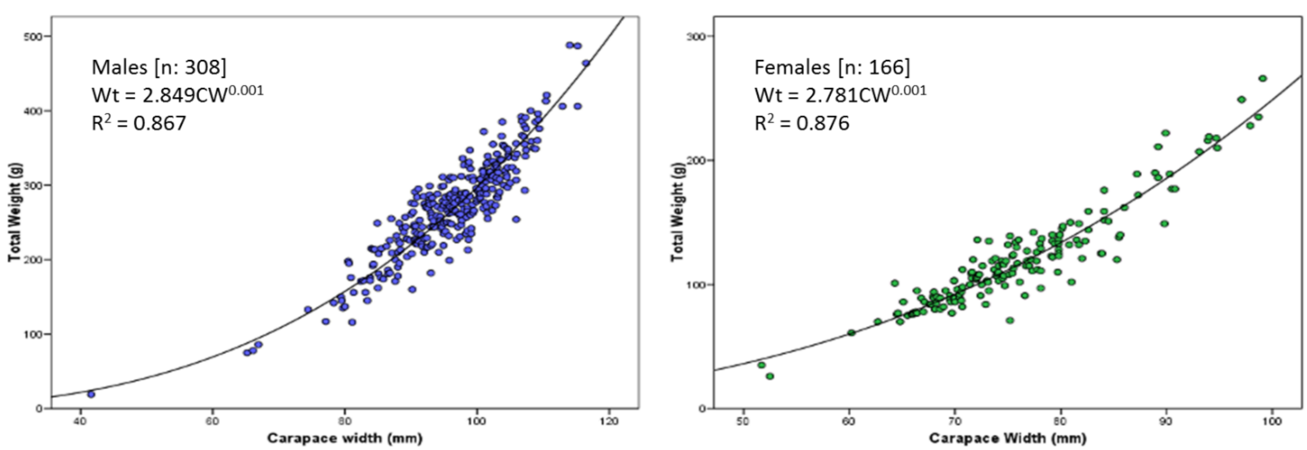

Figure 10: Length-at-weight data for *Chaceon erytheiae* as recorded from the 2008 Spain-Namibia survey (López-Abellán *et al*. 2008)

3.4 Age data and growth parameters

No information exists on the age and growth attributes of *Chaceon erytheiae*.

3.5 Reproductive parameters

Very limited reproductive data exist for *Chaceon erytheiae* from commercial samples. This dataset constitute female maturity and berry data collected during 2010-2014. However, the mating and spawning seasons for *C. erytheiae* within the SEAFO CA are still unknown.

3.6 Natural mortality

No natural mortality data exist for *Chaceon erytheiae*.

3.7 Feeding and trophic relationships (including species interaction)

No data exist for *Chaceon erytheiae*.

3.8 Tagging and migration

No data on migration exist for *Chaceon erytheiae* in the SEAFO CA.

11. Stock assessment status

4.1 Available abundance indices and estimates of biomass

Currently the only data available for the assessment for *C. erytheiae* abundance within the SEAFO CA are the catch and effort data from which a limited catch-per-unit effort (CPUE) series can be constructed.

4.2 Data used

The available SEAFO data (2005-2014) for purposes of considering possible assessment strategies are presented in Table 3.

Table 3: Description of the entire deep-sea red crab database highlighting important datasets.

Year	Flag State	Data Type - Source	Brief Description [NB Data Groups only]
2005	JPN	Catch Data – Observer Report	Set data (vessel ID, set-haul positions & dates), Depth, Catch, Effort - (157 records).
2007	NAM	Catch Data – Observer Report	Set data (vessel ID, set-haul positions & dates), Depth, Catch, Effort - (10 records - sets).
2010	JPN	Catch & Biological Data – Observer Report	Set data (vessel ID, set-haul positions & dates), Depth, Length, Weight, Catch, Effort - (Catch: 181 records, Biological: 5430 records).
2011	NAM	Catch & Biol. Data – Observer Report	Set data (vessel ID, set-haul positions & dates), Depth, Length, Weight, Catch, Effort - (Catch: 133 records, Biological: 3990 records).
2012	NAM	Catch & Biol. Data – Obs. Report & Captain's Logbook [log sheet data]	Set data (vessel ID, set-haul positions & dates), Depth, Length, Weight, Catch, Effort - (Catch: 129 records, Biological: 3600 records).
2013	NAM	Catch Data – Captain's Logbook [log sheet data]	Set data (vessel ID, set-haul positions & dates), Depth, Catch, Effort - (Catch: 103 records, Biological: 3090 records).
2014	NAM	Catch Data – Captain's	Set data (vessel ID, set-haul positions and dates), Depth,

		Logbook [log sheet data]	Length, Weight, Catch, Effort – (Catch: 107 records, Biological: 10660 records)

4.3 Methods used

CPUE Standardization:
In 2014 another attempt was made at standardizing the CPUE with the emphasis of including variables previously omitted (i.e. depth and soak time). In addition to this it was agreed that the number of pots and soak time both be used to calculate effort. Thus for the 2014 standardization only the kg/pot-hour CPUE was considered as the correct unit for effort.

Table 4: Description of the sets of catch and effort data available for the CPUE standardization.

2005	2007	2010	2011	2012	2013	2014
157	10	181	133	129	103	107

The records from year 2007 were excluded from the analysis as they were derived from an area not exploited in the remaining years and, constituting only 10 sets, were not comparable to datasets from the rest of the data series.

The following variables from each record were considered in the model:
Year = A 12-month period – explanatory variable (covariate).
Semester = A calendar semester in a fishing year – explanatory variable (covariate).
VesselID = Identification code for a participating vessel – explanatory variable (covariate).
Zone = Identification code for a fishing area – explanatory variable (covariate).
Depth = Fishing depth – explanatory variable (covariate).
SoakTime = Period of time for which baited crab pots are left in the water - explanatory variable (covariate).
CPUE = Catch/number of pots*hour – response variable.

An exploratory data analysis was performed before the adjustment of the generalized linear model (GLM) to evaluate the relationship of variables and CPUE. A GLM was applied using the stepwise AIC procedure to select the best model. The GLM was derived following Quinn and Deriso (1999) as:

$$U_{ijk} = U_0 \prod_i \prod_j P_{ij}^{X_{ij}} e^{\varepsilon_{ijk}} \qquad [1]$$

…where U is the observed CPUE, U_0 is the reference CPUE, P_{ij} is a factor i at level j, and X_{ij} takes a value of 1 when the j^{th} level of the factor P_{ij} is present and 0 when it is not. The random error ε_{ijk} for observation k is a normal random variable with 0 mean and standard deviation σ. Thus the generalized linear model for the error distribution of U is a follows:

$$U_{ijk} = \beta_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_j-1} X_{ij}\beta_{ij} + \varepsilon_{ijk} \qquad [2]$$

Since the model described by equations 1 and 2 might be over-parameterized, it is common to set a factor coefficient to zero, usually the first, whereupon the remaining n_{j-1} coefficients of each factor i represent incremental effects relative to the reference level. Coefficients obtained by fixing a factor level will differ with the choice of reference level. However, the relative differences among the estimated coefficients will not be affected by the choice of constraint.

Following Francis (1999), coefficients for factor i were transformed to "canonical" coefficients over all levels j calculated relative to their geometric mean (Starr, personal communication, March 2012). Geometric mean is calculated as:

$$\bar{\beta} = \sqrt[n_j]{\prod_{j=1}^{n_j} \beta_{ij}}$$

The canonical coefficient is

$$\beta_i{}' = \frac{\beta_i}{\bar{\beta}}$$

As CPUE analysis is done in the non-log space, the non-log space canonical coefficient is equivalent to

$$b' = e^{\beta_i - \bar{\beta}}$$

Although several factors could contribute to the variation in CPUE, the year of capture is usually given special significance: variations between years in this factor are interpreted as relative changes in the annual abundance of the crab.

The resulting series of 'fishing year' canonical coefficients is termed as the "Standardized" annual CPUE index and can be calculated as: if the year is the reference year 0, and β'_{20} if the year is some other year and β'_{2i} the CPUE index for year i relative to the reference year 0 is estimated as.

Finally, the procedure followed to fit the model was as follows:
1. Fit the GLM with each explanatory variable from a maximum set of predictor variables against CPUE.
2. Select the model (factors to enter into the model) using the AIC criterion using the Stepwise Algorithm implement in MASS package.
3. Calculate R^2 based on model deviance and number of degrees of freedom for selected model.
4. The selected explanatory variables in the GLM were used to estimate a time series of CPUE indexes based on the relationship between CPUE vs. available predictive variables.

<u>Exploratory – LCA & Y/R</u>:
In addition to the CPUE standardization an exploratory Length Cohort Analysis (LCA) and Length-based Yield Per Recruit (Y/R) analysis were run. These exploratory analyses used the estimated catch at length obtained by raising length-frequency data from commercial samples using 5 mm size classes, and growth parameters based on the *Chaceon maritae* species, adjusted to the maximum sizes observed in the *Chaceon erytheiae* species. An Excel implementation of the LCA and the Y/R was used.

4.4 Results

Results from the CPUE standardization are presented below to illustrate some of the more important outputs and methods applied.

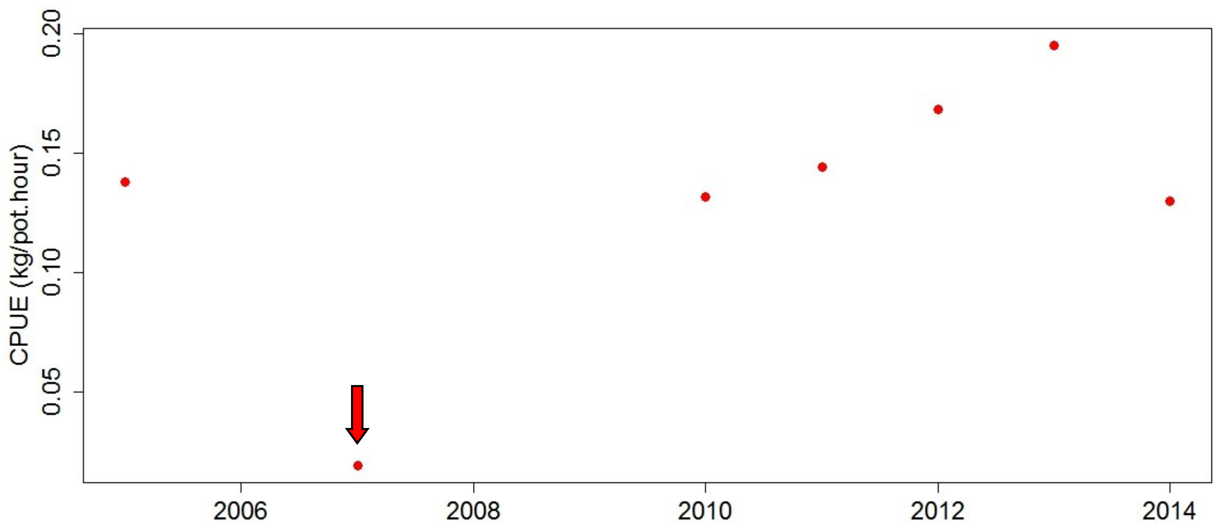

Figure 11: Mean CPUE (kg/pot.hour) across showing the disparity of the 2007 dataset with the rest of the dataset.

The maximum set of model parameters offered to the stepwise selection procedure was:

$$CPUE = \beta_0 + \beta_1 \text{ Year} + \beta_2 \text{ VesselID} + \beta_3 \text{ Depth} + \beta_4 \text{ Zone} + \beta_5 \text{ Semester} + \beta_6 \text{ SoakTime} + \varepsilon$$

A stepwise backward model selection procedure was deployed in selecting the covariates, to the model. The model with lowest Akaike value (AIC) was selected as the best model, since it has a better predictive power. The best model was then used for further analysis.

$$CPUE = \beta_0 + \beta_1 \text{ Year} + \beta_3 \text{ Depth} + \beta_4 \text{ Zone} + \beta_6 \text{ SoakTime} + \varepsilon$$

Table 5 presents the estimates of the coefficients, standard error and *t* values for different levels of the factors entered into the selected model. Model, covariate year, depth and soak time are very significant with a p-value $2.2*10^{-16}$, p-value 3.929^{-12} and p-value 6.019^{-07}that means these covariate influence the deep-sea red crab catch rates

Table 5: ANOVA results for the CPUE model.

Covariates	Df	Deviance	Residual Df	Residual Deviance	Pr(>Chi)
NULL			812	2.10918	
Year	5	0.37309	807	1.73609	< 2.2e-16 ***
VesselID	0	0.00000	807	1.73609	
Depth	291	0.74319	516	0.99290	3.929e-12***
Zone	2	0.00262	514	0.99027	0.4227
as.factor(SEMESTER)	1	0.00061	513	0.98966	0.5266
SoakTime	311	0.68185	202	0.30781	6.019e-07***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

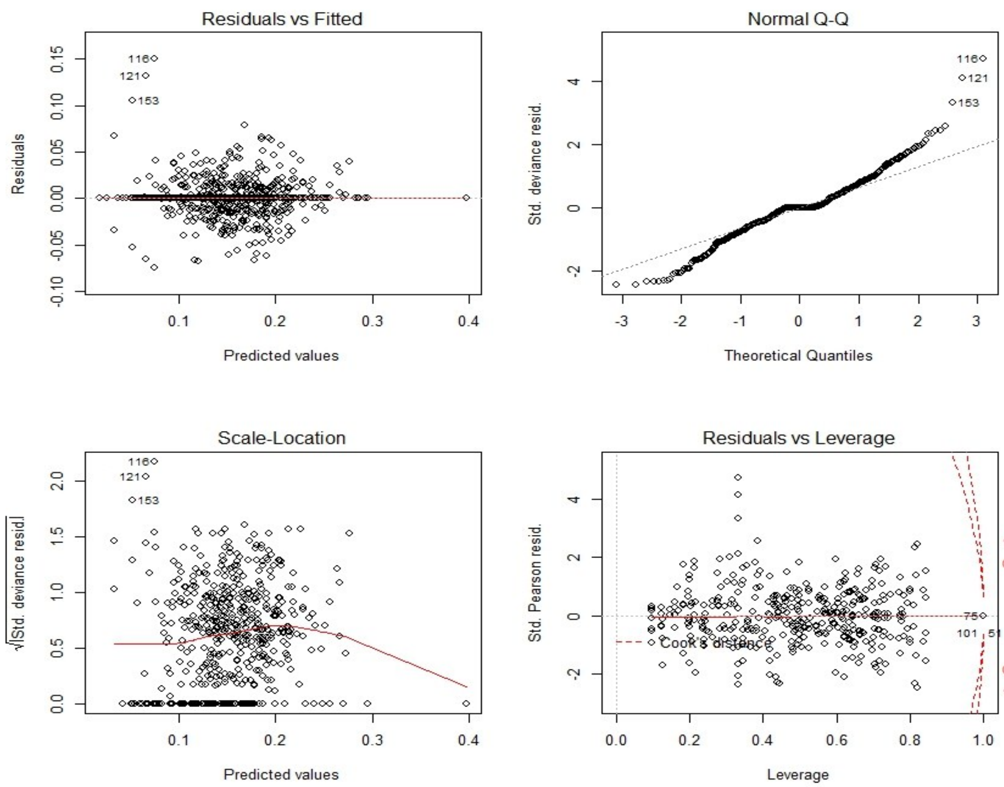

Figure 12: QQ and studentized residual plots of the best lognormal fit model for retained catch CPUE (kg/pot.hour).

Model diagnostics of the best model were assessed. This involved checking for normality of the residuals and the spread of the residuals across the fitted values. The diagnostic plots showed that model assumptions are not violated. The qqplots of the residuals indicated that the model residuals were slightly skewed towards the upper and lower tail. However this skewedness is of few data point relative to the amount of data presented. We have therefore considered the data to be normally distributed (Fig. 12). Plots of the residuals versus fitted values indicated evenly distributed data points, no apparent striking patterns in this plot (Fig. 12). Therefore there is no evidence of non-constant error variance in the residual plot and independence assumption also appeared reasonable.

Results from the standardized CPUE exercise suggest that CPUE has fluctuated over a very narrow range (of 0.9 and 1.08) during the period 2005 to 2014 – and that the CPUE, with the exception of 2010, remained relatively constant (at around 1) during this period of time (Fig. 13).

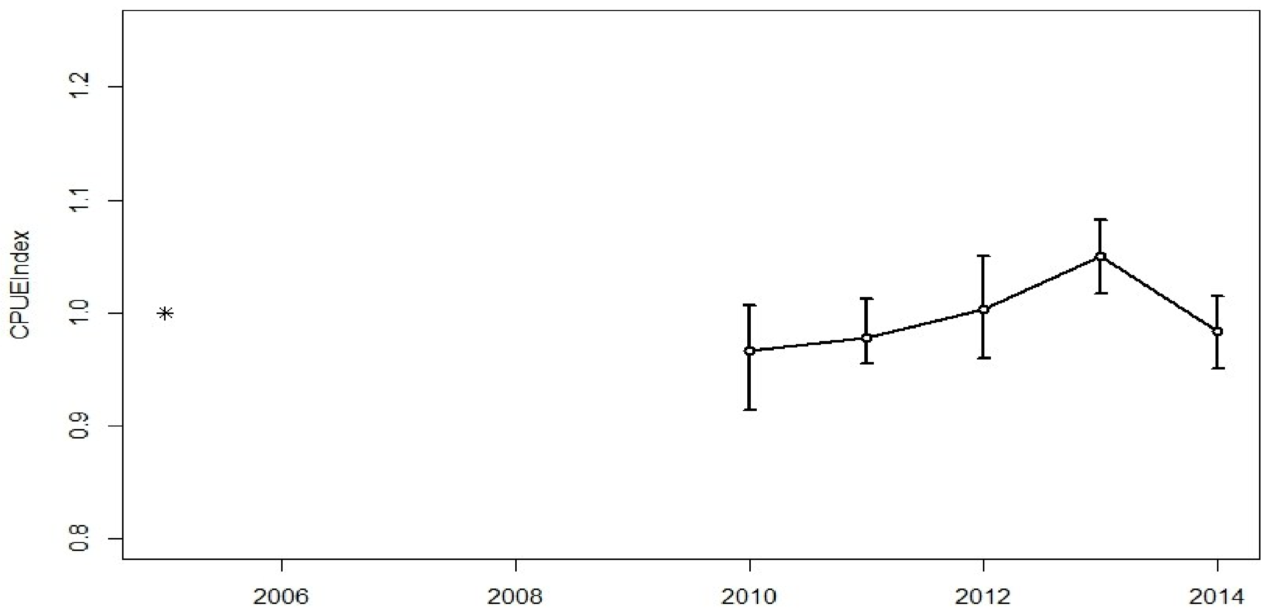

Figure 13: Trends in catch CPUE indexes for catches per pot-hour of crabs – with soak time as a categorical variable (factor). Standardized Index: black line with standard deviation (error bars/whiskers).

4.5 Discussion

The CPUE standardization conducted during 2014 for the SEAFO deep-sea red crab was a follow up on the initial attempt of 2013. Two additional parameters, depth and soak time, were added to the model and the CPUE was formalized to kg/pot-hour. The CPUE standardization revealed that, although the data series is very short, there was no change in the CPUE trend since 2010 and that it is well within range of the 2005 CPUE.

Furthermore the exploratory LCA, although inconclusive, revealed that the SEAFO deep-sea red crab resource currently is not under any risk of over-exploitation. LCA revealed that the current fishing mortality is reasonable and the stock is in a stable condition. There are no sign of overfishing looking at the CPUE and the length frequency data. LCA has proven to be an alternative assessment method, provided that data collections on the growth parameters are improved.

SC also noted that sampling on deep-sea red crab is quite good, but not all valuable data are available hence it is affecting our choice of an assessment method.

SC discussed the possibility of applying the harvest rule and it was decided that the Greenland Halibut harvest control rule used in NAFO may be the most appropriate option for deep-sea red crab.

4.6 Conclusion

The biological data series obtained from the SEAFO deep-sea red crab fishery, although short, is of relatively good quality. Nevertheless, important data such as growth parameter for the *C. erytheiae* stock, which will enhance the cohort analyses of the resource, was not available for the SEAFO CA and emphasis needs to be given in collecting this data for future assessments.

4.7 Biological reference points and harvest control rules

At this point in time it should be noted that no biological reference points exist for this stock in the SEAFO CA.

However, it is worthwhile to note that the *C. erytheiae* stock, based on the grounds of it being a long-lived and relatively stable stock, is a good candidate for an empirical Harvest Control Rule (HCR) similar to that applied to the Greenland halibut stock by the North Atlantic Fisheries Organization (NAFO). This is a simple HCR that merely considers that slope of an abundance index such as the CPUE and applies a catch limit to future years based in the current year's TAC. The concept is as follows:

$$TAC_{y+1} = \begin{cases} TAC_y \times \left(1+\lambda_u \times slope\right) & if \quad slope \geq 0 \\ TAC_y \times \left(1+\lambda_d \times slope\right) & if \quad slope < 0 \end{cases}$$

Slope: average slope of the Biomass Indicator (CPUE, Survey) in recent 5 years

- λ_u :TAC control coefficient if slope > 0 (Stock seems to be growing) : λ_u=1
- λ_d :TAC control coefficient if slope < 0 (Stock seems to be decreasing) : λ_d=2
- TAC generated by the HCR is constrained to ± 5% of the TAC in the preceding year.

For the interim this is considered to be a fairly good starting point, given the current status of the C *erytheiae* resource*,* until such time that additional data are available for more advance stock assessment approaches.

12. Incidental mortality and bycatch of fish and invertebrates

5.1 Incidental mortality (seabirds, mammals and turtles)

No incidental catches of seabirds, mammals and turtles have been recorded from the deep-sea red crab fishery to date.

5.2 Fish bycatch

Incidental and bycatch records from the deep-sea red crab fishery indicate that only one species is currently impacted by this fishery.

Table 6: Incidental (bycatch) catch from the deep-sea red crab fishery (kg).

	2009	**2010**	**2011**	**2012**
Species	**-**	**B1**	**-**	**-**
***MZZ**		5.23		

*** Marine Nei fishes (*Osteichthyes*)**

5.3 Invertebrate bycatch including VME taxa

No VME bycatches have been recorded from the deep-sea red crab fishery to date.

5.4 Incidental mortality and bycatch mitigation methods

There currently exist no incidental and bycatch mitigation measures for the deep-sea red crab fishery in the SEAFO CA.

5.5 Lost and abandoned gear

No lost and abandoned gear data have been reported for the deep-sea red crab fishery in the SEAFO CA.

5.6 Ecosystem implications and effects

The SEAFO deep-sea red crab fishery has very limited to no negative ecosystem impacts in terms of it temporal and spatial context.

13. Current conservation measures and management advice

In 2013 the Commission adopted a TAC of 200t in Division B1, and 200t in the remainder of the SEAFO CA for 2014 and 2015 (CM 27/13). Accordingly the SC did not provide TAC advice for this stock during 2014.

The SC noted that adopting an HCR might be considered for the deep-sea red crab fishery and suggested such a rule.

Table 7: Other Conservation Measures that are applicable to this fishery.

Conservation Measure 04/06	Conservation of sharks caught in association with fisheries managed by SEAFO.
Conservation Measure 14/09	Reduce sea turtle mortality in SEAFO fishing operations.
Conservation Measure 18/10	Management of vulnerable deep water habitats and ecosystems in the SEAFO Convention Area.
Conservation Measure 25/12	Reducing incidental bycatch of seabirds in the SEAFO Convention Area.
Conservation Measure 26/13	Bottom fishing activities in the SEAFO Convention Area.

14. References

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