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Update of the Chilean Jack Mackerel CPUE abundance index based on catch by fishing trip in the south-central Chile

Republic of Chile

Update of the Chilean Jack Mackerel CPUE abundance index based on catch by fishing trip in the south-central Chile.

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Abstract

The abundance index based on the CPUE model of the south-central Chilean purse seiner fleet is one of the main indices used in the jack mackerel stock assessment model. This index was updated up to June 2023. The CPUE model uses vessel hold capacity both in independent and dependent variables. To evaluate the effect of the use of vessel hold capacity in the CPUE model, an alternative model based on the catch with vessel hold capacity as covariable was fitted. The two models estimated a similar abundance index, which had a decreasing trend from 1983 to 2011, an increasing trend up to 2020, and a stabilization in the last three years. The current index level is similar to one in the year 2001.

The relationships between the CPUE index and hydro-acoustic survey results in the south-central area were analysed, including acoustic biomass, acoustic density, and fish distribution area. For the years 2000, 2021, and 2023, the acoustic surveys estimated decreasing trends in the biomass and in the area occupied by the fish, and a high increase in the density. A ramp model was fitted between the CPUE index and biomass. CPUE index tends to increase with acoustic density until an asymptotic level. A linear model was fitted between the CPUE index and area (excluding the last three years), which is proposed to correct the CPUE index. This correction reduced the recovery rate in the last three years. It is recommended to have a precautionary approach because the CPUE index seems to overestimate stock recovery.

Background

The abundance index based on the CPUE model of the central-south Chilean purse seiner fleet is one of the main indices used in the jack mackerel stock assessment model. Therefore, this index has to be updated for the next scientific meeting. This model uses CPUE as the ratio between catch (ton) and days off port multiplied by the vessel hold capacity, and vessel hold capacity bands as fixed

effects. To analyse the impact of using the vessel hold capacity on both dependent and independent variables, a model based on catch was also fitted in this report.

Another important index is the biomass estimated by hydroacoustic surveys in south-central Chile which is partially (1997-2009) used in the stock assessment model. The rest of the years (2010 to 2023) are not used because there were modifications of survey sampling designs, which were done to cover the changes in fish distribution (Catasti and Cordoba 2022). The most recent hydroacoustic surveys have shown a biomass recovery and change in fish distribution which need to be analysed and compared to the CPUE index.

Aims

1) To update the index based on the CPUE model up to 2023
2) To estimate an abundance index based on the catch model.
3) To compare the index based on the CPUE model with the one based on the catch model.
4) To analyse relationships between abundance indices and acoustics survey results.

Data

The IFOP database of catch per fishing trip was updated up to June 2023. The 1983-2023 period was used in the analysis.

Models

1) Index based on CPUE model.

   The CPUE model (Canales et al. 2008) is:

   CPUE = year + quarter + zone + hc + ε

   where CPUE is catch (t)/ days at sea multiply by the vessel hold capacity (m^3); year is the temporal effect (1983 to 2023); zone is the spatial effect (Z11, Z12, Z13, Z21, Z22, Z23, Z31, Z32 and Z33) and hc is the vessel hold capacity bands effect (1: 0:250; 2: 251:350; 3: 351:500; 4: 501:600; 5: 601:750; 6: 750: 850; 7: 852:910; 8: 911:1100; 9: 1102:1506; 10: >1506); and ε is the error term.

   The model was fitted as a GLM with gamma error distribution with a logarithm link function.

2) Abundance index based on catch model

   Because in the CPUE model the vessel hold capacity is part of both the dependent variable (CPUE) and an independent variable (hc bands), the following catch model was fitted:

$$\log(C) = year + quarter + zone + \log(CB) + offset(\log(DFP)) + \varepsilon$$

where C is the catch (t); CB is the vessel hold capacity covariable (m^3), and DFP is the days at sea; a e is the error. The DFP was used as an offset variable. The model was fitted as a GLM with a gaussian error distribution.

The acoustic results were taken from Catasti and Cordova (2022) and Cordoba (2023).

Results

1) Abundance index based on CPUE model

The CPUE index had a decreasing trend from 1983 to 2011, an increasing trend up to 2020, and a stabilization in the last three years (Table 1 and Figure 1). The current index level is similar to one in the year 2001. The updated index was consistent with indices used in the 5 previous stock assessments (Figure 2). The 2022 estimation was corrected with the update index, this is because the previous estimations used preliminary data.

Table. Abundance index, standard deviation and sample size.

Year	CPUEstd	Std	Sample Size
1983	0.832511	1.014857	6332
1984	0.773283	1.01526	6040
1985	0.683086	1.014817	7445
1986	0.580729	1.014354	8672
1987	0.689339	1.014442	8821
1988	0.611525	1.014546	8880
1989	0.601458	1.01457	9387
1990	0.52042	1.013787	10277
1991	0.57973	1.014097	9816
1992	0.536299	1.014625	7686
1993	0.485524	1.014809	7230
1994	0.527091	1.014637	8196
1995	0.475598	1.013977	9020
1996	0.474371	1.015921	6359
1997	0.392896	1.015666	7344
1998	0.337049	1.018988	3760
1999	0.34703	1.021805	2443
2000	0.33904	1.021924	2469
2001	0.407859	1.022052	2447
2002	0.35682	1.024005	1896
2003	0.317826	1.024012	2019
2004	0.346714	1.024347	1858
2005	0.318601	1.025846	1563
2006	0.349004	1.027096	1383
2007	0.263998	1.027365	1454
2008	0.175226	1.03588	811
2009	0.146733	1.032991	927
2010	0.114064	1.050089	357

2011	0.063785	1.044976	431
2012	0.196293	1.042445	487
2013	0.173813	1.043654	458
2014	0.138893	1.041671	508
2015	0.115264	1.063079	213
2016	0.209102	1.039171	574
2017	0.251121	1.039096	589
2018	0.163771	1.028519	1255
2019	0.282632	1.033175	864
2020	0.372555	1.035993	710
2021	0.396738	1.034647	760
2022	0.408789	1.031336	994
2023	0.41851	1.031636	972

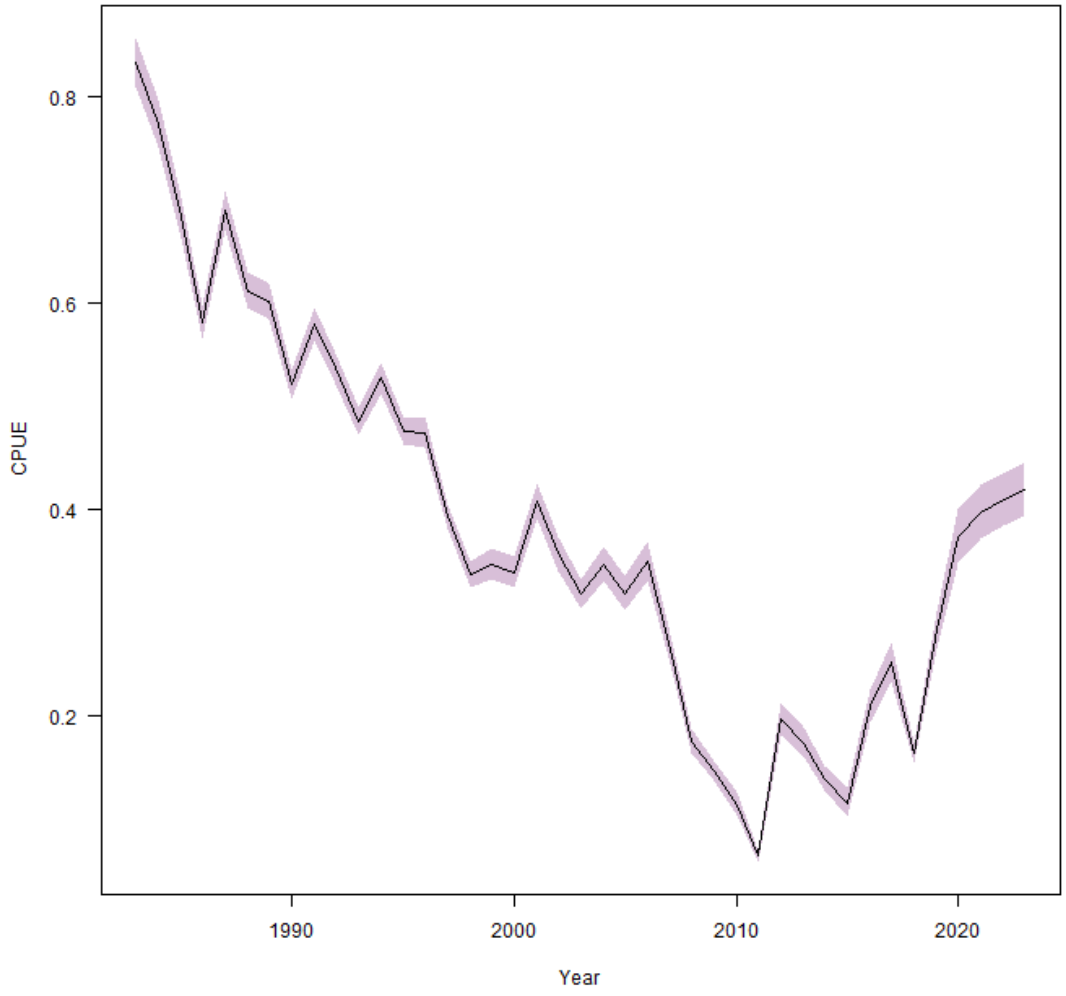

Figure 1. Abundance index based on CPUE model with 95%CI bands.

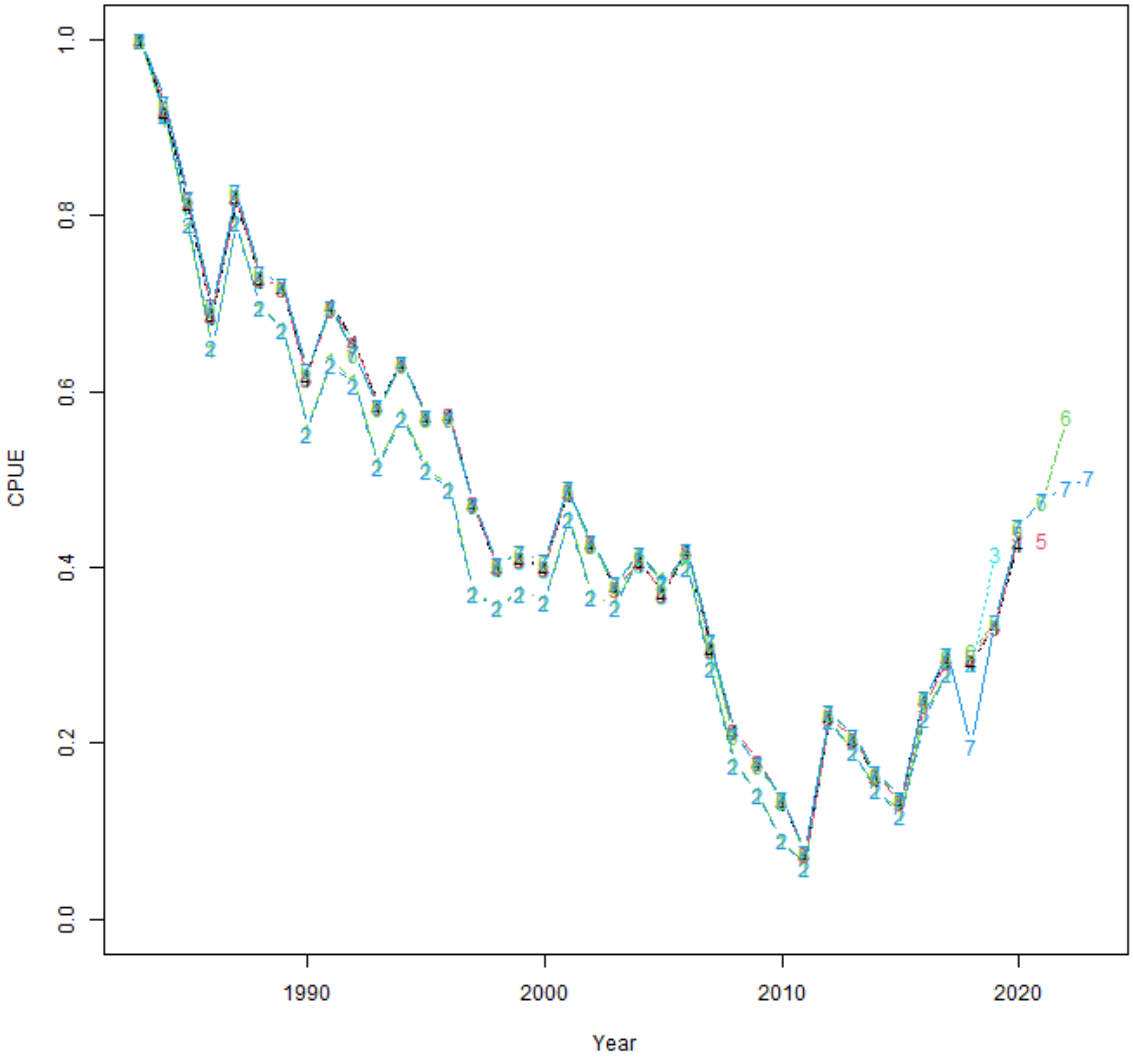

Figure 2. Abundance index (relative to 1983) based on CPUE model updated up to June 2023 and the same index used in the 5 previous stock assessments.

2) Abundance index based on catch model

The index based on the Catch model was similar to the one based on the CPUE model (Figure 3).

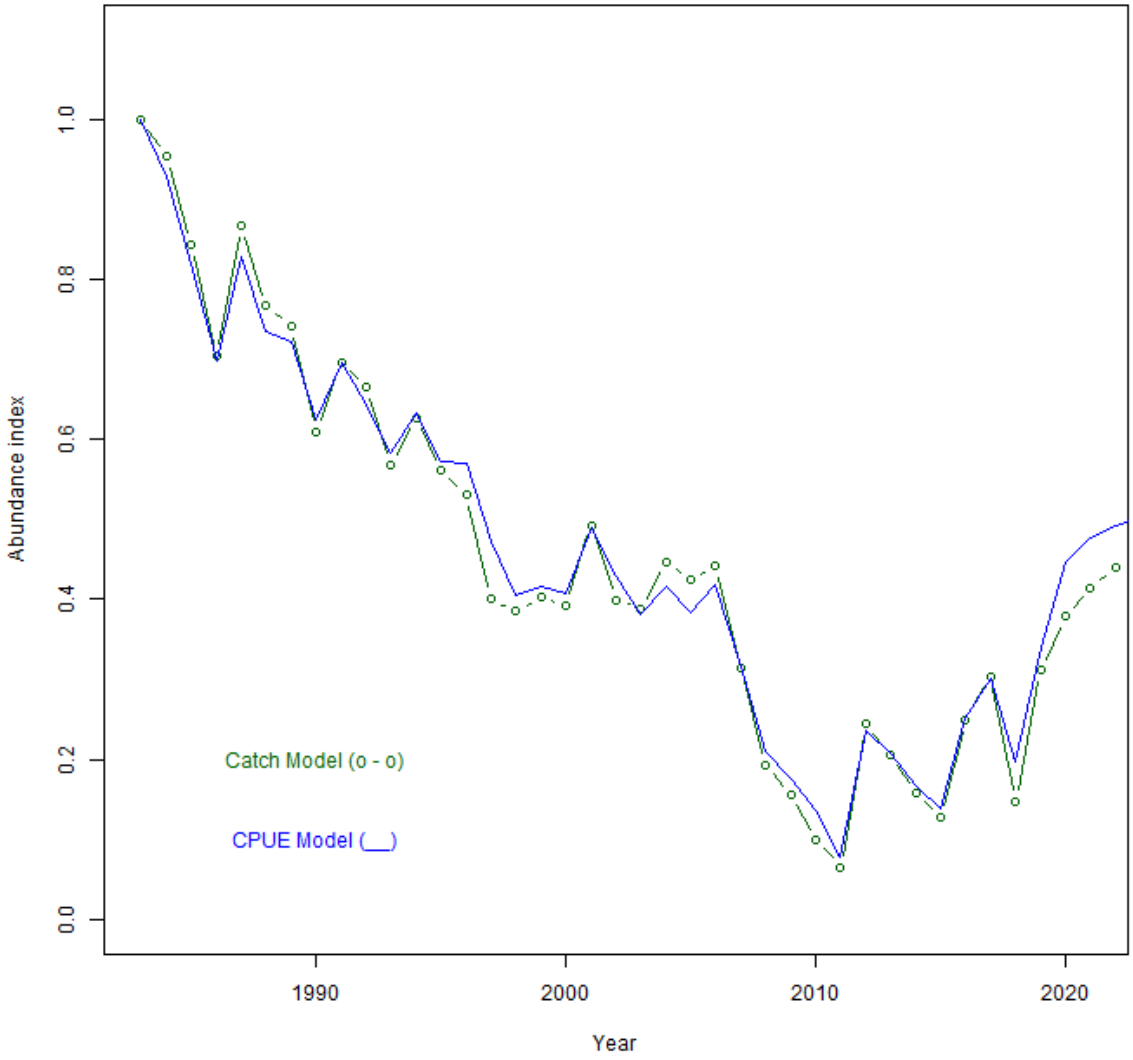

Figure 3. Abundance indices (relative to 1983) estimated using the CPUE model and the catch model.

3) CPUE index and hydroacoustic surveys in south-central Chile

There have been important changes in acoustic survey sampling designs to follow the changes in fish distributions (Figure 4). During the last two surveys, the fish were found concentrated very close to the coast.

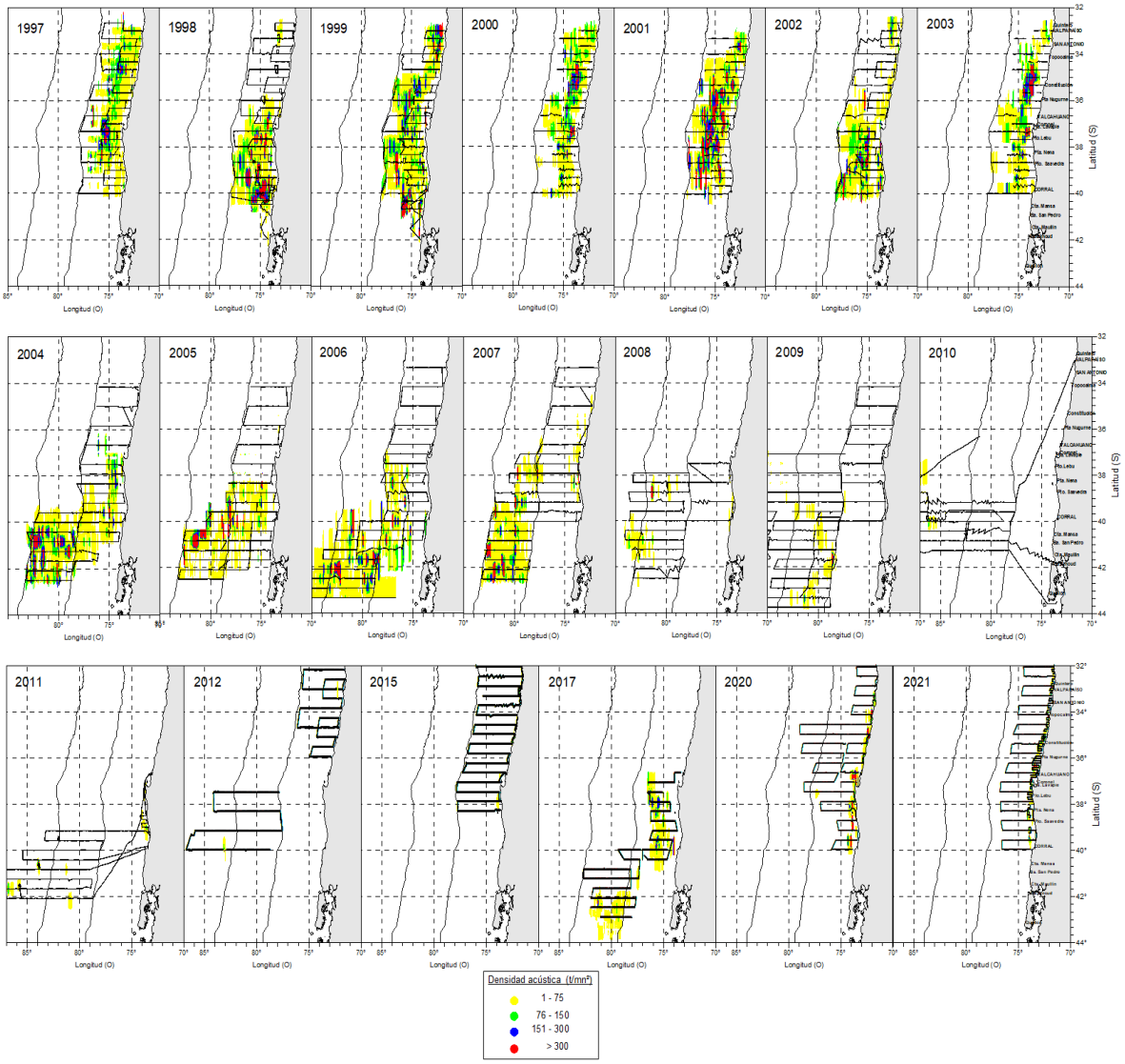

Figure 4. Spatial distribution of Jack Mackerel acoustic density (t/mn^2) by south latitude (Latitud (S)) and west longitude (Longitud (O)) and survey sampling design (track lines) in the Chilean south-central zone (taken from Catasti and Cordoba 2022).

The acoustic biomass showed a decrease in the two years which is contrary the CPUE index trend (Figure 5). Taking into account the whole time series (both series used and not used in the jjm model), these indices were not linearly correlated. A preliminary model suggests the CPUE index is independent of the biomass until a biomass threshold, and when biomass is lower than this threshold the CPUE index is proportional to biomass (Figure 6).

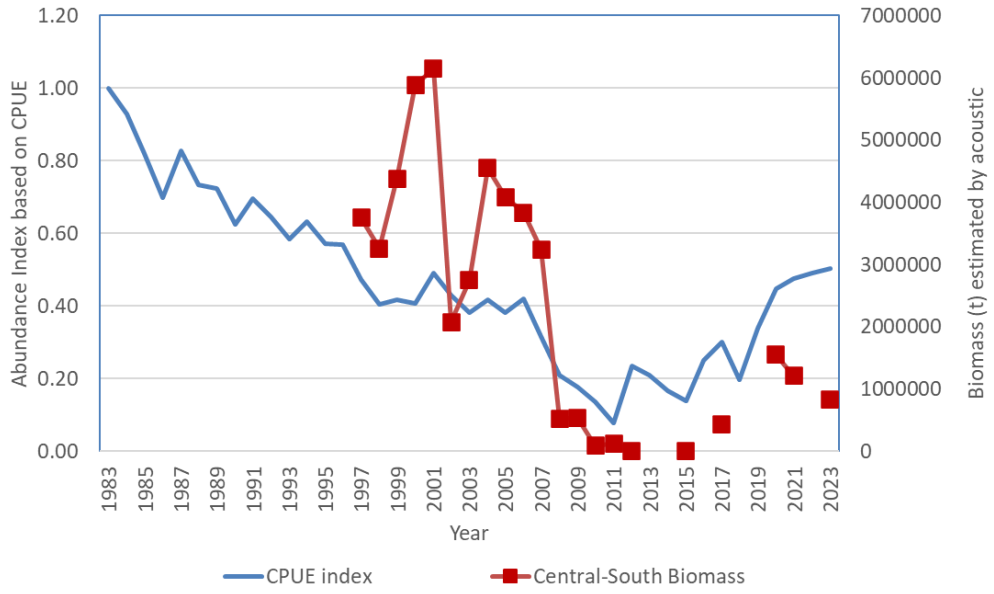

Figure 5. Abundance index based on CPUE and acoustic biomass estimated in the central-south area.

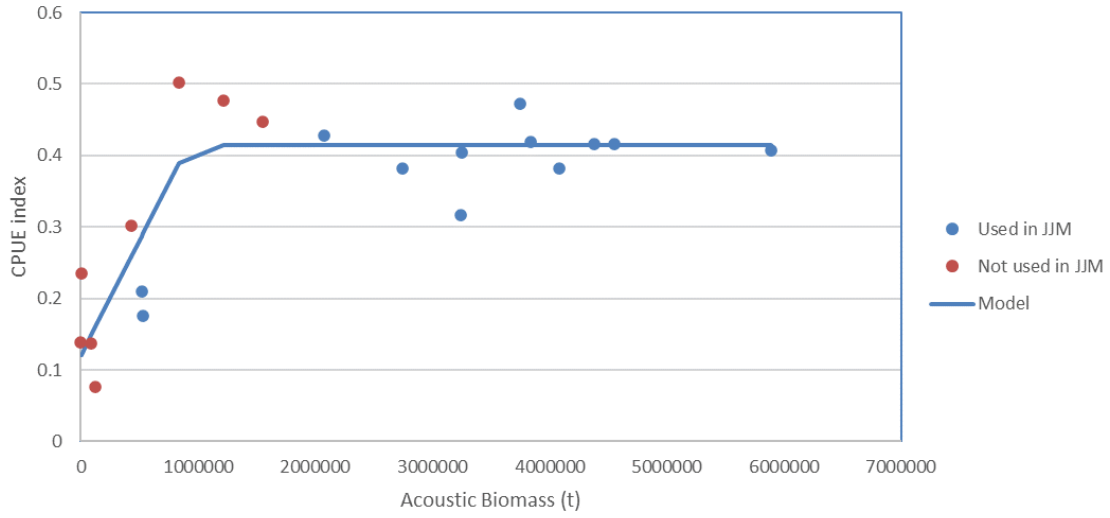

Figure 6. Ramp model for abundance index based on CPUE and acoustic biomass estimated in the central-south area.

The acoustic density in the last three years was very high, with the maximum historical figure in year 2023 (Figure 7). The CPUE index tends to increase with the acoustic density until reaches an asymptotic level, which corresponds to the last three-year data (Figure 8).

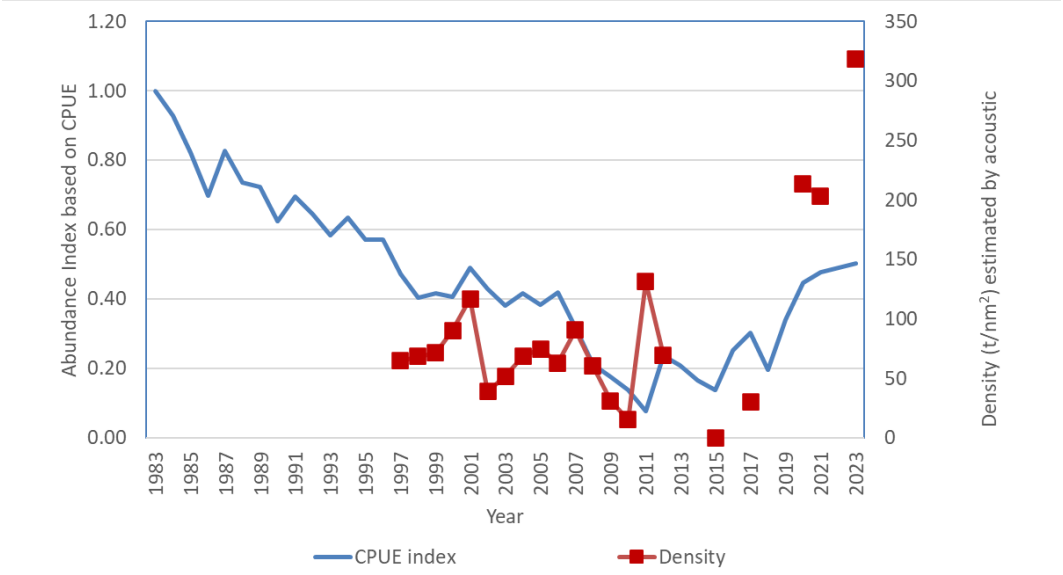

Figure 7. Abundance index based on CPUE and density estimated by acoustic surveys in the central-south area.

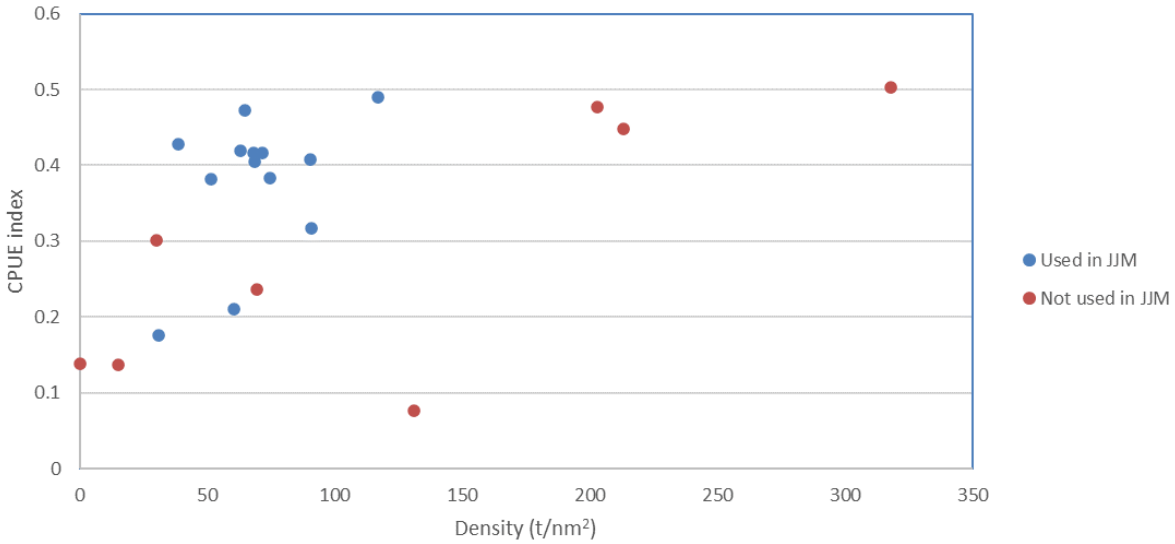

Figure 8. Abundance index based on CPUE and density estimated by acoustic surveys in the central-south area.

The area covered by fish in the last two years was very small compared to the area covered in the 1997-2006 years, and had a decreasing trend in the last 3 years (Figure 9). The CPUE index seems to be proportional to the area covered by the fish except for the last two years (Figure 10).

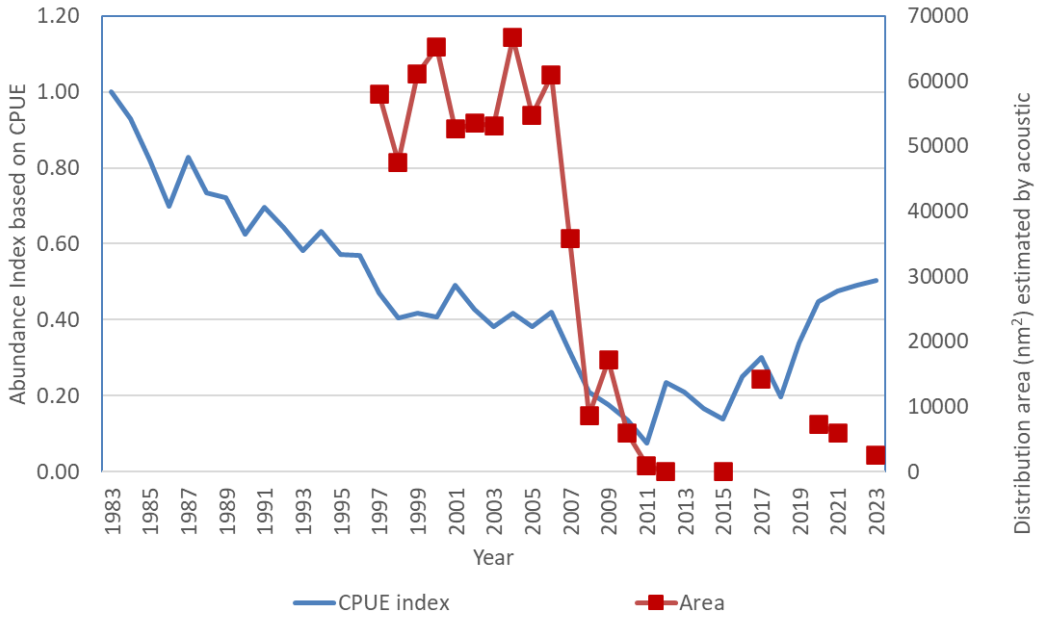

Figure 9. Abundance index based on CPUE and distribution area estimated by acoustic surveys in the central-south area.

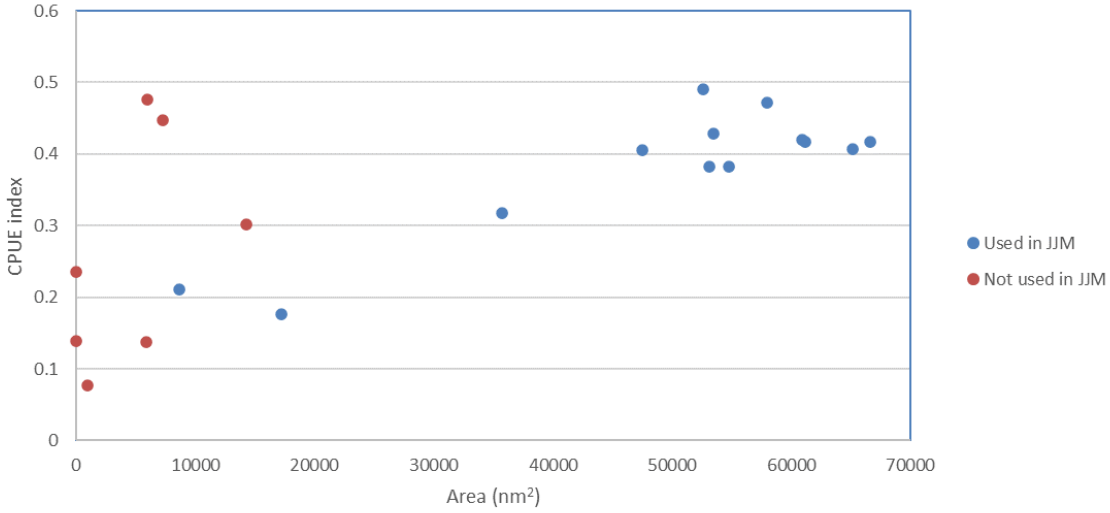

Figure 10. Abundance index based on CPUE and distribution area estimated by acoustic surveys in the south-central area.

There is a relationship between the CPUE index and area, excluding the last three years, which is proposed to correct the CPUE index (Figure 10). Although no acoustic survey was done in 2022, commercial catch distributions showed that fish was concentrated close to the coast during 2022 (Figure 12), and therefore, the area 2021 was assumed for area 2022. This correction reduced the recovery rate in the last three years (Figure 13 and table 1).

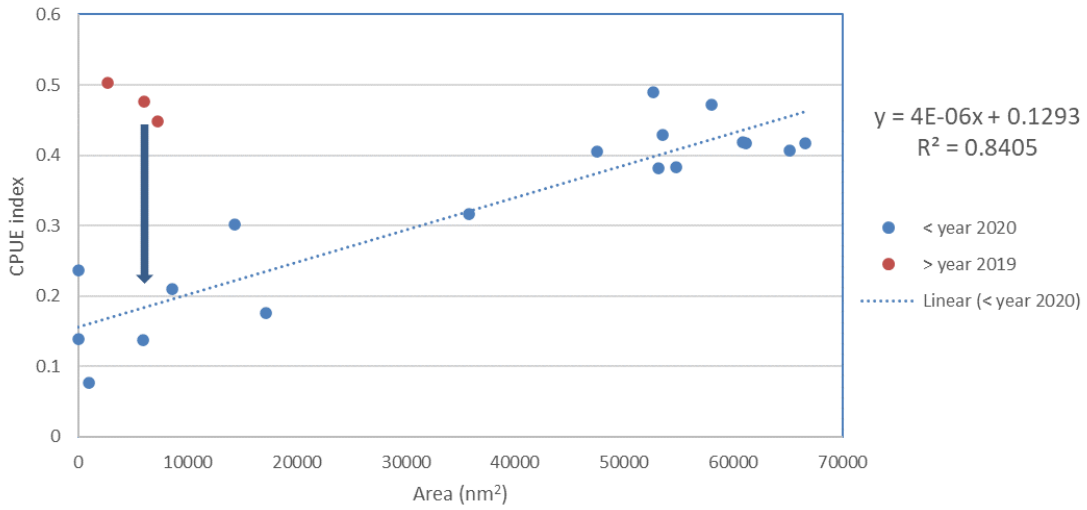

Figure 11. Linear relationship between CPUE index and distribution area estimated by acoustic fitted excluding the last two years, and correction proposed for the last two-year CPUE index.

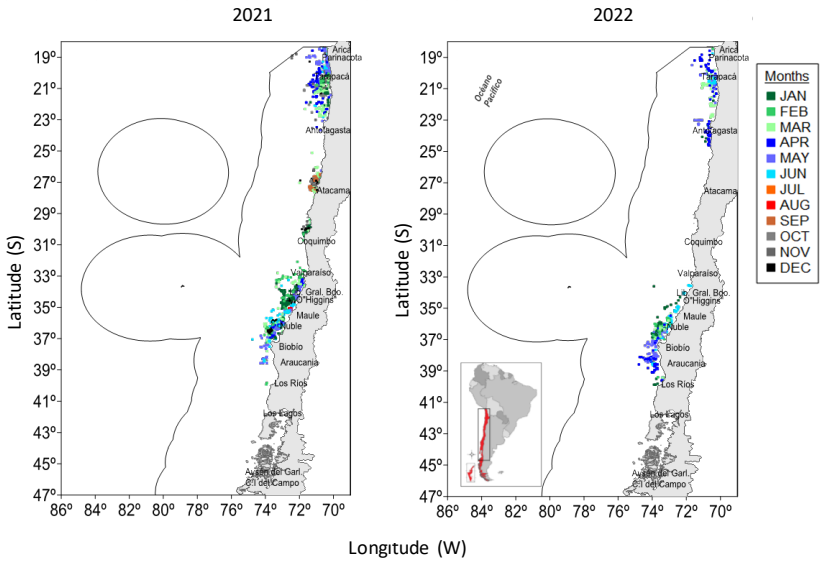

Figure 12. Jack mackerel commercial catch distributions by month during 2021 (left) and 2022 up to June (right). The 200 nm EEZ borders are shown by lines (figure provided by Karen Walker, IFOP).

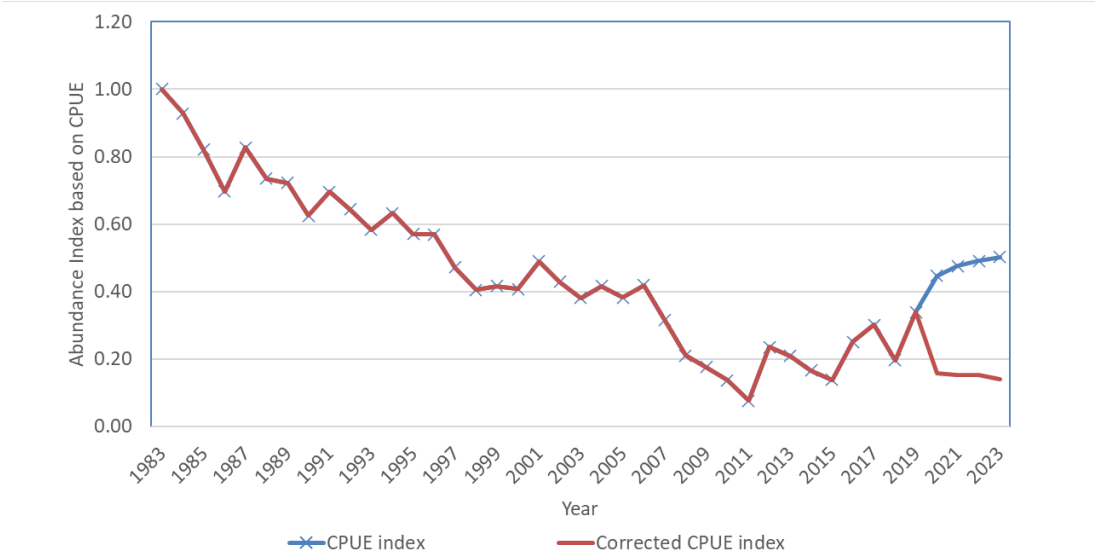

Figure 13. CPUE index and corrected CPUE index.

Table 1. CPUE index (relative to 1983) and corrected CPUE index.

Year	CPUE index	Corrected CPUE index
1983	1.00	1.00
1984	0.93	0.93
1985	0.82	0.82
1986	0.70	0.70
1987	0.83	0.83
1988	0.73	0.73
1989	0.72	0.72
1990	0.63	0.63
1991	0.70	0.70
1992	0.64	0.64
1993	0.58	0.58
1994	0.63	0.63
1995	0.57	0.57
1996	0.57	0.57
1997	0.47	0.47
1998	0.40	0.40
1999	0.42	0.42
2000	0.41	0.41
2001	0.49	0.49
2002	0.43	0.43

2003	0.38	0.38
2004	0.42	0.42
2005	0.38	0.38
2006	0.42	0.42
2007	0.32	0.32
2008	0.21	0.21
2009	0.18	0.18
2010	0.14	0.14
2011	0.08	0.08
2012	0.24	0.24
2013	0.21	0.21
2014	0.17	0.17
2015	0.14	0.14
2016	0.25	0.25
2017	0.30	0.30
2018	0.20	0.20
2019	0.34	0.34
2020	0.45	0.16
2021	0.48	0.15
2022	0.49	0.15
2023	0.50	0.14

Discussion

The current CPUE index figures are similar to the figures estimated for the late nineties, suggesting that the stock could be in similar conditions, however, the acoustic surveys show that density and fish distribution are quite different, therefore the CPUE could be overestimating the fish recovery rate. The procedure proposed is a first attempt to correct CPUE index using acoustic survey results, and has several limitations related with the changes in the sample design of the acoustic surveys. The surveys designs were adapted to try to cope with fish distribution changes though years. However, the acoustic surveys seem to be informative about densities and distribution area and show that fish condition in the middle of nineties was very different to the current conditions.

The relationships found between CPUE index and acoustic results are valid for the south-center zone only, and they should not be extrapolated for northern area and/or for the whole stock. The acoustic surveys conducted in the north since the year 2019 have shown an increasing trend in the biomass (Figure 14) and a stabilization in the distribution area (Figure 15). Therefore, the biomass decrease in the south was compensated by the biomass increase in the north, resulting in stable biomass. Further analyses are needed for the north zone, where to understand CPUE is more difficult because it is mainly based on bycatch of small pelagic fisheries.

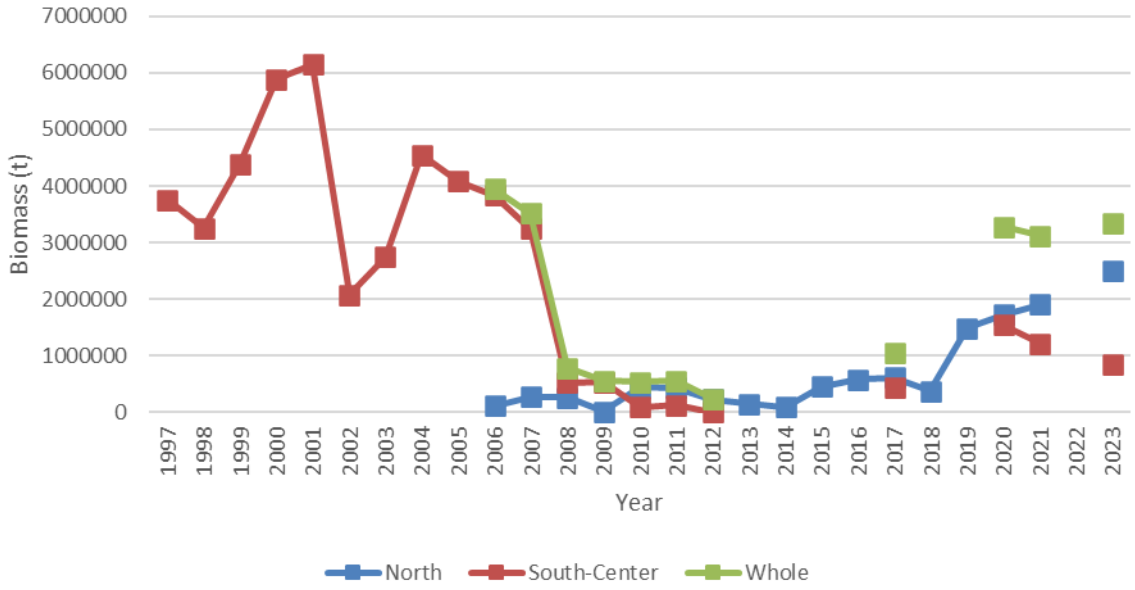

Figure 14. Biomass estimated by acoustic surveys by zone and whole. The whole biomass was calculated for those years with surveys in both zones only.

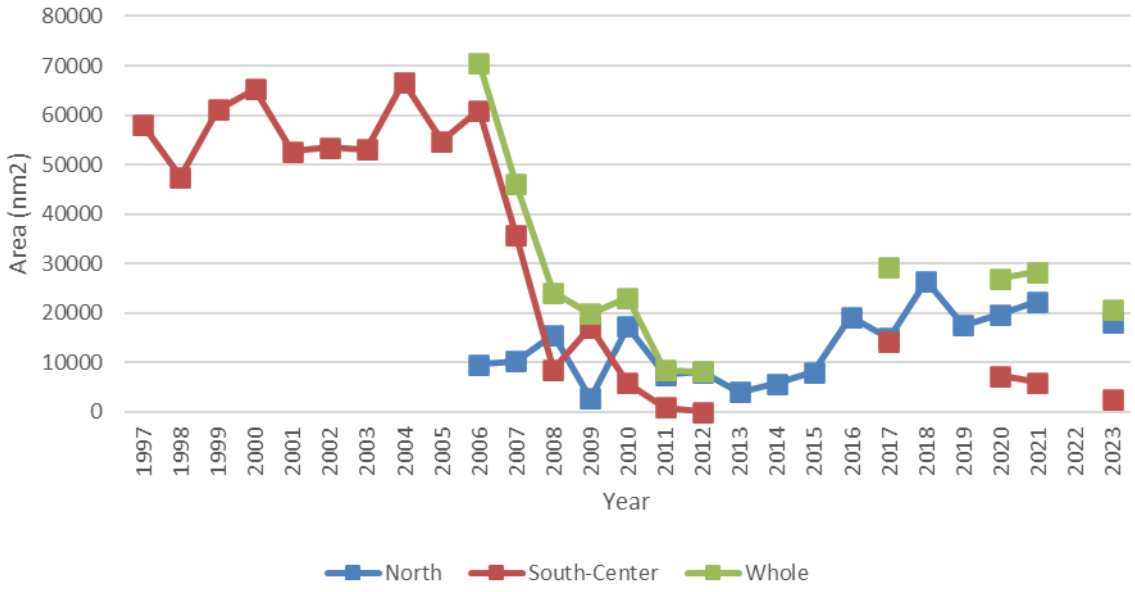

Figure 15. Fish distribution area by zone and whole. The whole area was calculated for those years with surveys in both zones only.

Conclusions

1) Abundance index based on the CPUE model and index based on the catch model were very similar, therefore, the use of vessel hold capacity in both independent and dependent variables seems to have no effects.
2) The CPUE index had an important recovery trend, however, the fish is highly concentrated close to the coast.
3) The CPUE index had a stabilization in the last three years.
4) The CPUE index could be affected by the high increase in fish concentration close to the coast.
5) It is recommended to have a precautionary approach when using the CPUE index because it seems to overestimate the stock recovery.
6) A linear relationship between the CPUE index and distribution area is proposed to correct the last three years of the CPUE index.

Reference

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