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Assessing the Sardine Multispecies Fishery of the Gulf of California

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***Abstract*— *In the fishery of small pelagics at the Gulf of California, the South American pilchard Sardinops sagax (Jenyns, 1842) is the main target. In the years when the abundance of this species is poor and its catches are low, the fishery is diverted into other species such as the Pacific thread herring (Opisthonema libertate (Günter)), and the Pacific anchoveta (Cetengraulis mysticetus (Günter)). Since the 90s, the anchoveta (Engraulis mordax) appeared in the catch records and later on, other species of lesser importance appeared such as the mackerel (Scomberomorus sierra (Jordan & Starks)), the red eye-round herring (Etrumeus teres (DeKay)) and the shortjaw leatherjacket (Oligoplites refulgens Gilbert & Starks). When this fishery was analyzed by species, it was found that, although it is a very profitable activity, there is not a management strategy, leading it to the risk of overexploitation, as the maximum yield level of the target species (the South American pilchard), corresponds to levels of fishing mortality in which the other species of the group are depleted. It was found that there is a substitution of the dominant species over time, because at the beginning of this century the South American pilchard was the target species whilst in 2014 it was the Pacific thread herring. Therefore, this work is focused to the analysis of each species of the fishery, intending to derive recommendations for its management within a sustainable framework.*

***Keywords*— Stock assessment; Sardine fishery; Gulf of California; South American pilchard; Pacific thread herring; anchovy.**

I. INTRODUCTION

The fishery of small pelagic fish at the Gulf of California, began in the late 1960s. It is a relevant economic activity in the region, representing around 30% of the Mexican total catch; it has the most important fishing fleet fleet and industrial plant of its kind in the country. The fishing takes place all year round (Nevárez-Martínez et al., 2006), and landings are characterized by wide fluctuations (Lluch-Cota et al., 1999). After a rapid initial growth, the fishery was over exploited between 1989 and 1993. It was coincident with a period of adverse environmental conditions, so environmental variables and a short life-span, play a dominant role in the processes leading to dramatic changes in abundance, evidenced in the wide range of the catch over the historical catch records (Lluch-Belda et al., 1986; Nevárez-Martínez et al., 2001). During the years when the abundance of sardine is poor and therefore its catches are low, landings are complemented to some extent with the catch of other species, such as the Pacific thread herring (Lluch-Belda et al., 1989). In addition, and since the 90s, the anchoveta, appeared in the catch records (Cisneros-Mata et al., 1991). Subsequently, other species with lesser importance have been caught, becoming a part of the fishery as nowadays, such as the mackerel, red eye-round herring, and the shortjaw leatherjacket. The status of the South American pilchard fishery in the Gulf of California was evaluated in recent years by Chávez & Chávez-Hidalgo (2013), finding that the fishery is reasonably stable and profitable activity, recommending the application of a fishing effort ranging between 4,000 and 6,000 fishing days per season, to ensure a stable activity.

The goal of this paper is to carry-on a stock assessment of the fishery from the biological point of view in a multi-specific context, using the FISMO model (acronym of Fisheries Simulation Model; Chávez, 2005, 2014), which analyzes the status of these species according to the exploitation over 15 years of catch records (2000-2014). It allows diagnosing the fishery with respect to the target species and suggests changes for the management of this and the other species caught with the South American pilchard (Pacific tread herring, Pacific anchoveta, anchoveta, mackerel, red eye-round herring, and the shortjaw leatherjacket) in the fishery of smaller pelagics of the Gulf of California (Fig. 1).

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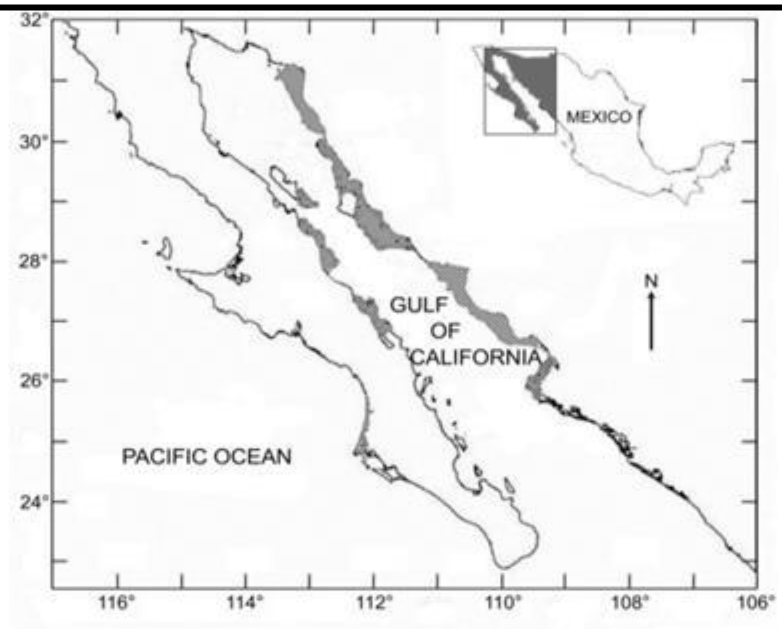

Fig. 1. The Gulf of California, Mexico. The fishing ground where the sardine and other species are exploited is indicated (Chávez & Chávez-Hidalgo, 2013)

II. MATERIALS AND METHODS

FISMO. The simulation model works with catch data and the population parameter values, using equations commonly applied in the evaluation of fisheries. The catch data and biological parameters of each species are used as input of each model (Chávez, 2005, 2014); it converts catch data into number of individuals per age group; analyzes the age structure over time and then applies the catch equation for assessing the stock. With these results, a diagnosis is made of the status of each exploited stock, as an effect of fishing mortality on recruitment rate, biomass and catches. After obtaining these results, a comparison is made between the catches and biomasses of each species analyzed in this paper, with the South American pilchard, which is the target species of the fishery.

Population parameter values. For the evaluation of each population it was necessary to transform the weights of individuals of each age to their corresponding numbers, with the aid of the von Bertalanffy growth equation and the length-weight relationship. This allowed applying the equations that describe natural mortality (*M*) and fishing mortality (*F*). The yield equation was applied to the data of each age expressed in weight. The correspondence between the number of one-year-old individuals and that of reproducers of the previous year is based on the estimation of the recruitment applied for each year of the catch data series, where the fitting of the values of the recorded and simulated catch were coincidental. The biological parameters values L_∞, W_∞, K, t_0, a and b, for each stock examined in this paper are shown in Table 1; they were obtained from the FishBase web page (Froese and Pauly, 2014)

Catch data. They were obtained from the CONAPESCA (2016) website, which contains the statistical information by species and entity of the years covered in this study. (Table 2).

Table 1. Biological parameter values of the seven target species, components of the sardine pelagic fishery of the Gulf of California (Source: Froese and Pauly, 2014). Where K = Growth rate, L_∞ = Asymptotic length, W_∞ = Asymptotic weight, tm = Age of first maturity, tc = Age of first catch, a = Condition factor, b = Coefficient of allometry.

Common Name	Scientific Name	von Bertalanffy growth Parameter values						Length-Weight	
		K	L_∞	W_∞	t_0	t_m	t_c	a	b
South Amer. pilchard	*Sardinops sagax*[1]	0.45	31.0	206	-0.17	1	1	0.0049	3.100

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Pacif. thread herring	*Opistonema libertate*[2]	0.57	30.0	250	-0.29	2	1	0.009	2.99
Pacific anchoveta	*Cetengraulis mysticetus*[3]	1.35	18.0	66	0.10	1	1	0.0035	3.404
Anchoveta	*Engraulis mordax*[4]	0.44	18.7	661	-0.5	2	2	0.117	2.95
Mackerel	*Scomber japonicus*[5]	0.22	51.7	1493	-0.66	3.1	2	0.007	3.11
Red-eye round herring	*Etrumeus teres*[6]	0.85	27.8	417	-0.9	0.9	1	0.0065	3.329
Shortjaw leatherjacket	*Oligoplites refulgens*[7]	0.7	26.3	344	-0.24	1.1	1	0.0189	3

[1] Froese and Pauly, 2014;
[2] Froese and Pauly, 2014; Jiménez Prado, 2004
[3] Froese and Pauly, 2014; Love, 2005; Bayliff, 1969
[4] Froese and Pauly, 2014; Lamb, 1986;
[5] Froese and Pauly, 2014; Castro-Hernández, 2000

Diagnosis. The South American pilchard has been the main target of the sardine fishery of the Gulf of California; however, it reduced its participation in landings, from 70% in the year 2000, to 14% in 2014. There has been a significant reduction in landing volumes, which during the last three years are below 100,000 t. The status of the catch in the study period is based on the comparison of the exploitation rate (*E*) and fishing mortality (*F*) with respect to the values of these two variables at the level of maximum yield (E_{MSY} and F_{MSY}) respectively, also known as limit reference points. According to this idea, in each year of the analysis, the estimated value of each variable with respect to *E* and *F*, which oscillate in parallel over time, is a reference to know when the resource is underexploited or overexploited. In underexploited populations, the values of these two variables are lower than the limit reference points and they attain higher values than the reference points when the stock is overexploited.

Potential yield. The model Fismo contains an application that with the data of the parameters of the population under study, plus the catch data, allows determining the levels of potential yield for each age of first capture as a function of *F*. The resulting values describe parabolic type curves of the capture, based on the scale of *F* values, which are displayed in the range between 0.1 and 1. In most cases, these curves reach a maximum value, which corresponds to the level of Maximum Sustainable Yield (F_{MSY}), and then decline again. This maximum is known as a limit reference point and in some countries is usually adopted as the objective for the fisheries management, although it has the drawback of being the threshold of overfishing and therefore its adoption is not recommended; for this reason, it is recommended instead, the adoption of some lower value of *F* (eg. $F_{Target} = 0.9F_{MSY}$), as a management goal.

III. RESULTS

Although the South American pilchard is the target species of the fishery, in some years it is replaced in catches by the Pacific thread herring (Fig. 2); for instance, in the year 2000, the South American Pilchard represented 70% of the total catch, leaving 30% to the rest of the species. In that year the Pacific thread herring represented only 5% of the catch, being surpassed by the mackerel with 12%. In contrast, in 2014 this species replacement was evident, observing that 51% of the catch belonged to the South American pilchard, followed by the Pacific thread herring and the Anchovy with 17% and 12% respectively (Table 2). The same phenomenon was observed in the catches of 1973, 1977, 1992, 1993 and 1998, years prior to the period covered by this study. However, despite this phenomenon, in the average of total catches from 2000 to 2014, the South American Pilchard represents 42%, followed by the Pacific thread herring and the Anchoveta with 30% and 16% respectively.

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Table 2. Catch data (t) by species and year landed in Topolobampo, Guaymas and Mazatlán, on the eastern coast of the Gulf of California (CONAPESCA, 2016).

Year	South Amer. pilchard	Pac. thread herring	Pacific anchoveta	Anchoveta	Mackerel	Red-eye round herring	Shortjaw leatherjacket
2000	190,862	13,003	25,229	4,493	34,240	345	4,741
2001	220,360	4,493	112,954	78	13,003	270	277
2002	198,757	6,992	78,261	2,853	4,493	4,889	890
2003	102,034	25,507	7,682	1,100	6,992	8,858	3,309
2004	94,559	32,943	63,253	5,717	25,507	4,683	5,494
2005	133,567	13,191	38,031	7,354	32,943	7,178	4,233
2006	143,805	123,939	110,327	40,035	12,660	5,723	2,290
2007	249,856	182,456	23,007	2,731	6,911	3,055	1,084
2008	525,637	103,504	31,978	8,093	6,428	958	-
2009	496,572	133,574	13,277	2,413	893	422	243
2010	225,722	172,728	11,540	5,655	12,873	8,475	641
2011	136,242	169,583	98,211	83,330	33,409	843	2,213
2012	84,790	114,115	256,299	64,118	39,980	1,658	562
2013	74,875	224,293	170,032	116,857	22,040	13,193	5,263
2014	81,832	242,031	58,327	38,389	35,436	7,158	10,866

Catch data proceed from the fishing charts of CONAPESCA (2017) referred to the states of Sonora and Sinaloa, as well as the statistical reports by species and entity.

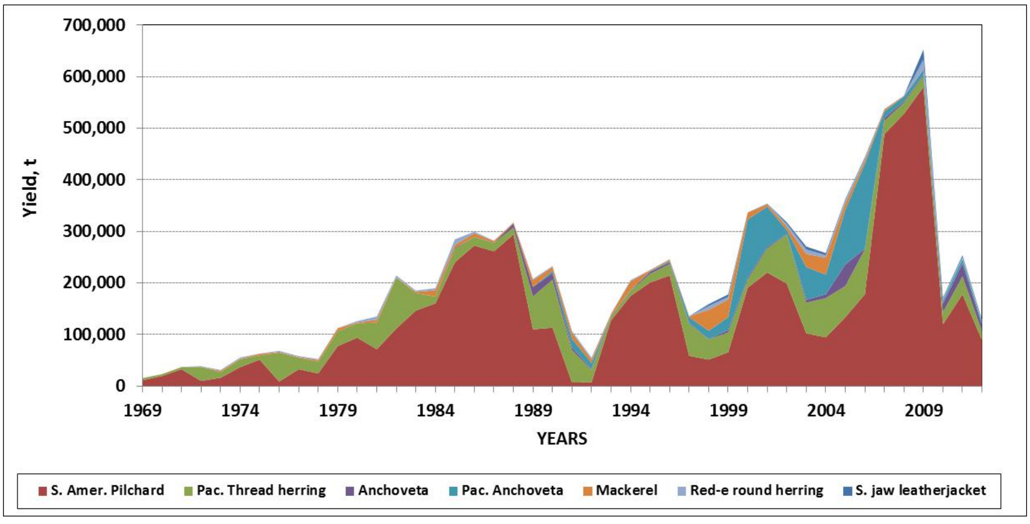

Fig. 2. Catch data of the sardine fishery of the Gulf of California since the beginning of the fishery, including all the seven exploited species (CONAPESCA, 2017).

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South American pilchard (sardina Monterrey)

Stock assessment. The catch describes an oscillatory trend, where catches range between 100,000 and 200,000 t, with a remarkable increase exceeding 500,000 t during the years 2007 - 2009, falling again during the following five years (Fig. 3). Biomass also describes an oscillatory trend, which apparently shows the effect of the intensity of the fishing pressure, since it varies in an opposite direction with two maxima, the first in 2006 and 2007 and the last in 2014, when the biomass amounts to 1.8 million tons in both cases.

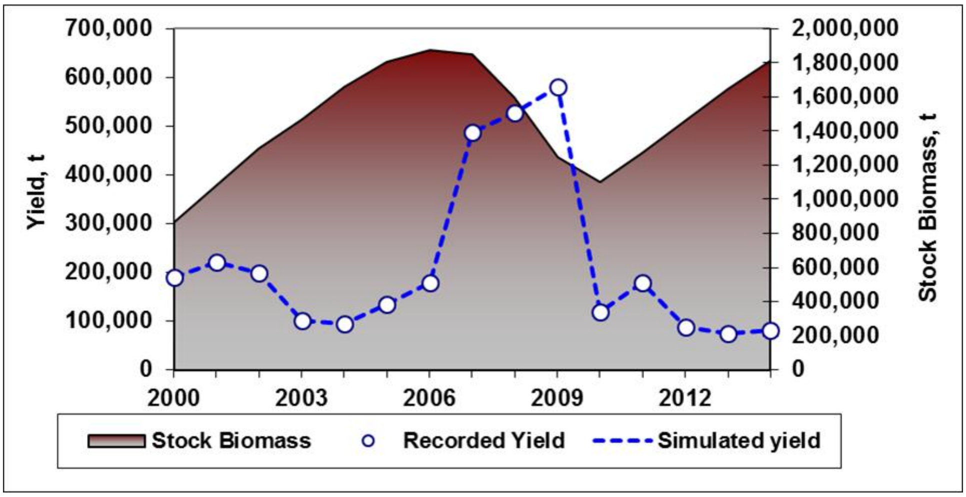

Fig. 3. Trends of biomass and catch (recorded and estimated) of the South American pilchard.

Diagnosis. The stock of South American pilchard was underexploited during the entire period of analysis, except in 2009 (Fig. 4), when it exceeded the values of E_{MSY} and F_{MSY}. It is striking to observe that during the years 2010 to 2012, the catch per fishing day was above 20 t (Chávez & Chávez-Hidalgo 2013), which is consistent with the trend indicated in figure 4 in the sense that the population was underexploited in those years. Then, it will be necessary to look for the most probable cause that may explain the decrease in catches of the most recent years with respect to the previous years.

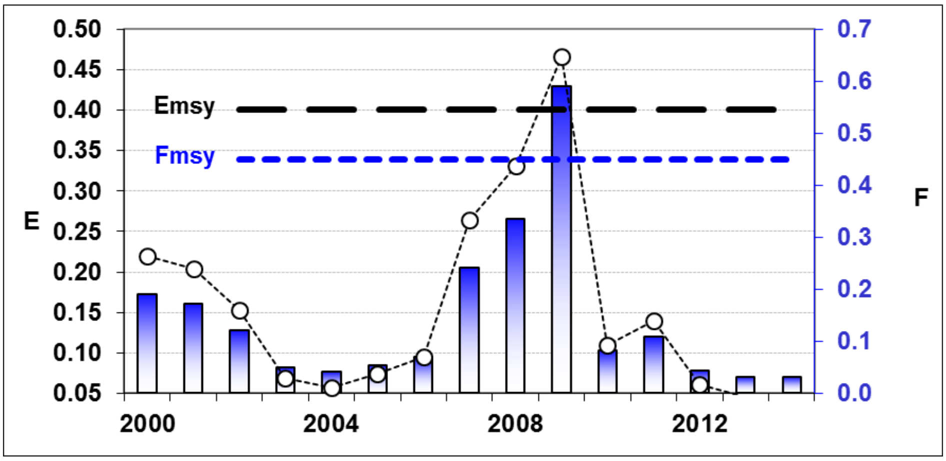

Fig. 4. Diagnosis of the South American pilchard contrasting the exploitation rate E with the fishing mortality F.

Potential yield. According to the above, the potential yield of the South American pilchard reaches a potential maximum yield of 318,000 t with F = 0.35, and an age of first capture of *tc* = 1. These maximum corresponds to a biomass of 7 million t (Fig. 5A). By increasing the *tc* values of 1 year, which is the current one to 5 years and increasing the fishing intensity to *F* = 0.45 (Fig. 5B), the potential yield may increase to 800,000 t. Given that the longevity estimated by the model, as 3/k is seven years, it is not considered prudent to do more tests with higher ages of *tc*, because of the risk of incurring in some possible error that could overestimate the biomass and the capture.

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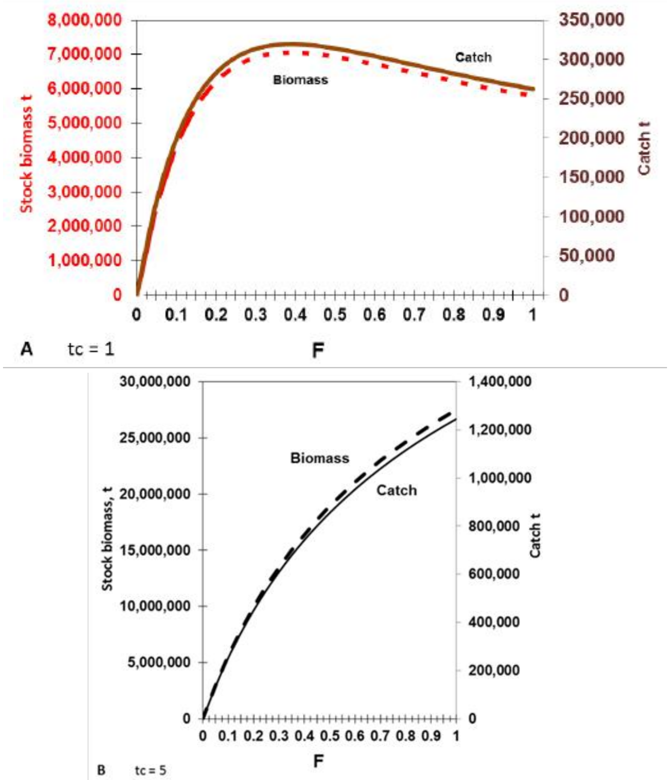

Fig. 5. Potential biomass and potential the catch of South American pilchard. A. Age of first capture of 1 year; B. Age of first capture of 5 years.

Pacific thread herring (sardina crinuda)

It represents the second most important species of the fishery; the most reported catch landings of this stock are from the state of Sinaloa, specifically in the port of Mazatlán.

Stock assessment. The catch describes an oscillatory trend in which catches range between 5,000 and 15,000 t, with two remarkable increases, the first in 2003-2004 from 25,000 to almost 33,000 t and the second from 2011 to 2014, ranging from 21,000 to 40,000 t (Fig. 6). The biomass also shows an oscillatory trend that apparently reacts inversely to the fishing pressure, increasing in 2010 to more than 120,000 t, one year after the minimum catch occurred, decreasing first in 2005 and later in 2013.

Diagnosis. The catch of the Pacific thread herring displays an oscillatory trend, ranging from underexploited to overexploited condition (Fig. 7); in the years 2001 and 2002 and from 2005 to 2010, the stock was underexploited; in 2003 and 2004 and from the years 2011 to 2014, it was overexploited.

Potential yield. The Pacific thread herring reaches its maximum potential yield with 35,998 t at $F = 0.75$, and an age of first capture of $tc = 1$. At this point, the stock biomass is 87,990 t (Fig. 8A). By increasing the age of first catch, from $tc = 1$ which is the current one to $tc = 3$, an increase of the F can be applied, from $F = 0.2$ to $F = 0.9$, then the potential yield may increase from 35,436 t to 64,000 t. The later corresponds to a biomass of 154,824 t (Fig. 8B). The longevity estimated by the model as $3/k$ is 5 years.

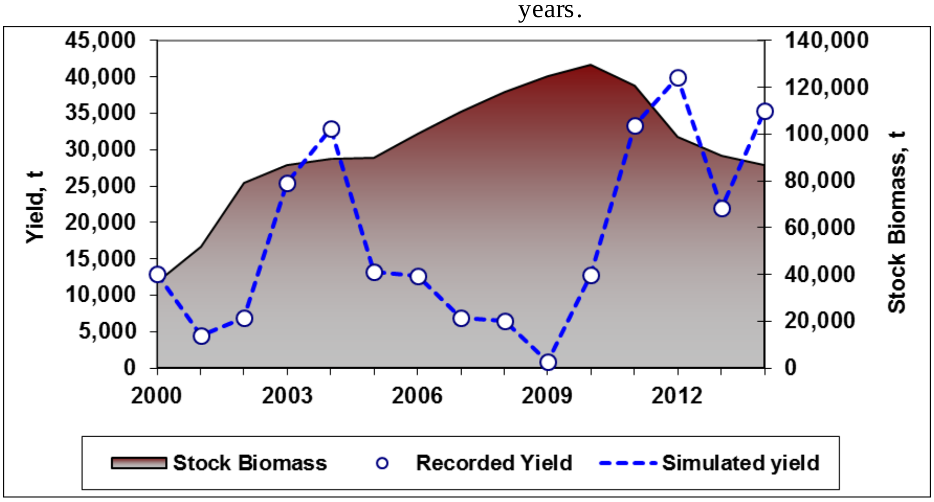

Fig. 6. Trends of biomass and catch (recorded and estimated) of the Pacific thread herring.

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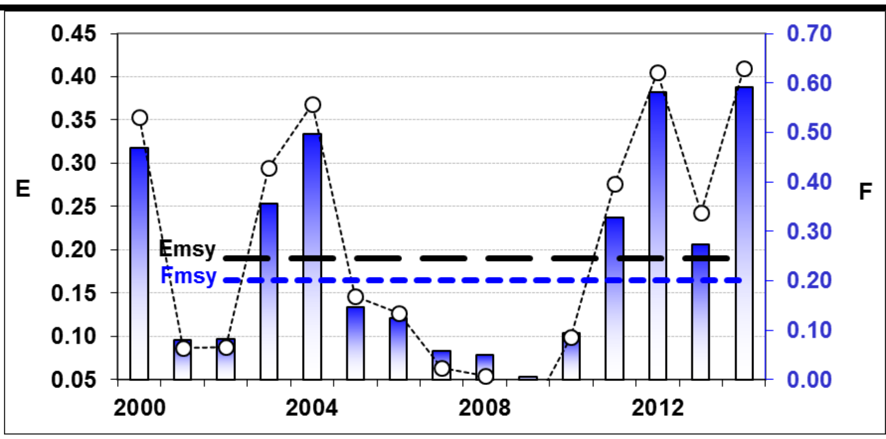
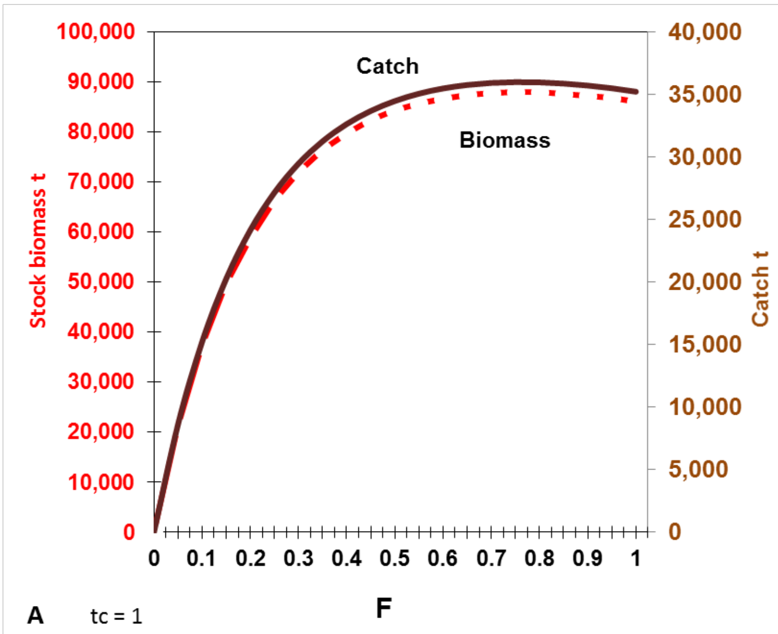


Fig. 7. Diagnosis of the Pacific thread herring, showing the trends of the exploitation rate E and the fishing mortality F.



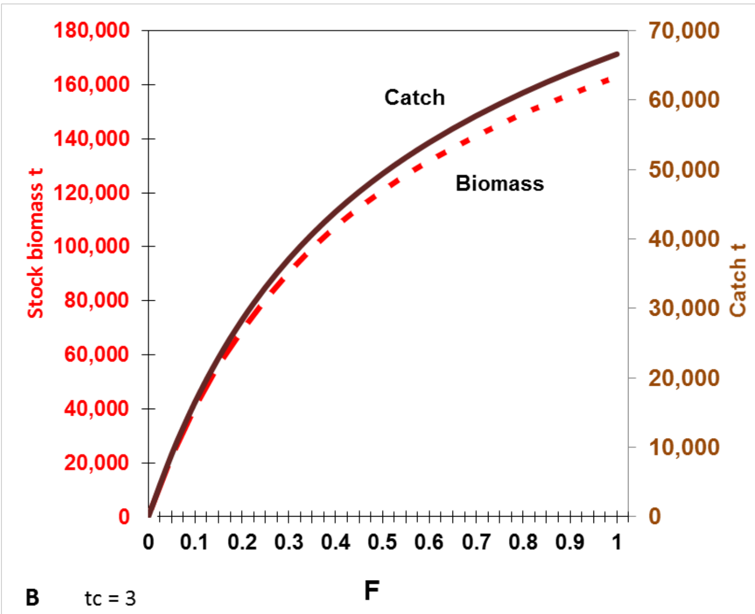


Fig. 8. Potential yield of the biomass and the capture of the Pacific thread herring. A. Age of first capture of 1 year; B. Age of first capture of 3 years.

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Pacific Anchoveta (sardina bocona)

This species, as well as the Pacific thread herring, are the main goals of the fishery by the fishing fleets of Sinaloa in the southern Gulf, specifically Mazatlán. Very low catches are recorded from Guaymas and Topolobampo, both in the state of Sonora.

Stock assessment. The catch evidences a trend where the catches range from 7,680 t in 2003, up to 250,300 t in 2013, this being the maximum yield recorded for this species, declining to 50,327 t in 2014. In general, the biomass describes a stable trend, above 1,080,000 t, except in 2012 when it decreases to 990,000 t (Fig. 9).

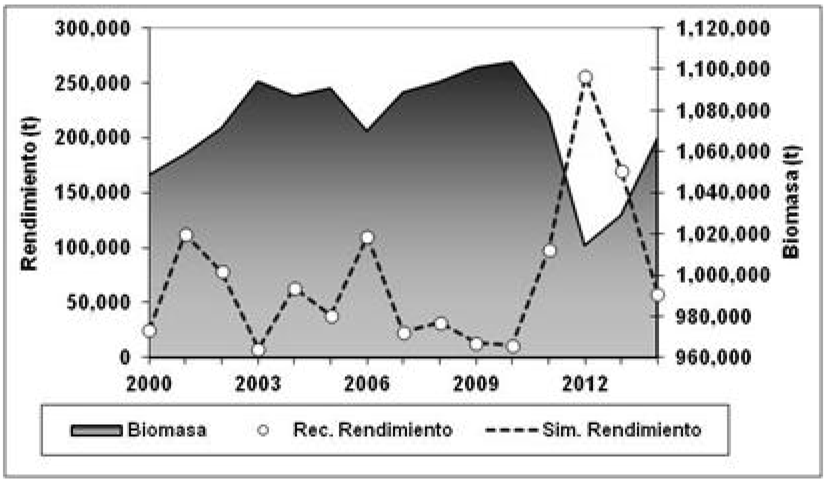

Fig. 9. Trends of biomass and catches (recorded and estimated) of the Pacific anchoveta in the sardine fishery of the Gulf of California.

Diagnosis. Due to the short life cycle of the species, the stock can recover its biomass in a short time and the E_{MSY} and F_{MSY} correspond to very high fishing intensity values. This does not necessarily mean that the species may withstand a higher effort for its capture, because it is likely to assume that the access to this stock may be simply unaffordable. According to the above, the population of the Pacific anchoveta was underexploited throughout the whole period of analysis (Fig. 10)

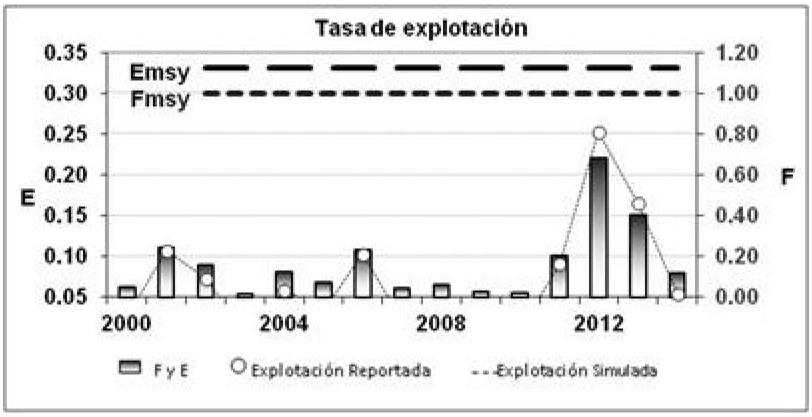

Fig. 10. Diagnosis of the catch of the Pacific anchoveta, showing the trends of the exploitation rate E and the fishing mortality F, in a condition where the stock is underexploited over the whole period of analysis.

Potential yield. The catch of the Pacific anchoveta reaches its maximum with the value of $F > 1$, that with an age of first capture of $tc = 1$, and a potential catch of 58,327 t may be obtained. It corresponds to a biomass of 1,067,833 t, which is reached with an $F = 0.117$ (Fig. 11) Since the longevity estimated by the model as $3/k$ is two years, it is not considered prudent to test higher ages of tc, so the potential maximum yield is 312,031 t and is reached with an $F = 1$.

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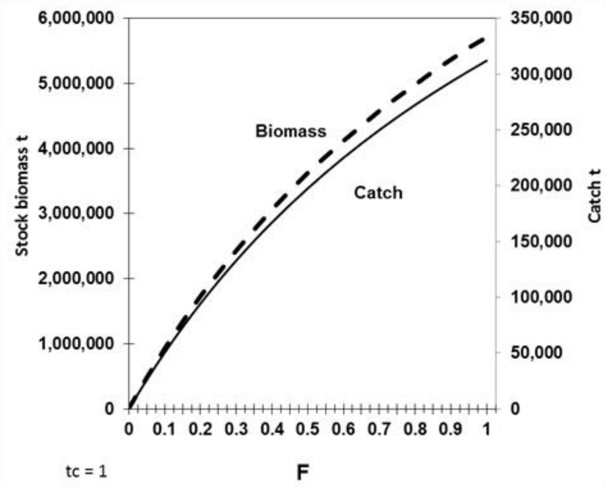

Fig. 11. Potential biomass and potential yield of the Pacific anchoveta. The age of first capture is tc = 1 year.

Mackerel (macarela)

The mackerel is a species with very low catches recorded. Just like the South American pilchard, the records of its capture are only from the northern Gulf ports in Sonora.

Stock assessment. The catch displays a cyclical catch trend (Fig. 12), where after some years of high catches, it is followed by some years when the landing data are very low. The maximum catch recorded in 2012 was 39,980 t, which is nonsignificant as compared to the yields of the South American pilchard. Because this is a long-lived species, it takes several years to recover its biomass after a severe overexploitation, explaining why it is highly sensitive to fishing pressure.

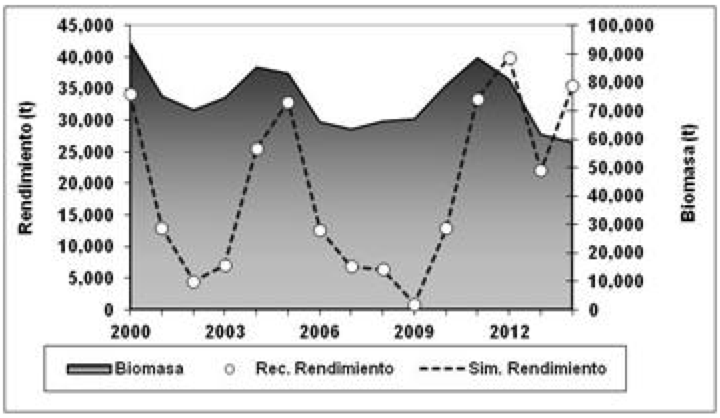

Fig. 12. Trends of biomass and catches (reported and calculated) of the mackerel in the sardine fishery of the Gulf of California.

Diagnosis. With an exploitation rate of E = 0.15 and a fishing mortality of F = 0.1, the maximum sustainable yield is easily attained (Fig. 13), so for seven years of the series, the mackerel was overfished, especially in 2014, a year when a fishing mortality of F = 0.5 was estimated and an exploitation rate of E = 0.55. By contrast, for the rest of the period it was underexploited.

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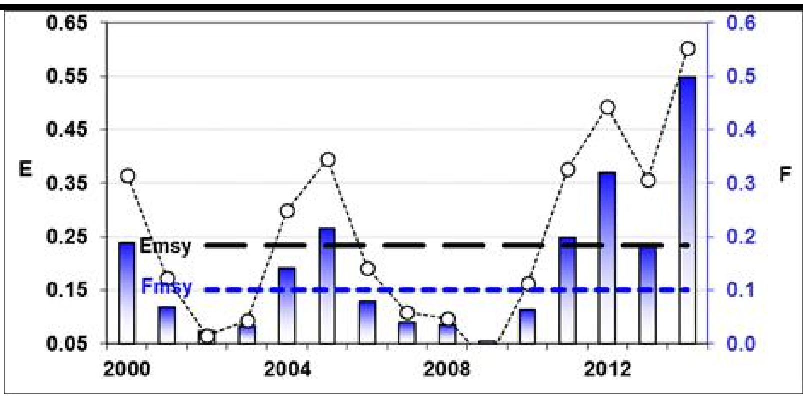

Fig. 13. Diagnosis of the mackerel stock, showing the trends of the exploitation rate E and the fishing mortality F.

Potential yield. The mackerel reaches its maximum potential yield of 75,000 t with F = 0.15, and a tc = 1; these values correspond to a biomass of 131,000 t (Fig. 14A). Given that the longevity estimated by the model as $3/k$ is fourteen years, allowing doing a trial with the age of tc = 6 years. Under this condition, the potential yield increases from 35,400 t to 306,558 t, corresponding to a biomass of 408 thousand t, with F = 1 (Fig. 14B).

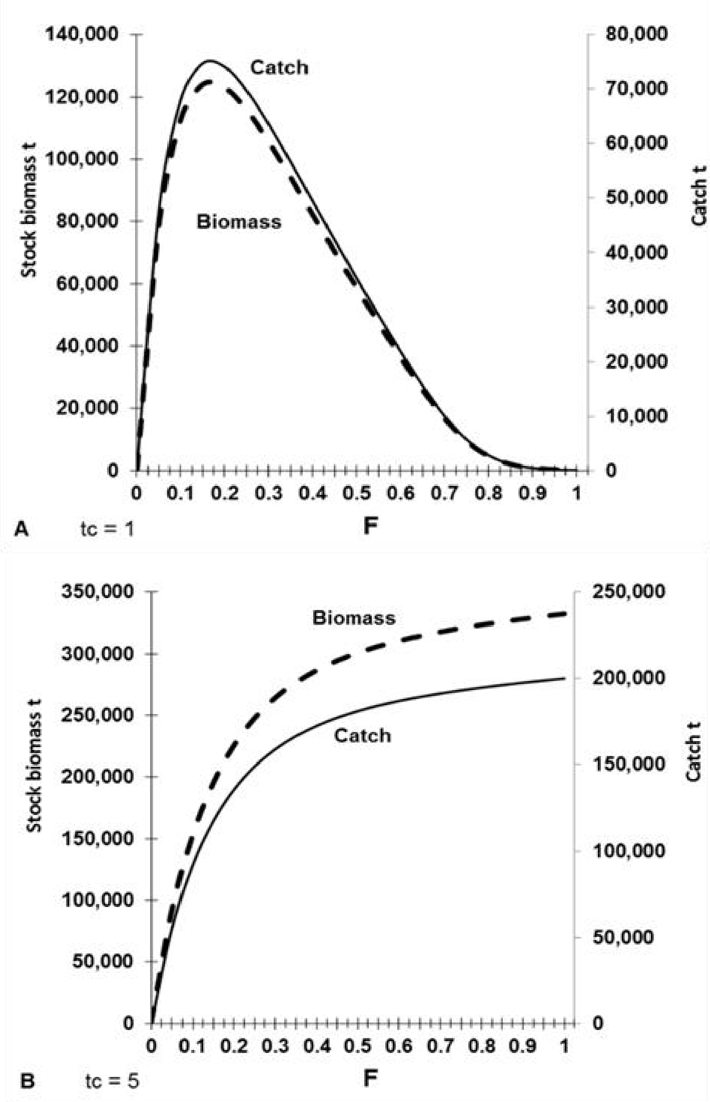

Fig. 14. Potential biomass and yield of the mackerel catch. A. At the age of first catch of one year; B. Age of first catch of 6 years.

Anchovy (anchoveta)

Stock assessment. Catch records of this stock throughout the history of this fishery have been insignificant compared to the Pacific thread herring, although from 2011 to 2013 it rebounded. However, as shown in Fig. 15, the anchovy is sensitive to high fishing pressure, since in the years in which its capture rebounded, the biomass decreased, resulting in a catch of 38,389 t for the last year of the study, unlike the previous year, when 116,857 t were caught.

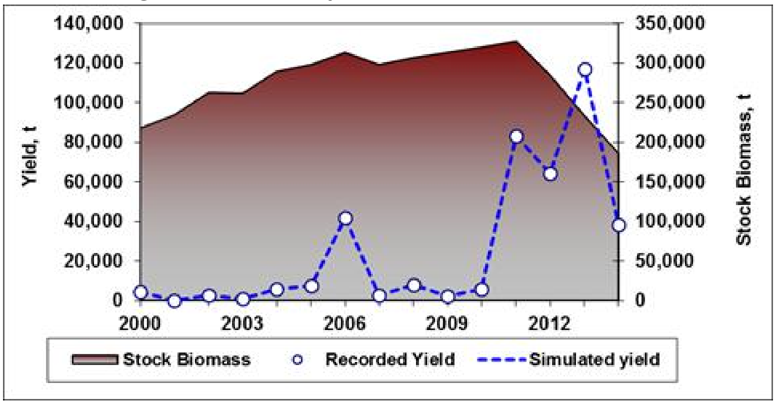

Fig. 15. Trend of biomass and catches (reported and calculated) of the anchoveta in the sardine fishery of the Gulf of California.

Diagnosis. This species has been underexploited (Fig. 16), since in most years of this study the exploitation rate remained below E_{MSY} (0.25) and F_{MSY} (0.33), with the exception of the year 2013 when the afore mentioned limits were exceeded with an exploitation rate of E = 50 and a fishing mortality of F = 0.61, resulting in a low catch the following year.

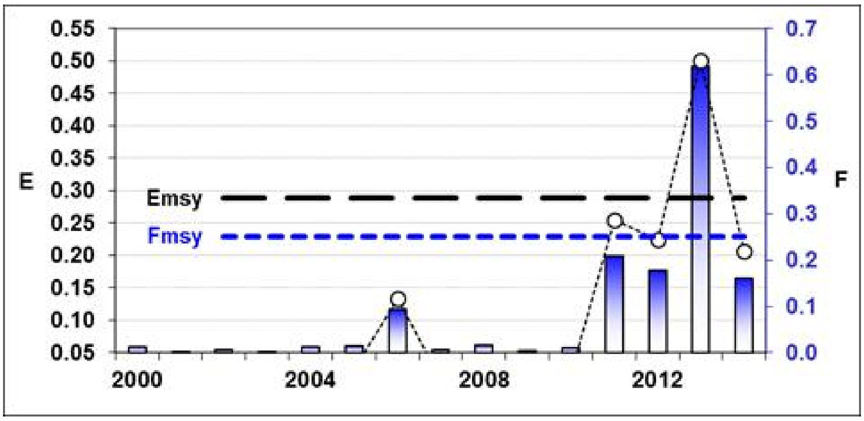

Fig. 16. Diagnosis of anchoveta, contrasting the exploitation rate E with the fishing mortality F.

Potential yield. The anchoveta reaches its maximum potential yield of 43,700 t, which may be obtained with F = 0.3, and an age of first catch of tc = 2. The corresponding biomass is 213,000 t (Fig. 17A). By increasing the values of tc = 2 which is the current value, to tc = 5, the potential yield increases from 44,400 t to 90,483 t with an F = 0.25 corresponding to a biomass of 410,870 t (Fig.17B).

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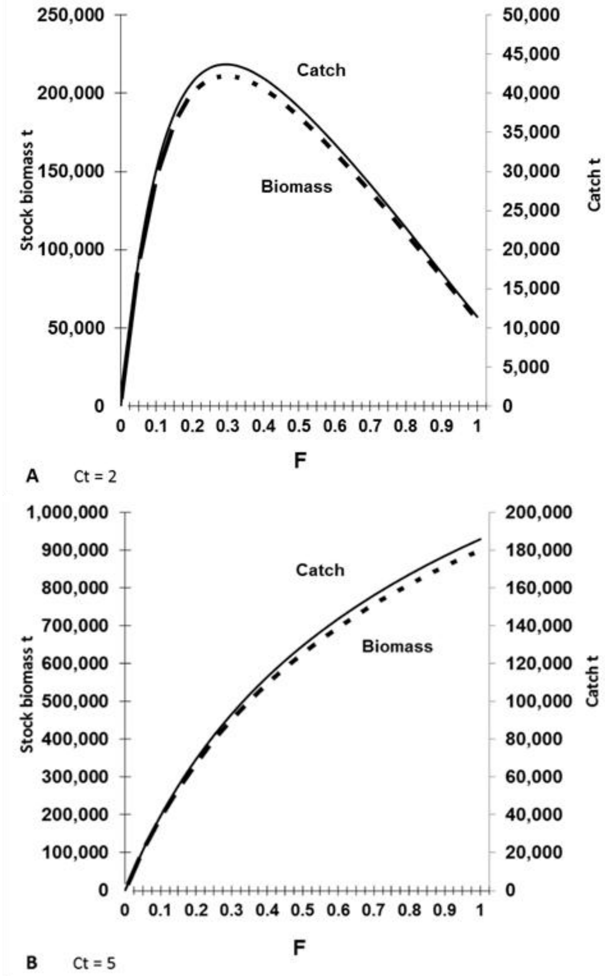

Fig. 17. Potential biomass and yield of anchovy. A. Age of first capture of 2 years; B. Age of first capture of 4 years.

Red-eye round herring (sardina japonesa)

Stock assessment. The catch describes an oscillatory trend, between 270 t and 8,000 t, with a notable increase in 2013, reaching 13,193 t, falling again the following year (Fig. 18). The biomass describes a constant trend, which apparently does not show the effect of the intensity of the exploitation.

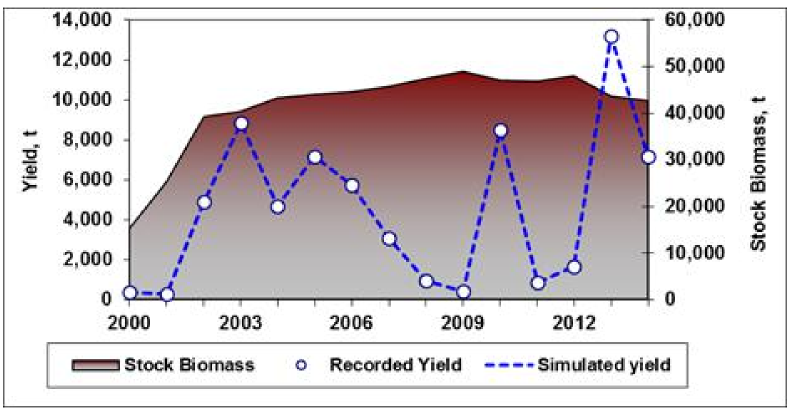

Fig. 18. Biomass and catch trend (recorded and calculated) of the Japanese sardine fishery.

Diagnosis. As shown in Figure 19, the exploitation rate is well below the maximum sustainable yield; this one is reached with exploitation rates above $E = 0.61$, and fishing mortality above $F = 2.0$. For this reason, this species is considered underexploited. The maximum exploitation rate is $E = 0.3$.

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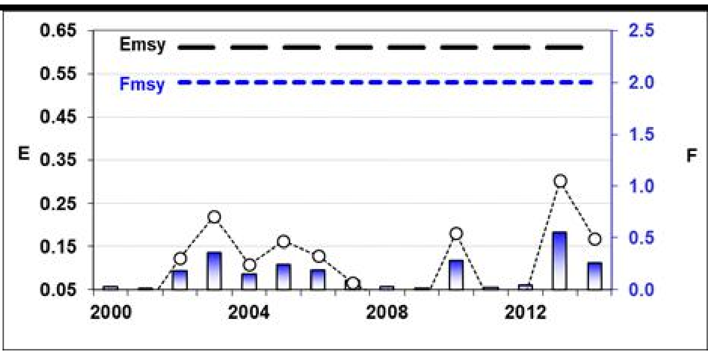

Fig. 19. Diagnosis of the Red-eye round herring contrasting the exploitation rate E with the fishing mortality F. The stock was underexploited through all the years of analysis.

Potential yield. The Red-eye round herring reaches its maximum with the value of *F* > 1, with an age of first capture of *tc* = 1, then a potential catch of 14,700 t is obtained, corresponding to a biomass of 33,400 t (Fig. 20). By increasing *tc* values from 1 which is the current one to 4 years and *F* = 0.9, the potential yield may increase to 14,126 t with a stock biomass of 83,000 t.

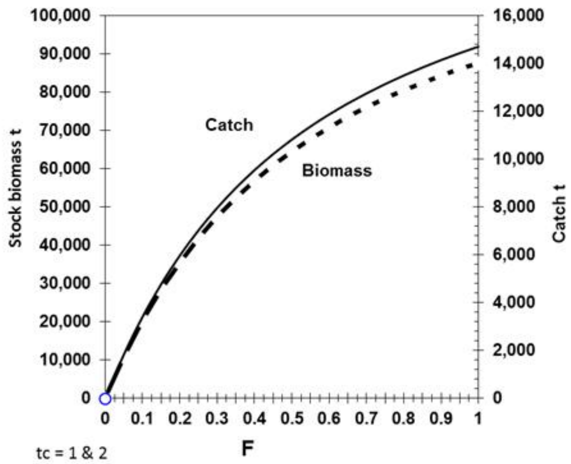

Fig. 20. Potential biomass and potential catch of the Red-eye round herring stock. A. Age of first capture of 1 year.

Shortjaw leatherjacket (Sardina piña)

Stock assessment. This is the species with the least volumes of catches reported in the sardine fishery; its most productive year the yield was only 10,866 t, evidencing its almost no-significant participation in this fishery. Although a biomass of 39,000 t was estimated in 2014 (Fig. 21), the catches fluctuate every year from 277 t to just over 5,000 t, with the exception of 2014, which was the most productive year with 10,500 t.

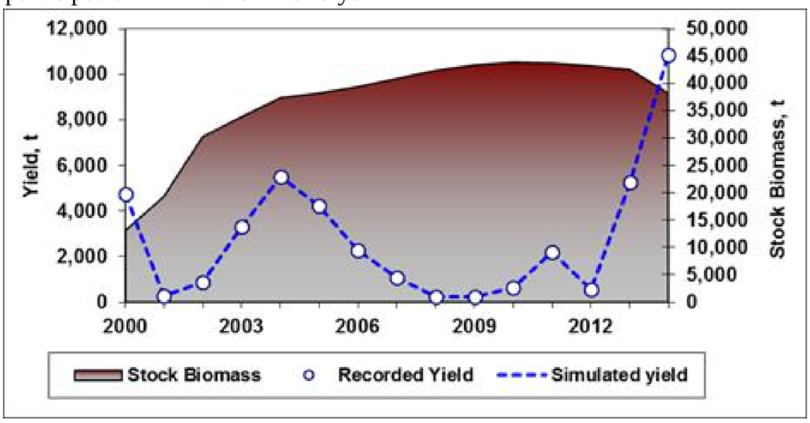

Fig. 21. Fluctuation of biomass and catches (reported and calculated) of the Short jaw leatherjacket (Sardina Piña) in the sardine fishery of the Gulf of California.

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Diagnosis. As shown in Figure 22, the exploitation rate for the most productive year is around *E* = 0.3 with a fishing mortality of *F* = 0.65; however the *Emsy* and the *Fmsy* are reached with very high *F* levels, which are above 1 and an exploitation rate near *E* = 0.5. The stock has short life span (4 years) and for this reason it can rebuild in short time.

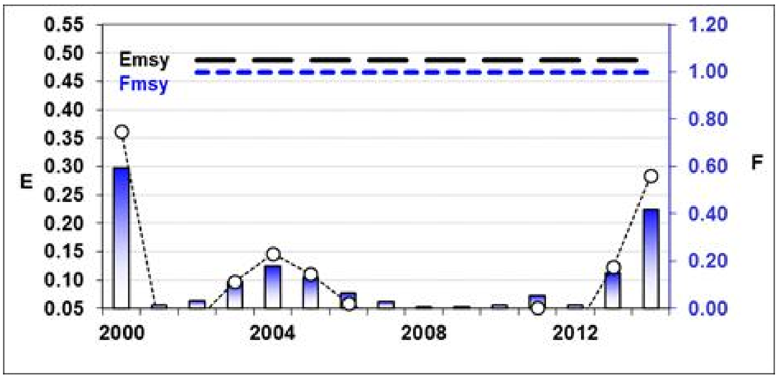

Fig. 22. Diagnosis of Short jaw leatherjacket (Sardina Piña) showing the exploitation rate E with the fishing mortality F. The stock was underexploited throughout all the period.

Potential yield. The stock reaches its maximum with the value of *F* = 1 and an age of first capture of *tc* = 1. With a current *F* = 0.43, the catch of 2012 is 10,800 t. However, the Short jaw leatherjacket (sardina piña) may reach a biomass of 38,300 t at *F* = 1 (Fig. 23A) by increasing the *tc* values from 1 which is the current to 3 and with *F* = 1. The maximum potential yield may be up to 15,000 t with a biomass of 47,500 t (Fig. 23B).

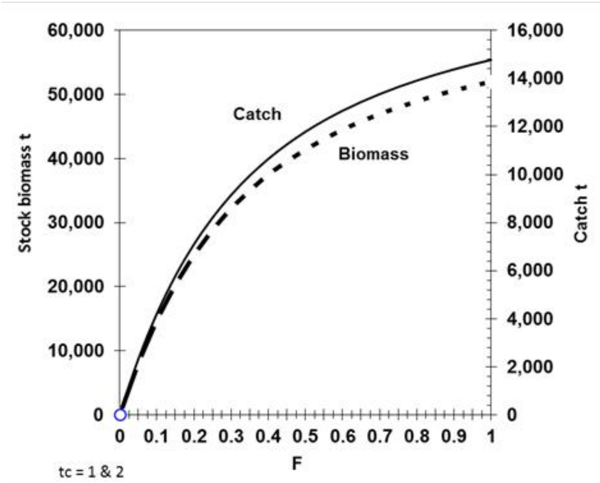

Fig. 23. Potential yield and biomass of the Short jaw leatherjacket (sardina piña). The age of first capture is one year.

IV. DISCUSSION

Consequences of continuing the exploitation of these stocks as it is nowadays, may imply serious and undesirable consequences. The most obvious would be the possible depletion of the target stock of the fishery, with other consequences on employment. The disturbance of the trophic web may also imply negative consequences, decreasing the available food of good quality and low-cost protein for animal consumption for a vast sector of the human population, as mentioned by

Heintz-Holtschmit, (1979), Félix (1986), Cisneros-Mata (1988), Doode (1999). These authors provide some explanation of this variability as follows, one of them states that the South American pilchard population has a cycle of approximately 80 years, at the end of which it moves to another area. This "phenomenon of cyclical distribution was demonstrated by Soutar and Isaacs (1969), after examining sediment cores of the Santa Barbara channel, California, finding that this species has had 12 cycles of occurrence in 1850 years, that is, cycles of approximately 80 years "(Heintz-Holtschmit, 1979).

The Fisheries Research Center (CRIP) in Guaymas, suggests that the displacement of the sardine is caused by to the oceanographic conditions. That is, its movement is attributed to hydrological variables, mainly the water temperature, induced by events like the phenomenon of "El Niño", which brings a considerable increase in water temperature and as a consequence of low

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concentration of plankton on which these fish feed. Other authors attributed the southward movement of the sardine to the low water temperatures delaying spawning in one or two months.

Even more, other authors argue that overexploitation of the South American pilchard is the main cause of the depletion of sardine in a certain area of the Gulf. However, this point cannot be confirmed with certainty, since there is a lack of basic data to support it. The information on which this statement is supported is the appearance of juvenile sizes of the species in significant amounts, in samples taken from the oceanographic vessels (Félix-Uraga, 1986; Cisneros-Mata et al., 1995; Felix-Uraga, 1996).

Another possible explanation regarding the fluctuations in catches possibly has to do with the trophic relationships of the target species and the accompanying species. The species are related amongst them because they share the same food sources or and trophically interconnected. That is a possible explanation of why they are together

Because the South American pilchard is the target species of this fishery, it is important to adopt new management criteria for the resources on which it is based. So, after the analysis carried-on, it is concluded that that by increasing the age of first catch from 1 year-old, to 3 years old and increasing by almost twice the current fishing effort, then biomass could support a higher fishing mortality from $F = 0.1$ to $F = 0.3$ (Fig. 24). By trying this option, the output suggests that three times more profits could be obtained, respecting to the current ones. For the rest of the species, the most advisable option to obtain the highest profits would be to reduce the fishing effort, although this option would mean important restrictions since this fishery cannot be selective, and while it is suitable for a certain species, the fishing mortality can be very high for the other components of the fishery. Although the model suggests that an increase of the fishing effort for the target species is feasible, it is not the best scenario for the other stocks in the fishery.

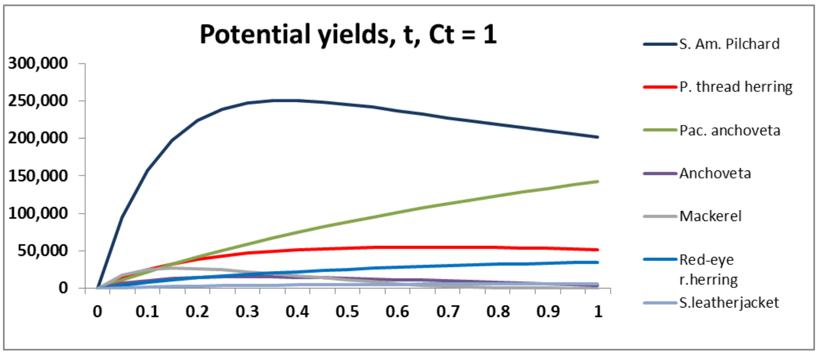

Fig. 24. Potential yield of the seven stocks of the sardine fishery of the Gulf of California as a function of F and at tc = 1.

The most convenient exploitation scenario for most species of the fishery is to increase the ages of first catch of one year, which is the current one, to 3 years. In this way, the juveniles are allowed to reach adult age, to reproduce and then to attain further increase in the stock biomass. This option would have as consequence of being able to withstand a higher fishing mortality permitting increase of fishing effort for all species and thus achieving higher profits without compromising the fishery. The only unknown is to see if other constrains appear as consequence of this or other changes in the harvest strategy.

REFERENCES

[1] **Bayliff, W.H.**, 1969. Synopsis of biological data on the anchoveta *Cetengraulis mysticetus*Günther, 1866. FAO Fish. Synop. 43:pag. var.

[2] **Castro Hernández, J.J., A.T. Santana-Ortega**. 2000. Synopsis of biological data on the chub mackerel (*Scomber japonicus* Houttuyn, 1782). FAO Fish. Synop. 157. 77 p. FAO, Rome.

[3] **Chávez, E. A**. 2005. FISMO: a generalized fisheries simulation model. Fisheries assessment and management in data-limited situations. University of Alaska, Fairbanks, pp 659-681.

[4] **Chávez, E.A**. 2014. Un modelo numérico para la administración sustentable de las pesquerías. CICIMAR Oceánides 29(2):45-56.

[5] **Chávez, E.A., A. Chávez-Hidalgo**. 2013. The sardine fishery of the Gulf of California. Calcofi Reports: Vol. 54: 205-214.

International Journal of Forest, Animal and Fisheries Research (IJFAF)
[Vol-3, Issue-4, Jul-Aug, 2019]
ISSN: 2456-8791
https://dx.doi.org/10.22161/ijfaf.3.4.1

[6] **Cisneros-Mata, M.A., J.A. De Anda-Montañez, J.J. Estrada-García, F. Páez-Barrera, A. Quiroz-Solís**. 1988. Pesquería de sardina del Golfo de California y costa de Sinaloa: Informe 1986/87 y diagnóstico. SEPESCA, Instituto Nacional de la Pesca, Centro Regional de Investigaciones Pesqueras-Guaymas. 68 pp.

[7] **Cisneros-Mata M.A., M.O. Nevárez-Martínez, Montemayor G., Santos-Molina J.P., R. Morales.** 1991. Pesquería de la sardina en el Golfo de California 1988/1989, 1989/1990. Boletín del Centro Regional de Investigación Pesquera de Guaymas. Guaymas, Sonora: Instituto Nacional de Pesca, Secretaria de Pesca.

[8] **Cisneros-Mata M.A., M.O. Nevárez-Martínez, M.G. Hammann**. 1995. The rise and fall of the Pacific Sardine, Sardinops sagax caeruleus Girard, in the Gulf of California, Mexico. CALCOFI Rep. 36:136-143.

[9] **CONAPESCA.** 2016, 2017. **Comisión Nacional de Acuacultura y Pesca**. Información estadística por especie y entidad. Mexico.

[10] **Doode, M. O. S**. 1999. Los Claro Obscuros De La Pesquería De La Sardina En Sonora. Colegio de Michoacán. México. Cap 2: 47-69

[11] **Félix-Uraga, R**. 1986. Edad, crecimiento y estructura poblacional de Sardinops sagax en Bahía Magdalena, de 1981 a 1984. Tesis de maestría, Centro Interdisciplinario de Ciencias Marinas, IPN, México, 103 pp.

[12] **Félix-Uraga, R., Alvarado-Castillo, R.M., R. Carmona-Piña**. 1996. The sardine fishery along the western coast of Baja California, 1981 to 1994. CalCOFI Rep., 37: 188–192.

[13] **Froese, R., D. Pauly.** 2014. FishBase. www.fishbase.org (accessed 13 Jan 2014).

[14] **Heintz Holtschmit, K**. 1979. La pesca de la sardina en Guaymas. Ponencia presentada en la Reunión estatal sobre pesca, CEPES/IEPES. Guaymas, Son., p. 219.

[15] **Jiménez Prado, P., P. Béarez**, 2004. Peces Marinos del Ecuador continental. Tomo 2: Guía de Especies / Marine fishes of continental Ecuador. Volume 2: Species Guide. SImBIOE /NAZCA /IFEA.

[16] **Lamb, A., P. Edgell**. 1986. Coastal fishes of the Pacific northwest. Madeira Park, (BC, Canada): Harbour Publishing Co. Ltd., 224 p.

[17] **Lluch-Belda, D., F.J. Magallón, R.A. Schwartzlose**. 1986. Large fluctuation in the sardine fishery in the Gulf of California: possible causes. CALCOFI Rep. 27: 136-140.

[18] **Lluch-Belda D., R.J.M. Crawford, T. Kawasaki, A.D. MacCall, R.H. Parrish, R.A. Schwartzlose, P.E. Smith**. 1989. Worldwide fluctuations of sardine and anchovy stocks: the regime problem. S Afr J Mar Sci 8:195–205.

[19] **Lluch-Cota, S.E., D. Lluch-Cota, M.O. Nevárez-Martínez, D. Lluch-Belda, A. Parés-Sierra, S. Hernández-Vázquez**. 1999. Variability of sardine catch as related to enrichment, concentration, and retention process in the central Gulf of California. CALCOFI Rep. 40: 184-190.

[20] **Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, L.K. Thorsteinson**. 2005. Resource inventory of marine and estuarine fishes of the West Coast and Alaska: A checklist of North Pacific and Arctic Ocean species from Baja California to the Alaska-Yukon border. U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104.

[21] **Nevárez-Martínez, M.O, D. Lluch-Belda, M.A. Cisneros-Mata, J.P. Santos-Molina, M.A. Martínez-Zavala, S.E. Lluch-Cota**. 2001. Distribution and abundance of the Pacific sardine (*Sardinops sagax*) in the Gulf of California and their relation with the environment. Progress in Oceanography, 49: 465-580.

[22] **Nevárez-Martínez, M. O., Ma. de los A. Martínez-Zavala, C.E. Cotero-Altamirano, M.C. Jacob-Cervantes, Y.A. Green-Ruiz, G. Gluyas-Millán, A. Cota-Villavicencio, J.P. Santos-Molina.** 2006. Peces Pelágicos Menores. In: Sustentabilidad y Pesca Responsable en México. Evaluación y Manejo. INP-SAGARPA. Pp: 264-301.

[23] **Soutar, A., J. D. Isaacs.** 1969 - History of fish populations inferred from fish scales in anaerobic sediments off California. Rep. Calif coop. oceanic Fish. Invest. 13: 63-70.