CeDePesca

Centro Desenvolvimento e Pesca Sustentável
Filial Fortaleza - Brasil

Analysis of the exports data supplied by SINDIFRIO

Preliminary conclusions to contribute to a sustainable management of the lobster fishery.

November 11th, 2014

1. Introduction

   Throughout the year 2014, the CeDePesca-Brazil team worked together with SINDIFRIO companies to collect, digitalize and systematize the exports data classified according to weight as a contribution to understand the status of the fishing stocks. The goal was to offer researchers and evaluators a data base representing the lobster populations exploited in Brazil.

   Even if there is room for improvement in the data base, the goal has been attained as the current data base is representative enough, except for two years so far, 2004 and 2007. Nevertheless, when assessing the data, no different trends can be observed.

   For the analysis, some obstacles were encountered that where solved as follows:

   a) Most data made no difference between the red and the green lobster, therefore both species have been considered as a single stock. However, in those data bases that do make the difference, the green one does not represent more than 20% of total exports. Therefore, the deviation is not significant for this level of analysis.
   b) The transformation of whole lobster into lobster tail commercial classes was solved proportionally. However, some tests should be performed in practice.
   c) The transformation of average weights per commercial class into lengths was not done with the normal lengths distribution, but with the linearly proportional average directly distributed.
   d) The transformation of lengths into ages was based in equations determined by Brazilian researchers quoted on the literature. Also in this case, a linearly proportional distribution was applied for length ranges that included more than one age.
   e) All the assumptions made in this work used the potential deviations always in favour of the stock situation. This means that reality could be WORSE than what is shown here but it would never be better.

2. Determination of age structure in exports

   The data base includes data coming from five companies, still pending the inclusion of some data from 2011 and 2012 that will not change its basic structure:

Classe	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
02	-	509	36	-	2	2.241	10.132	27	73	413
03	2.091	6.164	1.545	345	4.594	11.127	15.811	30.091	9.669	39.498
04	11.273	19.109	20.455	5.455	39.845	39.250	25.323	62.844	34.377	89.296
05	10.527	14.855	16.200	9.218	59.812	68.523	44.944	70.829	35.826	101.917
06	7.673	15.218	14.745	8.600	44.705	67.636	44.580	49.634	27.566	69.993
07	4.818	18.436	15.982	10.400	32.541	53.182	55.793	39.159	22.605	59.233
08	3.000	15.400	11.309	7.309	25.242	34.295	58.280	44.980	18.414	40.051
09	5.000	18.673	17.800	6.836	21.432	26.759	62.723	33.041	13.723	25.613
10/12	9.291	40.055	41.164	12.818	32.400	46.400	104.041	33.601	4.208	48.219
12/14	4.236	21.036	23.055	4.855	32.655	24.373	63.864	40.636	19.338	10.480
14/16	2.400	12.218	12.545	3.218	19.568	11.036	31.227	23.053	10.752	6.097
16/20	1.945	8.727	8.091	2.182	10.450	5.236	9.891	5.125	195	7.197
20/UP	1.382	4.364	2.927	818	455	91	8.655	6.930	4.712	1.059
TOTAL	63.636	194.764	185.855	72.055	323.700	390.150	535.261	439.951	201.458	499.067
Exportacoes cauda (tn)	2.556	2.376	2.088	2.050	2.418	2.021	2.422	2.261	1.474	1.991
% dados/export	2	8	9	4	13	19	22	19	14	25

The last line shows the percentage that analysed data represent out of the total exports (in equivalent weight of tails). In general, the proportion is high, thus the analysis is reliable. Nevertheless, it would be advisable to collect more information from years 2004 and 2007.

This table was transformed into quantities of lobsters exported per each commercial class, where each total weight per class was divided by the average weight of the said class.

To transform those quantities per commercial class into quantities per age, first the average weight was transformed into average length, using the following equation:

$$CT = EXP(3{,}4556 + 0{,}386 * LN(Pc))$$ [1]

Where,
CT: total length, and
Pc: tail weight

Later, average weight was transformed into average age using the following equation:

$$T = -4{,}31 * LN(1 - (\frac{CT}{10})/43{,}8)$$ [2]

Where,
T: age, and
CT: total length

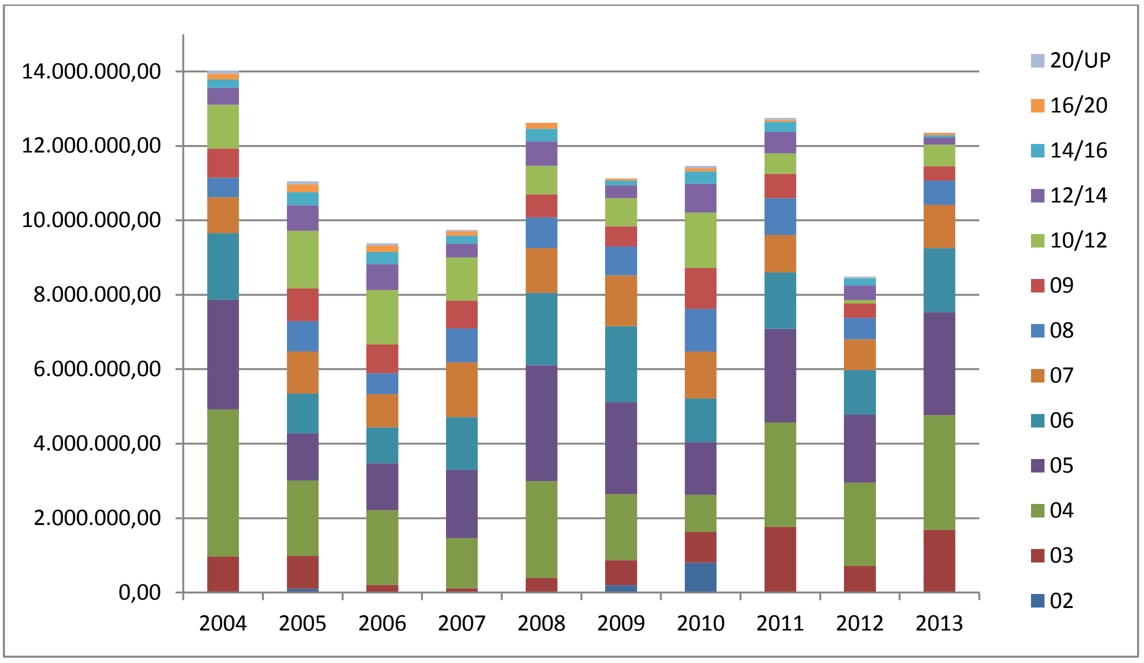
Later on, quantities where proportionally redistributed among ages from 1 through to 8 years. For example, if a length range corresponded to ages from 2.56 through to 3.12 years, it was proportionally distributed from 2.56 till 2.99 in age 2, and from 3 till 3.12 in age 3.

[1] Sobreira Rocha, C. e Fontenele Sampaio, A. Relações biométricas das lagostas espinhosas *Panulirus argus* (Latreille) e *Panulirus laevicauda* (Latreille) do nordeste do Brasil.
[2] Fonteles-Filho, A. Síntese sobre distribuição, abundância, potencial pesqueiro e biologia da lagosta-vermelha *Panulirus argus* (Latreille) e a lagosta-verde *Panulirus laevicauda* (Latreille) do nordeste do Brasil.

As a result, the following table is obtained:

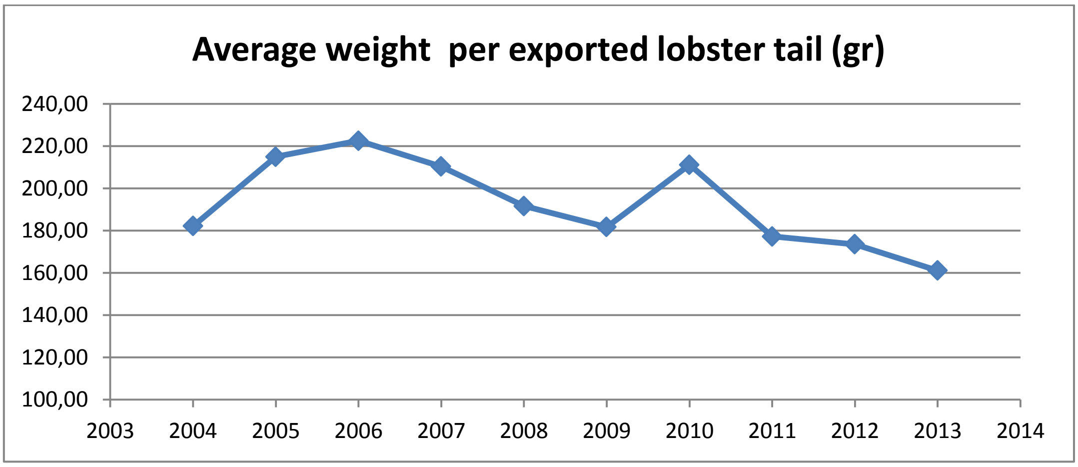
Idade	2.004	2.005	2.006	2.007	2.008	2.009	2.010	2.011	2.012	2.013
1	0	98.635	6.489	0	54	184.400	727.638	651	2.553	7.741
2	7.043.480	3.823.590	3.118.180	2.782.757	5.235.682	4.241.491	2.915.183	6.380.323	4.267.072	6.753.255
3	4.109.731	3.377.020	2.771.036	4.317.829	4.848.848	4.877.991	3.986.312	4.220.417	3.114.598	4.306.087
4	1.864.698	2.306.305	2.122.963	1.815.391	1.324.178	1.236.736	2.469.479	1.155.414	469.294	921.378
5	653.334	971.684	962.802	559.939	875.882	459.989	1.045.516	748.283	485.081	268.903
6	179.485	265.783	243.369	160.559	239.219	90.779	206.146	163.414	95.467	54.765
7	105.744	136.723	112.623	77.176	88.591	30.551	62.956	41.567	12.935	37.099
8	73.542	70.528	43.575	30.842	4.500	624	51.850	47.064	45.625	5.513

This means that between 8.5 and 14 million lobsters were exported each year from different ages and lengths.



According to this information, we can estimate the average weight per lobster in exports. We can see that this average weight is on the downward trend, thus sending a depletion signal:

Ano	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Peso meio cauda (gr)	182,17	214,97	222,55	210,34	191,66	181,71	211,21	177,23	173,57	161,13



3. Sequential analysis to reconstruct total population between 2004 and 2013

According to the analysis model proposed by Aubone[3], based on the equation of Baranov, the procedure is as follows:

a) *Calculation of the number of lobsters in the last assessed period (2013)*

Based in the combination of fishing mortality estimates at age arising from exports at age and our estimate procedures included in Chapter 4 of the present document, an initial vector of fishing mortality per age ($\mathbf{F_{i,tm}}$) is introduced. Together with an estimate of natural mortality, they set up the model parameters to be adjusted at a later point in time.

To define natural mortality, according to Ivo, the most conservative option was chosen, **M**=0.3[4.5], considered constant for all ages.

The number of lobsters per age in the year 2013 is thus calculated:

$$N_{i,tm} = C_{i,tm} \frac{(F_{i,tm} + M)}{F_{i,tm}.(1 - e^{(-Fi,tm-M)})}$$

b) *Determination of fishing mortalities for each year and age in the period 2004-2012*

With the numerosity estimate for the year 2013 and exports from 2004 through to 2012, we can estimate fishing mortality for the whole period, assuming that from age 3 through

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[3] Aubone, A. Modelos discretos de dinámica de poblaciones de peces explotadas. En Serie de Lecturas en Biomatemática; 305p, 1ra Ed., Noviembre 2010.

[4] FAO/Western Central Atlantic Fishery Commission. Report of the fifth Regional Workshop on the Assessment and Management of the Caribbean Spiny Lobster. Mérida, Yucatán, Mexico, 19–29 September 2006. FAO/Comisión de Pesca para el Atlántico Centro-Occidental. Informe del quinto Taller Regional sobre la Evaluación y la Ordenación de la Langosta Común del Caribe. Mérida, Yucatán, México, 19-29 de septiembre de 2006. FAO Fisheries Report/FAO Informe de Pesca. No. 826. Rome, Roma, FAO. 2007. 99p

[5] Ivo, C.T.C., 1996. *Biologia, pesca e dinâmica populacional das lagostas Panulirus argus e Panulirus laevicauda (Laterille) (Crustacea; Palinuridae), capturados ao longo da plataforma continental do Brasil, entre os Estados do Amapá e Espírito Santo.* Tese de Doutorado apresentado ao programa de Pós-graduação em Ecologia e Recursos Naturais da Universidade Federal de São Carlos, 279 p., São Carlos.

to 8 each lobster caught is exported. This introduces an error approximately equal for the whole procedure, thus validating relative values.

We estimate using the following equation:

$$C_{i,t} = \frac{F_{i,t}}{(F_{i,t} + M)}\left(e^{(Fi,t+M)} - 1\right)N_{i+1,t+1}$$

iterating with the Solver tool from Excel.

c) *Determination of the number of lobsters per age for each year of the period 2004-2012*
With the fishing mortalities already obtained and the population dynamic equation, we retrocalculate for ages 3 through to 7:

$$N_{i,t} = N_{i+1,t+1}.\,e^{(Fi,t+M)}$$

As age 2 is not enough represented in exports, we assume a fishing mortality equal to that of age 3, and we calculate using the previous equation.

For age 1, we assume no catches, so just natural mortality is operating, and we calculate:

$$N_{1,t} = N_{2,t+1}.\,e^{M}$$

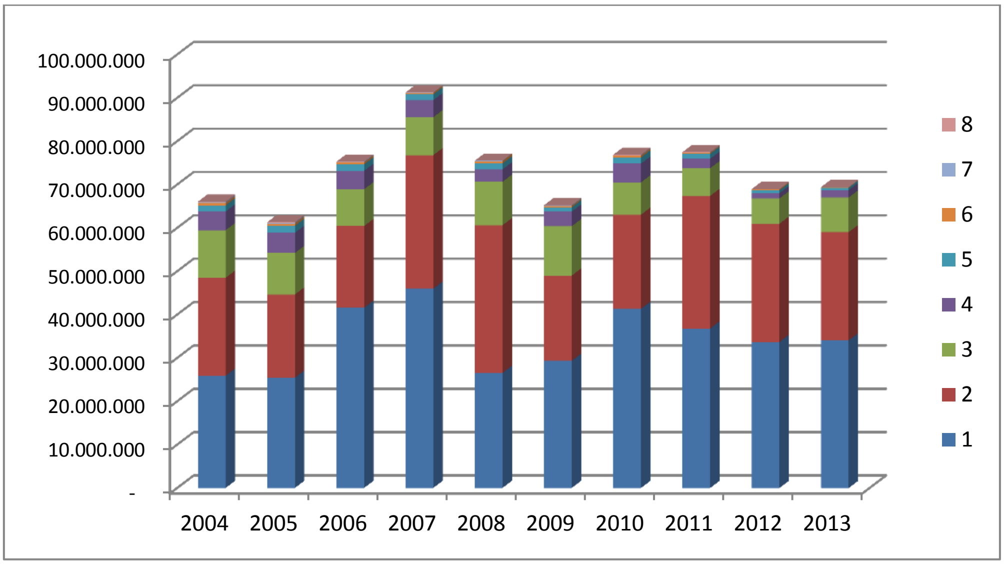
For age 8 and more (which is called 8+) we assume that all lobsters above 7 years of age are included, and the number of lobsters is determined by means of a particular procedure according to the following formula:

$$N_{8+,t} = (C_{8+,t-1}.\,C_{7,t-1}).\,e^{(-F8,t-1-M)}.\frac{(F_{8,t-1} + M)}{F_{8,t-1}.\,(1 - e^{(-F8,t-1-M)})}$$

d) *Results of the sequential analysis*
Number of lobsters per age per year (in thousands)

Idade	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	25.891	25.437	41.567	45.969	26.536	29.330	41.303	36.799	33.703	34.059
2	22.591	19.180	18.844	30.793	34.055	19.659	21.728	30.598	27.261	24.968
3	10.977	9.582	8.486	8.745	10.034	11.390	7.462	6.367	5.833	7.994
4	4.318	4.656	4.240	3.938	2.850	3.356	4.324	2.187	1.214	1.710
5	1.441	1.626	1.511	1.358	1.389	996	1.440	1.138	651	503
6	486	517	394	319	533	300	351	205	222	83
7	205	208	160	89	101	193	145	88	18	84
8	143	108	62	36	5	4	120	99	64	12
Total	66.052	61.315	75.264	91.246	75.503	65.229	76.873	77.480	68.966	69.413

Between years 2004 and 2013 total lobster population has moved between 61 and 91 million of individuals.



It can be observed that recruitments (blue part of the columns) have rosy periods (2006, 2007 and 2010) and gloomy periods (2004, 2005, and 2008). These variations are reflected in catches two or three years after the recruitment has taken place, due to the fact that the higher age fractions are much diminished.

Fishing mortalities per ages and average between ages 3 through to 8 ($F_{3\text{-}8}$) per year

Idade	F2004	F2005	F2006	F2007	F2008	F2009	F2010	F2011	F2012	F2013
3	0,558	0,515	0,468	0,821	0,795	0,669	0,927	1,357	0,927	0,940
4	0,677	0,825	0,839	0,742	0,751	0,546	1,035	0,912	0,582	0,940
5	0,724	1,118	1,257	0,635	1,233	0,744	1,651	1,335	1,758	0,930
6	0,547	0,872	1,188	0,847	0,714	0,426	1,086	2,123	0,673	1,340
7	0,875	1,329	1,534	2,886	2,993	0,201	0,681	0,773	1,585	0,700
8	0,875	1,329	1,534	2,886	2,993	0,201	0,681	0,773	1,585	0,700
F(3-8)	0,613	0,735	0,770	0,818	0,864	0,646	1,059	1,286	0,987	0,942

Fishing mortalities are very high, which is coherent with the analysis presented on the following chapter (See chart in page 7).

e) *Population estimate without fishing*

If we consider the population estimate for the last year, assuming that recruitment will be constant and equal to the average of the period 2004-2012, we can assess to what extent the population may grow if just natural mortality operates. If we agree that the recruitment of the last period has been relatively low, this forecast would be conservative, resulting as follows:

Idade	N Sem pesca
1	34.059.353
2	25.231.790
3	18.692.169
4	13.847.500
5	10.258.480
6	7.599.669
7	5.629.973
8	16.091.920
Total	131.410.855

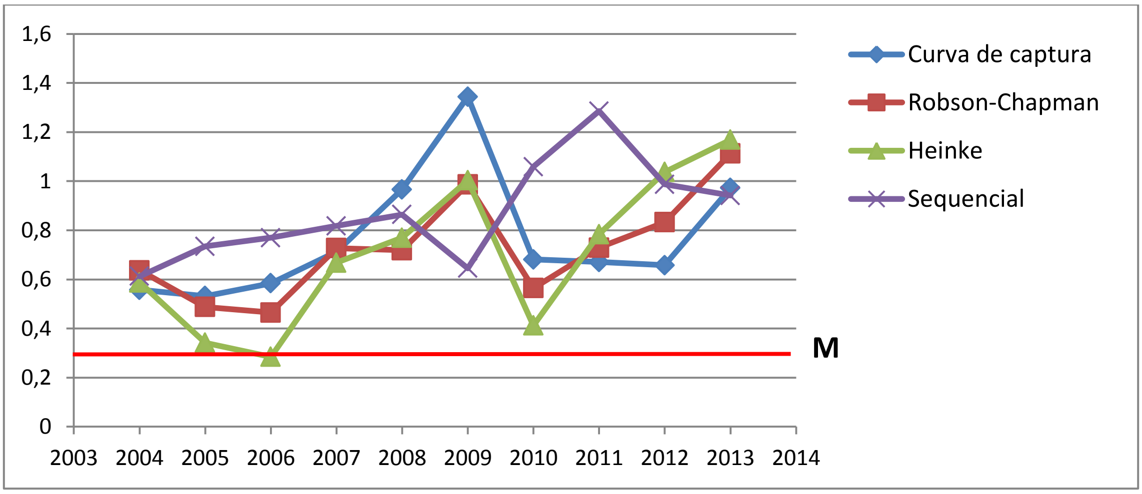
This table is very important to define biological reference points for the fishery (see Chapter 5).

4. <u>Analysis of fishing mortality using different methodologies</u>

In order to compare and verify previous results, methods of approximate estimating are used. These methods have been validated by systematic use in world fisheries: catch curve, Robson-Chapman and Heinke methods. They can be easily found in literature. Input data for those models are lobster caught per age, being calculated for ages 3 to 8 that are well represented in our data base.

Including also fishing mortalities calculated in the previous chapter, the following table and chart are obtained:

Metodo	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Curva de captura	0,5577	0,5319	0,5842	0,7123	0,9664	1,3442	0,6812	0,6708	0,6576	0,9723
Robson-Chapman	0,6370	0,4879	0,4648	0,7276	0,7188	0,9869	0,5649	0,7293	0,8332	1,1131
Heincke	0,5873	0,3420	0,2850	0,6682	0,7698	1,0035	0,4126	0,7844	1,0376	1,1688
Sequencial	0,6128	0,7348	0,7697	0,8183	0,8643	0,6457	1,0586	1,2855	0,9873	0,9416



It can be seen that, despite the differences, fishing mortalities are very high if compared with natural mortality M, tripling it. In general, it is accepted that fishing mortality, to be sustainable, it should have a level similar to that of natural mortality. Therefore, current levels are not sustainable.

5. Biomass estimates

Multiplying average weight per age by number of estimated lobsters per age, it is possible to calculate the annual biomass between 2004 and 2013.

Idade	2.004	2.005	2.006	2.007	2.008	2.009	2.010	2.011	2.012	2.013	No fishing
1	4.062	3.991	6.522	7.213	4.164	4.602	6.481	5.774	5.288	5.344	5.344
2	8.071	6.852	6.732	11.001	12.166	7.023	7.763	10.931	9.739	8.920	9.014
3	6.165	5.382	4.766	4.911	5.636	6.398	4.191	3.576	3.276	4.490	10.499
4	3.765	4.060	3.697	3.434	2.485	2.927	3.770	1.907	1.058	1.491	12.075
5	1.629	1.837	1.708	1.534	1.569	1.126	1.627	1.286	736	568	11.591
6	661	703	535	433	724	408	477	278	301	113	10.327
7	325	330	254	141	160	306	230	139	29	133	8.918
8	259	195	113	64	9	7	217	180	116	23	29.207
Total	24.937	23.351	24.327	28.732	26.914	22.796	24.755	24.071	20.544	21.081	96.975

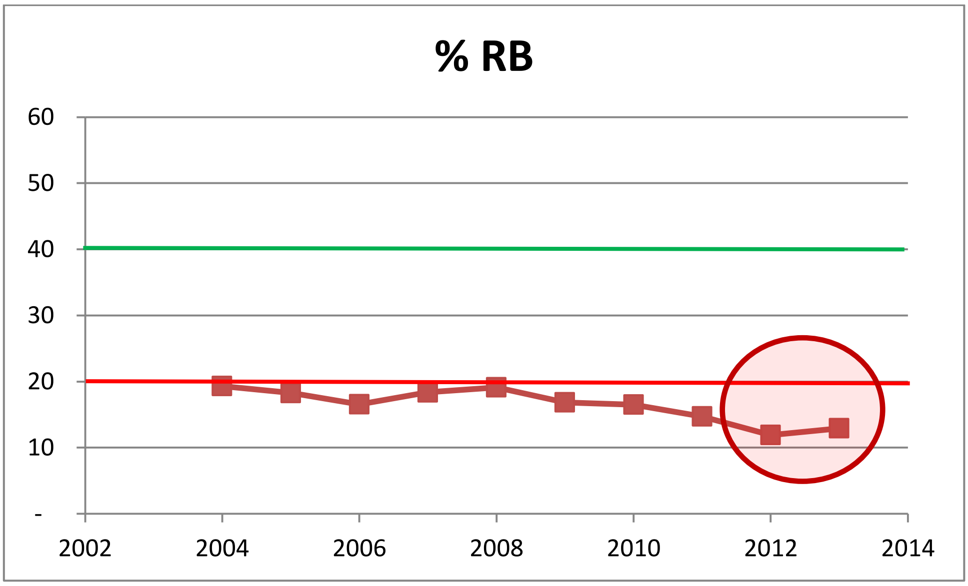
Likewise, using the table in Chapter 3.e), long term potential biomass was calculated in case of a permanent closure of the fishery. In that scenario, the biomass would reach almost 100 thousand tons, whereas currently it shows a declining trend since 2007, dropping down almost to 21 thousand tons in 2013.

As reference point, it would be even more important to know what would be the reproductive biomass without fishing and its current value. In that aim, we assume that at age 1 no specimen is sexually mature, for age 2 half the specimens are mature and for age 3 and older, all are mature, which is in agreement with the literature (Fonteles-Filho).

Biomasas	Sem pesca	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
BR	87.124	16.840	15.934	14.439	16.018	16.667	14.682	14.394	12.832	10.386	11.277
% BRv	100	19	18	17	18	19	17	17	15	12	13

Reproductive biomass in 2013 was around 13% of the value without fishing. This is a clear signal of overexploitation as it is considered that reproductive biomasses should not be below the critical point corresponding to 20% of the reproductive biomass without fishing (assessed in 87 thousand tons).

Next chart clearly illustrates this downward trend:



This charts shows the 20% level, considered a limit (red line), and the 40% level, considered a target that should be reached (green line). Current reproductive biomass is well below the red line (13%), in a very risky area.

These conclusions coincide with the results presented by Brazil in 2007 at the WECAFC, already quoted[6].

6. Estimates of non-exported catches

If we consider that there are no catches of specimens in age 1 (which is false as there is evidence of "baby lobster" being sold) and we calculate the number of specimens at age 2 caught with a fishing mortality similar to that of age 3, which seems a reasonable assumption since the selectivity is very low, and then we subtract the quantities exported at age 2, we can calculate the quantity and tons of specimens caught that have not been exported:

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
N	1.414.517	2.935.864	3.034.821	12.422.178	11.220.367	4.177.360	8.691.821	13.901.773	10.289.094	6.696.662
Tn	221	458	473	1.938	1.750	652	1.356	2.169	1.605	1.045

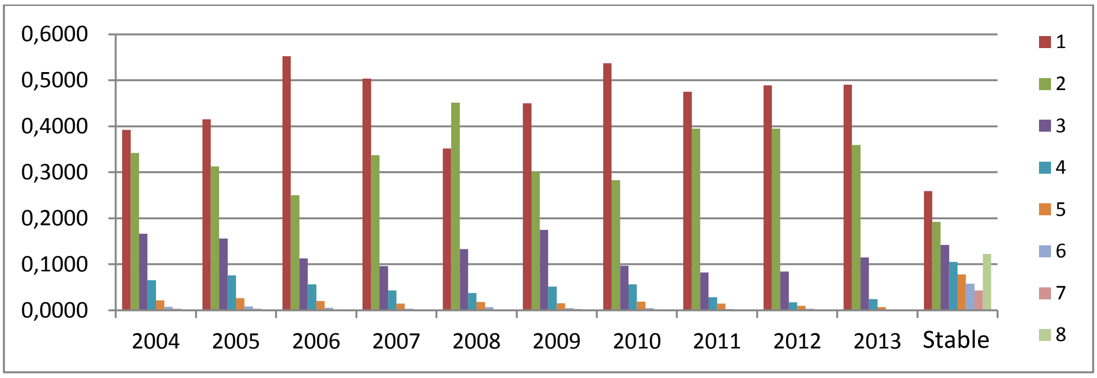
The average of the last seven years has been around 9 million of specimens in age group 2, weighting around 1,500 tons of whole lobster (or 500 tons of lobster tail). As a reference, the average of exports in the same period has been of 11 million specimens, weighting around 6,500 tons of whole lobster. This means that almost the same number of lobsters are exported and consumed in the local market. The main difference is that exported lobsters have a volume

[6] It is observed that in the last 7 years the mature stock biomass has decreased considerably in spite of the large recruitment peaks observed during the same period. This may be due to a significant increasing trend in the fishing mortality rates (F) since 1986 when F=0.23. These rates reached levels above the natural mortality rate (M=0.30) in 1989 and since then it has increased steadily to levels between 0.54 and 0.8 during the 2000's. These fishing mortality rates are well above the fishing mortality reference point that may generate a 40 percent level of the pristine spawning biomass (F40% SPR=0.20). If they were sustained, the current fishing mortality rates, could drive the spawning potential ratio to a level below 15 percent.

13 times larger in weight, generating a much higher value with considerably less fishing effort. These values show the urgent need to limit catches of undersized lobster as an essential part of a stock recovery strategy.

7. Analysis of population stability

Population stability is a very interesting analysis. If we calculate the age composition of the total lobster population, only considering natural mortality, we can see that it reaches a stable level without later changes. The population is in equilibrium. Comparing this demographic tree with the current one we can observe the stability or instability degree of the population. The next chart illustrates the current situation of the lobster:



It is noticeable that in 2013 the population was even further away from the stable structure than in 2004, increasingly depending on the recruitment success (age 1), as 85% of the population corresponds to ages 1 and 2. In contrast, in can be observed that in the stable structure, a lack of recruitment for one year, due to natural causes, will not have as much impact on the population. It would be easily absorbed as ages 1 and 2 only represent around 43% of the total population. Under the current scenario, the fishery turns more unpredictable and the risk of collapse is much higher.

8. Analysis of the proportion of the catch

It is proven[7] that the relationship between catches and the total number of specimens in the population per year is equal to the product of three probability factors that intervene in fishing success: accessibility, vulnerability and selectivity. Each one represents a probability: the first one is the probability of overlapping in space and time between the fishing fleet and the stocks, the second is the probability of encountering between the fishing gear and the specimens, and the third one, is the probability of catching the specimen once the encounter has taken place.

This proportionality can be expressed thus:

$$\frac{C_{i,t}}{N_{i,t}} = A_{i,t}.V_{i,t}S_{i,t}$$

[7] Aubone, op. cit.

Let´s see how this relationship evolves in the lobster fishery:

Idade	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
3	0,374	0,352	0,327	0,494	0,483	0,428	0,534	0,663	0,534	0,539
4	0,432	0,495	0,501	0,461	0,465	0,368	0,571	0,528	0,387	0,539
5	0,453	0,598	0,637	0,412	0,631	0,462	0,726	0,657	0,745	0,535
6	0,369	0,514	0,618	0,504	0,449	0,303	0,588	0,799	0,430	0,659
7	0,515	0,656	0,703	0,868	0,875	0,158	0,434	0,474	0,713	0,442
8	0,515	0,656	0,703	0,868	0,875	0,158	0,434	0,474	0,713	0,442

These figures represent proportion of specimens in the population caught per age group and per year. These are **high** proportions.

Thinking about Selectivity, currently no fishing gear or technique leaves scape for any specimen once the contact is established. Therefore, the value of this probability is 1 and it is going to be very difficult to change this situation in the short or medium term. In other lobster fisheries, Selectivity is improved leaving scape for undersized lobster, either by devolution (fish-pots) or by catch avoidance (diving).

Regarding Vulnerabilities, it is very difficult to quantify from 0 to 1, but probably it is close to 1, as fishermen know well where to place their fishing gears to be more effective. Let´s say 0.85.

Regarding Accessibility, presently it has two limitations: seasonal closures and the migration of the older population towards deeper waters. However, for younger specimens, representing 90% of the fishery, seasonal closures are the only catch limitation. This is the reason why the C/N ratio (as well as fishing mortality) is not even higher. Therefore, under the present circumstances, reducing seasonal closures could be deleterious. Beforehand, it is necessary to solve the limitation in the C/N ration by other means, via Accessibility, Vulnerability, Selectivity or all of them.

If seasonal closures were reduced in two months, probably there would be a small increase in catches in the first two years to decrease thereafter down to a level even lower than the current one, increasing the risk of total collapse even more.

9. <u>Recommendations for recovering the fishery</u>

Making a forecast of the evolution of the lobster population under the present conditions of fishing mortality, we can draw the following conclusion: the fishery could continue indefinitely at this low level provided the recruitments do not oscillate very much. Nevertheless, any severe weather or environmental change could produce almost a total collapse of the fishery.

To achieve a quick stock recovery to the level of 40% of the reproductive biomass without fishing, it would be necessary to reduce present catches by about 75%, which is socially impossible.

An alternative long-term strategy should be based in two goals:

a) Reduce rapidly by half age 2 lobster catches (undersized lobster)
b) Reduce by 20 % legal lobster catches and maintain reduced catches for three years.

This will give the population the opportunity to grow a little each year and fishing mortality will be gradually reduced.

After 3 years, the progress should be reassessed to determine if the strategy should be continued or modified.

The question is HOW to attain those goals.

To achieve 50% undersized lobster catches, the most important thing would be to ensure the maximum possible level of compliance of the seasonal closure. In this aim, all form of ownership, transport or commercialization of lobster should be forbidden from February 1st till June 10th in the Brazilian market.

A second measure could be to establish a processing quota in processing plants of 1/6 of the processing done in the previous year for the month of June or to forbid the beginning of the processing until June 10th.

In addition, the population should also be encouraged to join in the effort, by means of TV campaigns and agreements with fishmongers, supermarkets and restaurant associations.

To reduce legal lobster catches by 20%, the following measures could be adopted:

a) Only whole and alive lobsters can be admitted in processing plants, with a survival tolerance limit not below 85%. The Ministry of Agriculture should verify the enforcement of the measure. If survival is under 85%, the batch should be rejected. The idea is to **diminish the efficiency of fishermen** (Vulnerability), but improving simultaneously the price per unit. This could also encourage the rejection of non-legal fishing gears.
b) An exports limit should be established at 1,500 tons of lobster tail or equivalent for three years (which means another limit to Accessibility).

As a complement, to support the recruitment success, egg-bearing lobsters should not be admitted in processing plants.

Continuity in the collection of companies' data and the addition of some monitoring measures in beaches and harbours would permit an annual follow-up of the lobster population evolution, adjusting the corresponding strategies. The reduction of the seasonal closure would be possible if the efficacy of other measures would compensate and allow a gradual increase of stocks.