Small Pelagic Fishery in Panama, Stock Assessment and Recommendations for a Management Plant

March 2015

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Small Pelagic Fishery in Panama

This fishery includes the following main species: Pacific anchoveta or sardine (*Cetengraulis mysticetus*) and Pacific thread herring (mainly *Opisthonema libertate* and *Opisthonema medirastre*). The Pacific bumper (*Chloroscombrus orqueta*) and other small pelagic species are also caught opportunistically in smaller volumes.

The fishery stated in the 1950s, with anchoveta as a target species to be used as bait for the tuna fishery. However, in the 1960s it gained importance for the manufacturing of fish meal and oil, probably reaching from 1966 onwards its state of fully exploited.

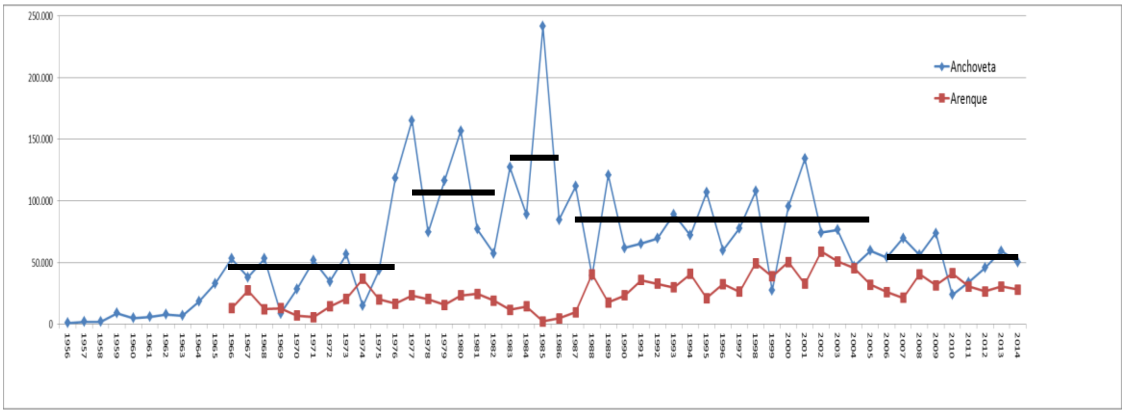

Chart 1: Historic evolution in small pelagic fishery 1956-2014. Sources: FISTAT and Promarina

Anchoveta: Anchoveta
Arenque: Herring

Catch data in Chart 1 illustrate the different stages in the anchoveta fishery. Until 1965 it was a developing fishery. From 1966 till 1975, catches moved around 45 thousand tons. From 1976 till 2001, catches grew significantly, probably due to a combination of higher productivity and over-exploitation.

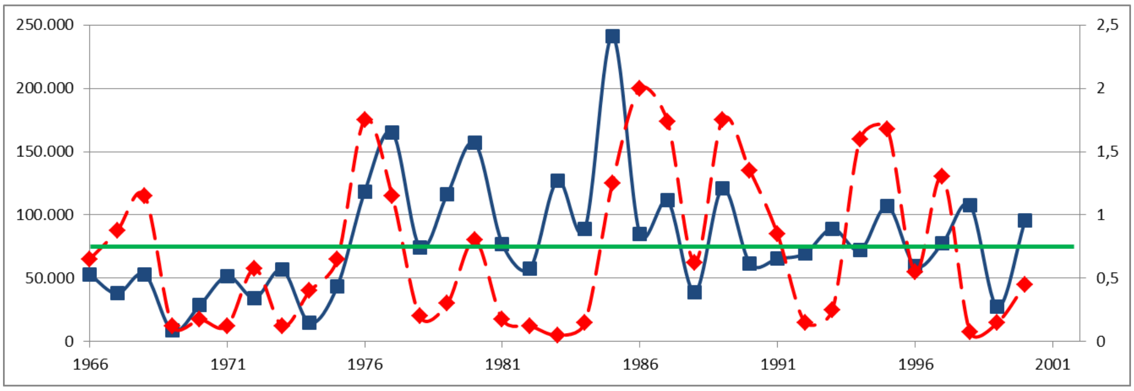

Chart 2: Upwelling Index (dotted red line, source: De Croz et. Al. 2003) and landing of anchovies (continuous blue line) 1966-2000. The green line shows the average of both curves.

Chart 2 illustrates the situation after the strong upwelling from 1976 onwards that could have created a large abundance event so, despite the fact that between 1978 and 1984 the upwellings were weak, the significant growth in landings was maintained, increasing even further till 137 thousand tons, reaching a peak at 240 thousand tons in 1985. The idea of over-exploitation around those years is based on the fact that, despite the important upwellings of the years 1986-1987, 1989-1990, and 1994-1995, the average catch was reduced to around 75 thousand tons.

From the year 2004, there is a noticeable drop in yields, probably due to the weakening of the upwelling after the year 2003, with a decline in catches to around 50 thousand tons. Bearing in mind this situation, in 2006 the two companies participating in the fishery decided of their own accord to reduce the fishing effort, moving gradually from 30 to 15 vessels in operation, thus reducing the processing capacity with the closure of one of the two fish meal and oil plants.

It should be borne in mind that the growing pollution of the Panama Bay and the reduction in the mangroves area in the Juan Díaz region might have had a deleterious influence over the reproductive and feeding processes, highly coastal, both in the case of anchoveta as well as of herring.

To have a clear idea of the performance of the fishery on the whole it is of paramount importance to understand, first of all, the performance of the fraction that corresponds to anchoveta. Indeed, between April and July this is the main species. When it shows spawning signs, fishermen themselves turn to herring. Towards the end of October, probably because of reproductive behavior, the herring abandons the fishing grounds and yields drop significantly. Confronted with this situation, the fleet, instead of chasing the stock, suspends its activities till April next year.

The following charts are useful to better understand this dynamic:

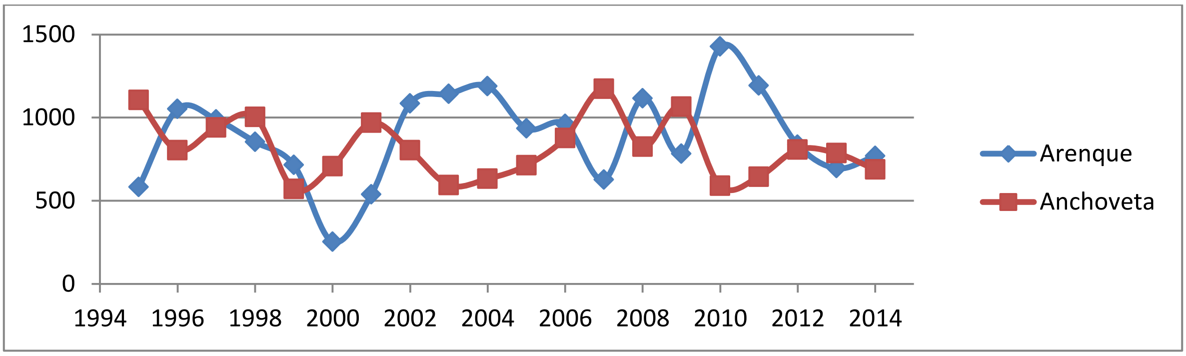

Chart 4: Amount of fishing trips 1995-2014. Source: Promarina

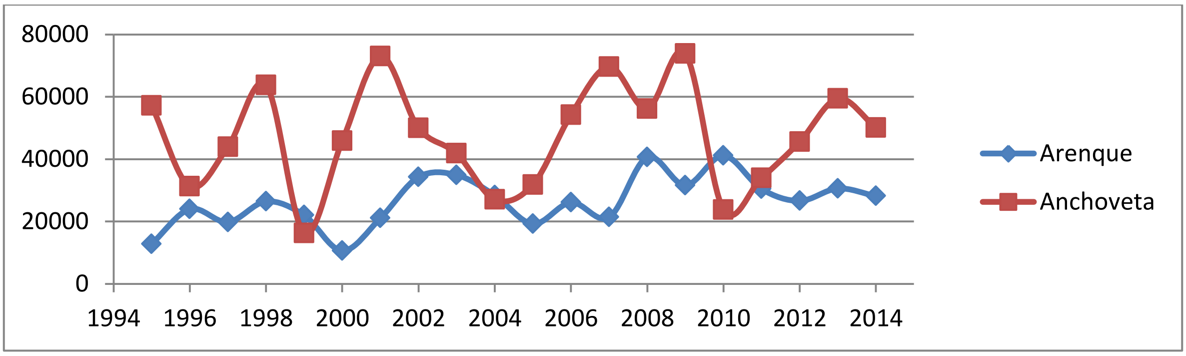

Chart 5: Landings of anchoveta and herring 1995-2014. Source: Promarina

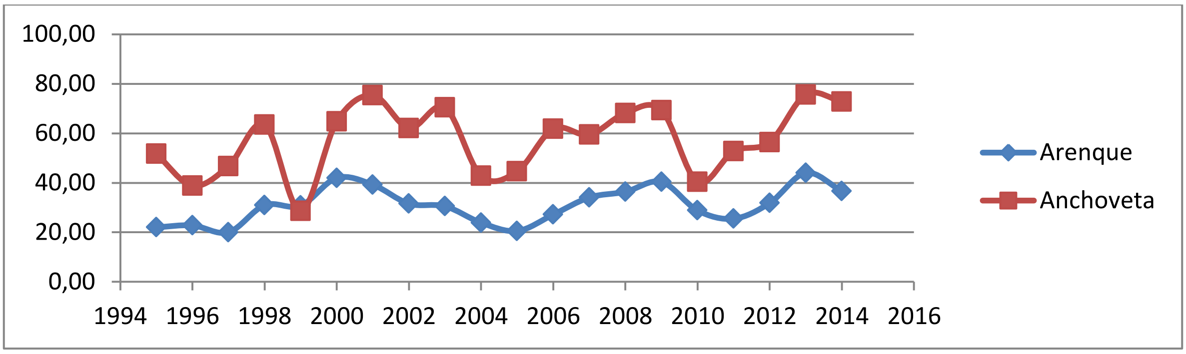

Chart 6: CPUE (Catch-Per-Unit-Effort –fishing trip -) for anchoveta and herring 1995-2014. Source CeDePesca.

Chart 4 shows the inverse relation between anchoveta and herring fishing trips. When the number of trips fishing for anchoveta is reduced, the number of trips fishing for herring increases. Linking this chart with Chart 5, we realize that there are less trips fishing for anchoveta when the catch of this resource is diminished, the reason being that in this fishery, effort (and catch) are dependent on availability. In summary, it seems that when the catch of anchoveta was not enough early in the season, a greater effort is invested in the catch of herring in the last months. Finally, Chart 6 illustrates the reason why anchoveta is a priority: the yields (CPUE) per trip are much higher, almost double those of herring, as the latter is more mobile and elusive.

Unfortunately, this analysis shows that the available data regarding effort and catch do not allow for a prediction of the abundance of both stocks. The behavior of the fleet, reducing the effort when abundance or availability are reduced (thus creating a hyper-stable CPUE situation) prevents the use of CPUE as an abundance indicator. Therefore, it is important to **keep going the data gathering effort (time taken) between successful sets after arrival to the fishing area, by means of the Onboard Observers program,** so as to obtain abundance indexes applicable in global assessment models such as that of Schäeffer for both resources.

From the mapping of the areas of operation (See Chart 7) and the comparison with the fishing season in 1987 of the research vessel Fridtjof Nansen (Chart 8), it is clear that the hydroacustic estimates of this vessel were only performed in depths above 10 fathoms, outside common fishing grounds, where waters are clearer and the use of purse seines is less effective.

Moreover, in May and August, Nansen´s survey found significant concentrations of herring and other species in Central Gulf areas, far away from the coast, where local purseiners do not fish for these resources. **Therefore, a better understanding of these migratory cycles is very important for the future assessment of these stocks by means of specific studies, such as hydroacustic assessment**.

Bearing in mind this space and time limitations, it is interesting as a starting point to realize that the herring biomass was estimated by Nansen´s campaign around 76 thousand tons and that of anchoveta in 29 thousand tons (Sætersdal et al, 1999).

Chart 7: Identification of fishing grounds during 2014. Source: CeDePesca-Promarina Onboard Observers Program

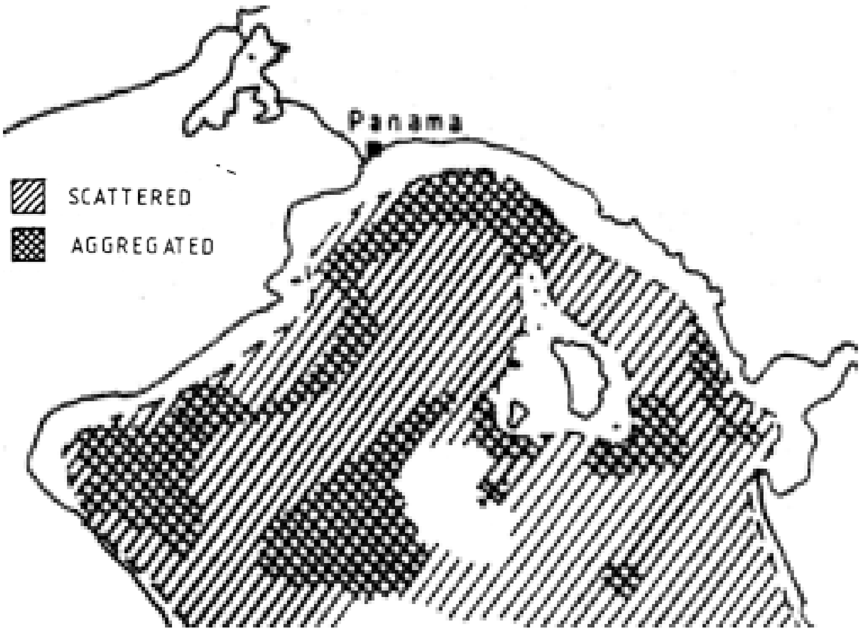

Chart 8: Identification of small pelagic concentrations in August 1987. RV Fridtjof Nansen Fishing Season. Bear in mind that the fishing areas highlighted in Chart 7, here appear mostly in white because the research vessel draught prevented exploration in areas of less than 10 fathoms in depth.

Assessment of the herring stock

Some monthly series of size frequency are available for this analysis from August 2013 till March 2015. These series have been gathered by the Onboard Observers Program. However, it has been impossible so far to differentiate between the herring species. This will require further sampling methods to estimate species composition.

Even if there are biological-fishery studies referring to these species in Mexico, Costa Rica and Ecuador, they had never been done before in Panama, despite their importance in the small pelagic fishery and the ecosystem of the Gulf of Panama.

Unfortunately, those studies cannot be applied because growth and reproductive parameters of the same species vary significantly depending on several physical (temperature, salinity), chemical (proportions of silicates, iron, and dissolved oxygen) and biological (organic nutrients, phytoplankton and zooplankton). Thus, for instance, a herring of 18 cm could be two years old in the Gulf of California, and just one year old in the Gulf of Panama.

These parameters are of key importance to understand the demography of the herring populations and, therefore, to understand their current level of exploitation and define targets and tools to achieve them.

The real solution to solve this lack of information, the same as for anchoveta, would be a **systematic age analysis of the sampled specimens**, either by the microscopic reading of the rings appearing on scales or other hard parts such as *otoliths or cleiras*, linking these readings with the respective sizes. Moreover, in this case, herring species should be differentiated.

While this study is still missing, a FAO software package could be used temporarily and with a lot of caution. This package is called FISAT II and through its program ELEFAN it deduces age from size frequencies. It should be stressed that this program, even if it provides a "favorite" set of **K** parameters (annual growth rate) and $\mathbf{L_\infty}$ (maximum size of species in the location under analysis), both should go through a biological "common sense" analysis, choosing a set that, reaching a good score in the program, also fits into the species biological rationale. Meanwhile, it becomes clear that *O. libertate* and *O. medirastre* show different parameters in reality. Therefore, we would be using here grouped parameters. This considerations show how pressing it is to move from these high levels of uncertainty to an analysis based on the identification of species and realistic age readings, and a direct determination of growth parameters.

Using the package mentioned here above, $\mathbf{L_\infty}$=27.85 cm was adopted (maximum size recorded in the sample was 26 cm) and **K**=0.67. These parameters are used in the so called Von Bertalanffy Equation that relates size and age of a certain species, according to Chart 9.

As observed, this curve does not start in 0. Therefore, it requires a "non biological" adjustment, called $\mathbf{t_0}$. The latter can be calculated according to the following equation (Pauly, 1979)

$$\text{Log}_{10}(-\mathbf{t_0}) = -0.3922 - 0.2752 * \text{Log}_{10}\mathbf{L_\infty} - 1.038 * \text{Log}_{10}\mathbf{K}$$

In this case, $\mathbf{t_0}$ = -0.246

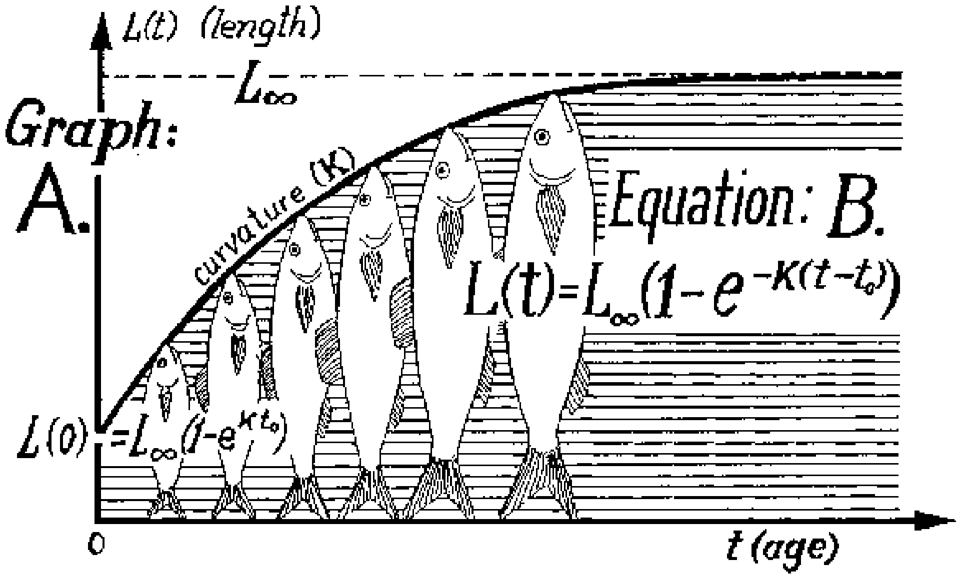

Chart 9. Explanation of Von Bertalanffy Growth Equation. Source: Sparre et al 1997

As a result, we transform size spectrums obtained in samplings into age spectrums, presented as follows by FISAT II:

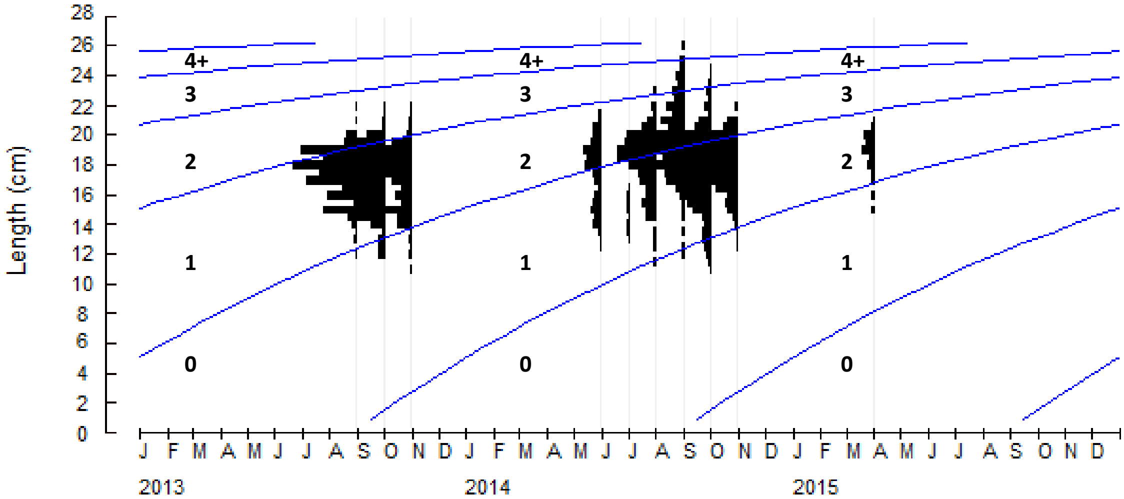

Chart 10. Output of the FISAT II program showing the evolution of the herring group cohorts within the limited amount of samplings available so far. It illustrates, for instance, how classes born in 2013 are only tangentially affected by the fishery that year. However, they supply most of the catches in 2014 when they are one year old and they appear on the 2015 exploratory trip when they are 2 years of age.

Once these parameters calculated, and obtaining from our data base superficial annual average temperature in the Gulf of Panama (**T** equals 27.244 °C), we use another equation of Pauly (1980) to estimate herring natural mortality (**M**):

$$\text{Log}_{10}\mathbf{M} = -0.0066 - 0.279 * \text{Log}_{10}\mathbf{L}_{\infty} + 0.6543 * \text{Log}_{10}\mathbf{K} + 0.4634 * \text{Log}_{10}\mathbf{T}$$

Moreover, it was taken into account the fact that Pauly had realized that for species and genders of the *clupeidae* family, such as herring, the M obtained should be multiplied by the factor 0.6, so that

M = 0.832.

To obtain total mortality (**Z**) and fishing mortality (**F**), we group the amount of sampled fish by size, in quantities per age (using the von Bertalanffy equation), and we calculate by means of the following equation (assuming constant abundance between 2013 and 2014):

$\mathbf{Z}_{it} = -LN\ (Ш_{it+1}/Ш_{it})$

Where $Ш_{it+1}$ is the proportion of specimens of age i found in the year t+1 in the sample, and $Ш_{it1}$ is the proportion of specimens of age i found in the previous year t.

On the other hand, fishing mortality is simply the difference between Z and M per age.

Age	Ш2013	Ш2014	Z_{it}	M	F_{it}
1	0,895	0,681	1,087	0,832	0,255
2	0,105	0,302	1,798	0,832	0,967
3+	0,000	0,017			

Table 1. Mortality analysis for herring stock.

In addition, even though we still do not know herring life cycle in detail, from the samples we can deduce that the reproductive peak of these species in the Gulf of Panama begins in October and could continue throughout November. However, due to the closure of the fishery data are not available for that month. During this October peak, we found reproductive specimens from 16 till 22 cm. Findings show that the average size at which 50% of females are spawning is of 17.4 cm.

Before drawing conclusions from this previous information, it is important to highlight that these conclusion are preliminary, due to the scarce historic series available and the presence of two species. However, a precautory approach has been adopted.

Table 1 illustrates that the fishery is based in specimens age 1 and 2. However, average catch size of each one of the nine months sampled fluctuated around or was above the average size at maturity found, except for June 2014, where the sample was very small and not representative.

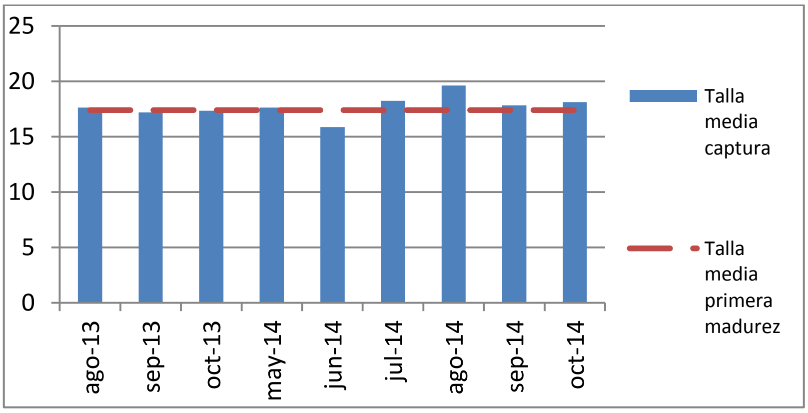

Chart 11. Comparison between average size at maturity and average catch size of herrings between August 2013 and October 2014.

Table 1 depicts a scenario where the fishery catches a lot of age 1 specimens, but the main mortality source for them is natural mortality, thus confirming the important role this species plays for the health of the Gulf of Panama ecosystem. From this viewpoint, a fishing mortality for age 1 of F=0.255 seems adequate from the ecological point of view.

Moreover, fishing mortality for age 2 presents values similar to those of natural mortality. Literature considers this as an indication that exploitation is at the level of maximum sustainable yield. However, it is obvious that combined fishing mortality for ages 1 and 2 is much lesser. Therefore, the current exploitation levels seems adequate from the ecological viewpoint and, simultaneously, there seems to be no room for later increases in the fishing effort for this species due to the danger that it would present both for the environment, as well as for the maintenance of an adequate escape stock for the renewal of the herring populations.

Assessment of the anchoveta population (*Cetengraulis mysticetus*) in the Gulf of Panama

The anchoveta from Panama was studied extensively at the end of the 50s and beginning of the 60s by the technical equipment of the IATTC. The fishing activity for this species began in the 40s as bait for the tuna fishery. At the time, a fleet of vessels based in California came to the Gulf of Panama to load their holds with living bait from this source that if, fished at early stage of life, could stay alive for several months.

In the 60s, the fishery of small fish for fish meal begins. Both fisheries become sequential because purse seine vessels preferred bigger fish to obtain good yields in the reduction plant.

The scientist that devoted more efforts to the study of this species was Bayliff. In 1969 he wrote for FAO a piece of work that summarizes all previous studies (Bayliff, 1969). In this work, he establishes that "from what is known from the life of this species, it seems highly likely that fish from different areas belong to different sub-populations". This observation is very important to identify the stock unit under analysis, which completes its life cycle inside the Gulf of Panama waters.

Furthermore, with the exception of the first months of life of this species, when they migrate to deeper and clearer waters, close to islands and islets, after the 4th month of life, they settle in muddy coastal areas, close to the mouth of rivers or mangroves, feeding from diatoms and other micro-organisms, where they spawn after the first year of life.

The reproductive period starts at the end of August and lasts till January, with a peak between November and December. Therefore, when the fishing season begins in April, it operates on a combination of specimens of 4 to 7 months, and of 16 to 19 months. To reduce the amount of specimens of less than a year of age in the catch, sizes are assessed in exploratory trips and fishing activities only start when the average size is above 13 cm (1.1-1.2 years).

Although the species can reach sizes above 21 cm and ages above 4 year, the population is mostly composed of ages 0 and 1, with a dramatic drop after the second year of life.

We could believe that such a situation is due to the fishing activities. However, Bayliff detected the same scenario in early stages of the fishery.

To compare the data used by Bayliff and those gathered by the Onboard Observers Program and, as a result of the **absence of local studies about the parameters to be used in the Von Bertalanffy growth equation,** by means of a minimization of square differences, we apply a conversion between the empirical parameters proposed (Bailyiff, 1969) and those generated by an approximate curve, but including sizes and ages above those found in the 60s.

	Bayliff	Converted
L∞ (cm)	17	21,5
K	1.31	0.572912
to (years)	0	0.418438

Table 2. Determination of growth parameters coherent with those found by Bailyff

As a result, Chart 12 shows the two growth curves:

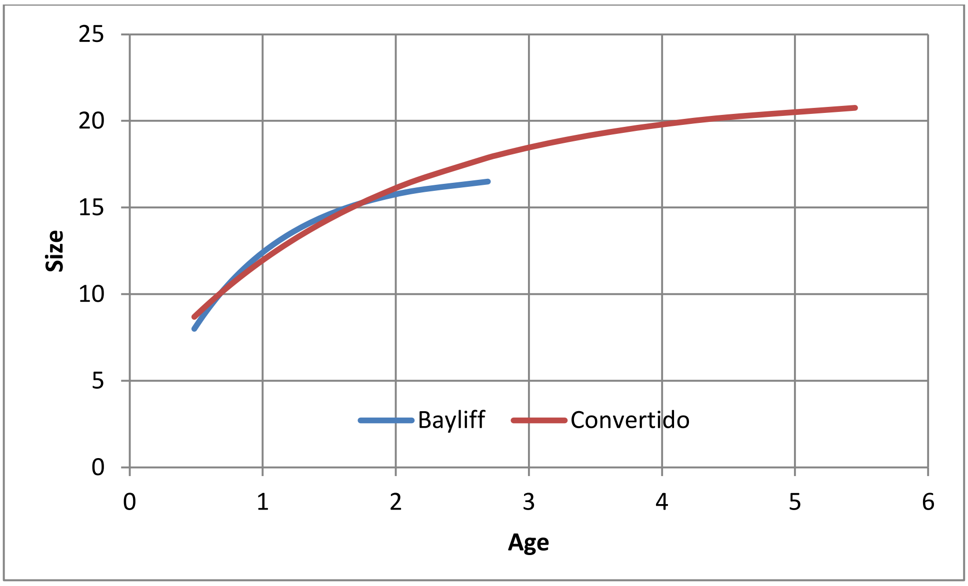

Chart 12. Bayliff growth and converted curves to include sizes that did not appear in his works. Between ages 0 and 2 differences are minimal.

Thus we can modify the size spectrum gathered throughout 2014 (Chart 13) into an age spectrum (Chart 14).

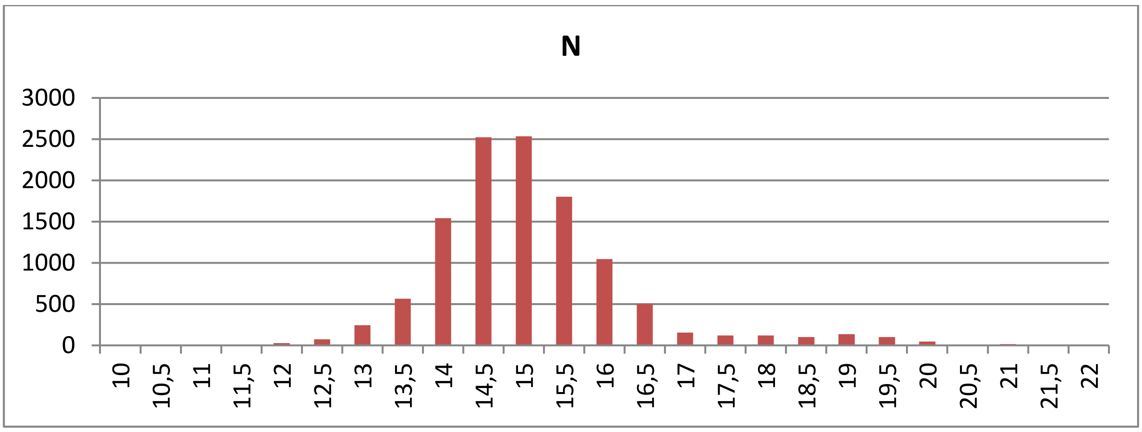

Chart 13. Size spectrum in anchoveta catches in 2014. Source: Onboard Observers Program.

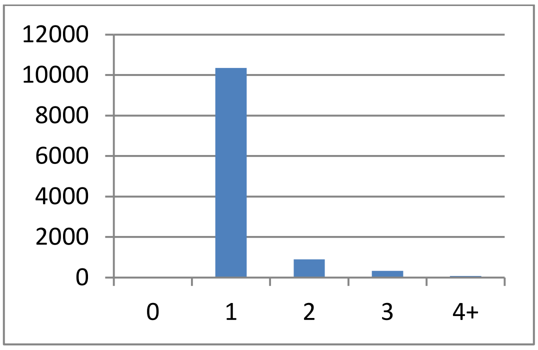

Chart 14. Age spectrum in anchoveta catches in 2014

As there are no data available from previous years, we will use a false cohort analysis. The latter looks appropriate in this case, where the same age structure seems to be repeated year after year. As a result, we can calculate the total mortality rate per age:

Age	N	Z
0	7	
1	10,349	2.446
2	897	1.003
3	329	1.606
4+	66	

Table 3. Mortality analysis for anchoveta stock

It is remarkable that total mortality rate for age 1 matched exactly the one calculated by Bayliff in the 1960s, when the fishery was just incipient, as illustrated in Table 4:

Age composition and coefficients of annual total mortality (Z) of the anchoveta in different areas

Area	Months included	Age group			Z
		0+ and 1+	1+ and 2+	2+ and 3+	
Gulf of Panama, 1961-1963	May-January	24,019	2,346	62	2.45

Table 4. Mortality analysis for the anchoveta stock (Bayliff, 1969)

Bayliff estimated that the natural mortality of this species reaches a value of M=2.11, thus indicating the large importance of this population in the Gulf of Panama trophic chain. Indeed, seabirds and larger fish in the coastal area feed from this population.

If we accept such value of M, data available show that current fishing mortality for age 1 in 2014 was F=0.336, which is an adequate value for the exploitation of this resource, bearing in mind the need to maintain the consumption of its predators in the ecosystem. However, it should not be increased so as not to alter this equilibrium.

Bayliff thus describes the biomass variation process along a single year, from April till December 1960:

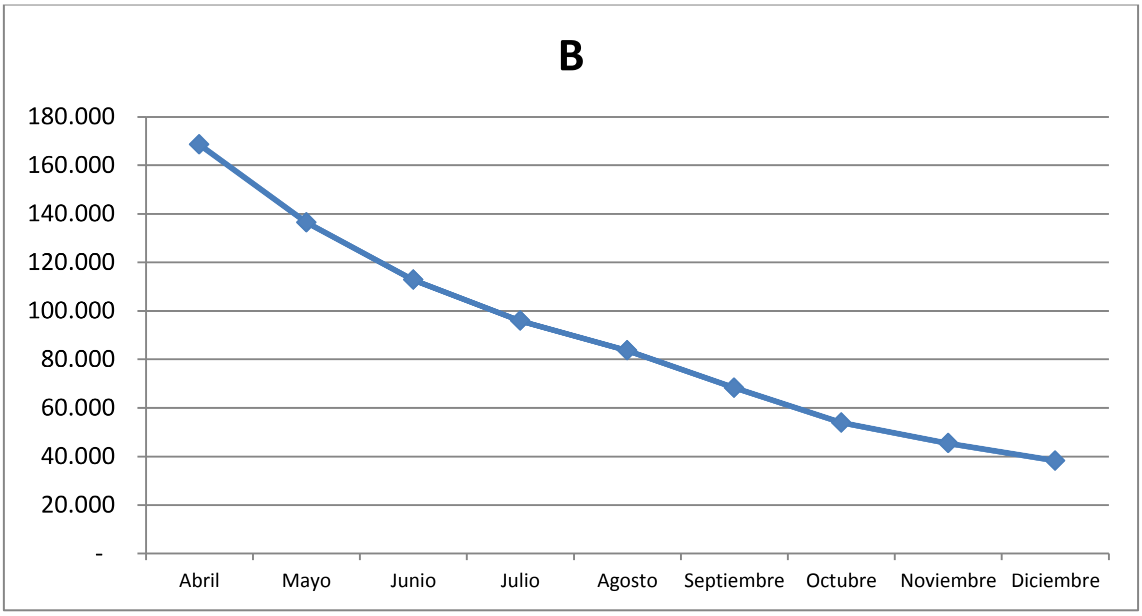

Chart 15. Quasi extinction of the age 1 cohort throughout 1960, with a very low fishing mortality (Bayliff, 1969)

Therefore, we can say that, in essence, anchoveta behaves as a short life cycle resource, whose cohorts almost disappear naturally in a period of two years. The fishery is highly dependent on the previous reproductive success in this same period and the recruitment of the current year.

In turn, these two moments are highly dependent on three factors: the remnant stock two years earlier, environmental factors during the reproductive period and environmental factors during the feeding and recruitment period.

As we will see in the next section, the success of the reproductive period seems to be linked to rainfall between October and December not exceeding historic averages. In turn, recruitment success seems to be associated with the upwelling strength, measured by the number of cold days along the first quarter of the year.

Taking these factors into account, we could establish an acceptable biological and environmental catch to maintain the current exploitation levels and to correct them in the future if necessary.

Environmental variables as predictors in the anchoveta sub-fishery

Surface temperature of the sea water

The correlations made between the number per year of “cold days” and catches revealed that this data can be very important when making a retrospective analysis about the exploitation level of the anchoveta resource and establishing a harvest strategy, and a proxy to predict sustainable catch for the current year.

The material used initially was the NOAA data base of the satellite AVHRR_OI (aggregate__ghrsst_NCDC-L4LRblend-GLOB-AVHRR_OI.ncml) that provided average daily surface temperature (SST) in a localized point in the middle of the Gulf of Panama (8.4 N; 79.1 W, very close to Las Perlas archipelago) between the years 1982 and 2013. Year 2014 was reconstructed with information from the satellite GAMSSA (aggregate__ghrsst_ABOM-L4LRfnd-GLOB-GAMSSA_28km.ncml).

Comparing the data for these 32 years, it was verified that temperatures under 298.5 Kelvin (25.35°C) were only characteristic of the period from January to April of each year, when persistent Northeast winds blow and the upwelling of the Gulf of Panama occurrs. In addition, it was assumed that the amount of days per year with Surface Sea Temperature (SST) below 25.35°C (cold days) could indicate the upwelling strength for each year.

Indeed, when correlating cold days per year with catches data, the result was 0.43 which is a more than acceptable value. This correlation increases significantly after eliminating those years with large landings despite the quantity of cold days being scarce or nil.

Chart 16 posted larger mismatches, with years with few cold days and high catches, pointing at over-exploitation.

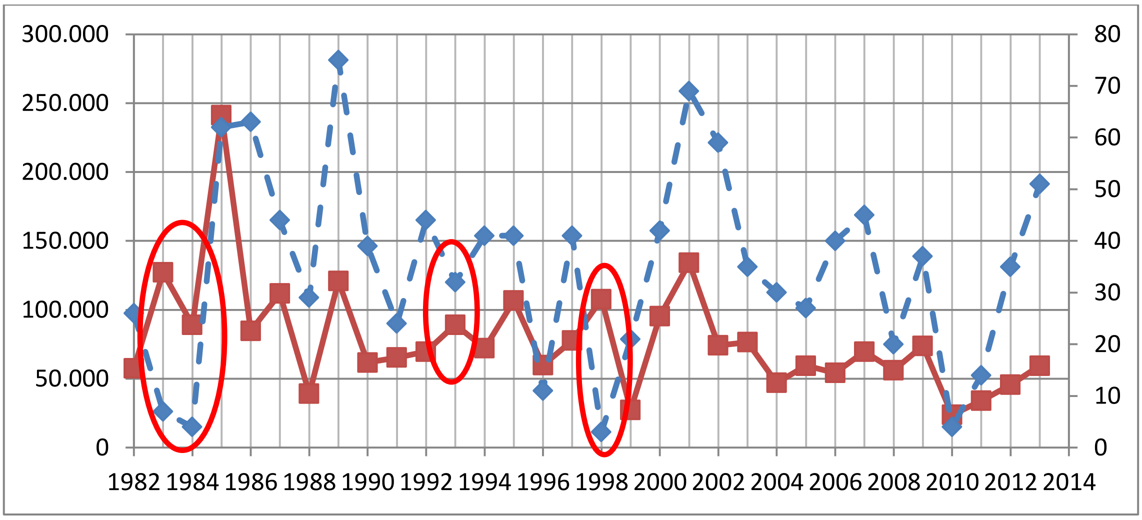

Chart 16. Comparison of the number of cold days in the dry season (dotted blue line) and anchoveta catches in that same season (continuous red line). Years 1982-2013. Some years with mismatch appear, with low upwelling and higher catches.

Refining those points with higher mismatch, we reach a correlation of 0.84, thus showing a “normal” relation between number of cold days and catches in Chart 17.

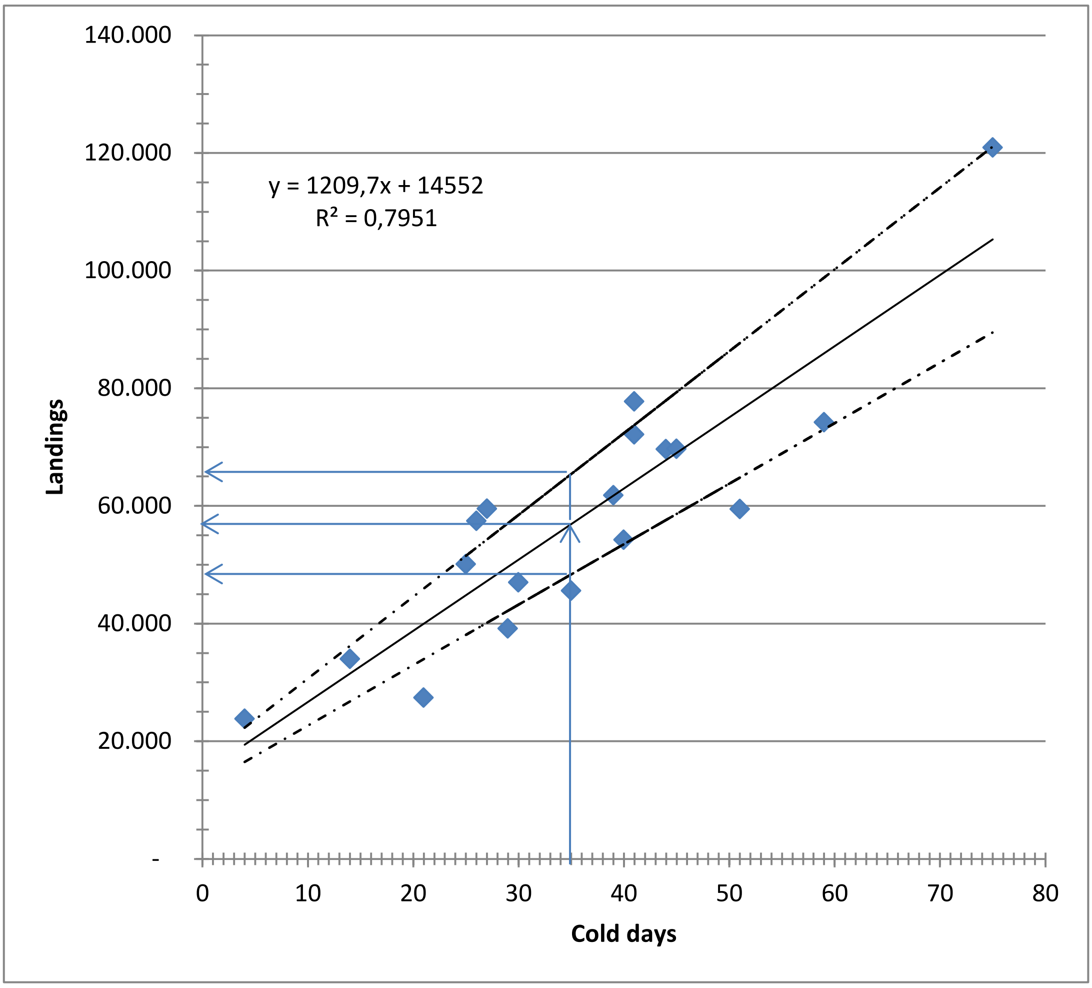

Chart 17. “Normalized” relation between number of cold days and catches

As a result, the following equation was determined

Cn = 14,552 + 1,209.7 * DF ± 15%

Where

Cn = Environmentally acceptable normal catch of anchoveta

DF = Number of cold days in the dry season previous to the season opening

Considering that the cold days average per year for this series is of 35 days, we can also find the “Average Normal Catch” for this series, in a range between 48,000 and 65,000 tones.

Applying to the median of this Average Normal Catch a factor that results from dividing the amount of cold days per year by its average (35) we obtain the Normal Annual Catch that should have been respected to avoid over-exploitations of the stock, assuming recruitment is only dependent on the sea surface temperature factor.

Thereafter, dividing real catch by this annual normal catch, we obtain an “environmental exploitation indicator”, as observed in Chart 18.

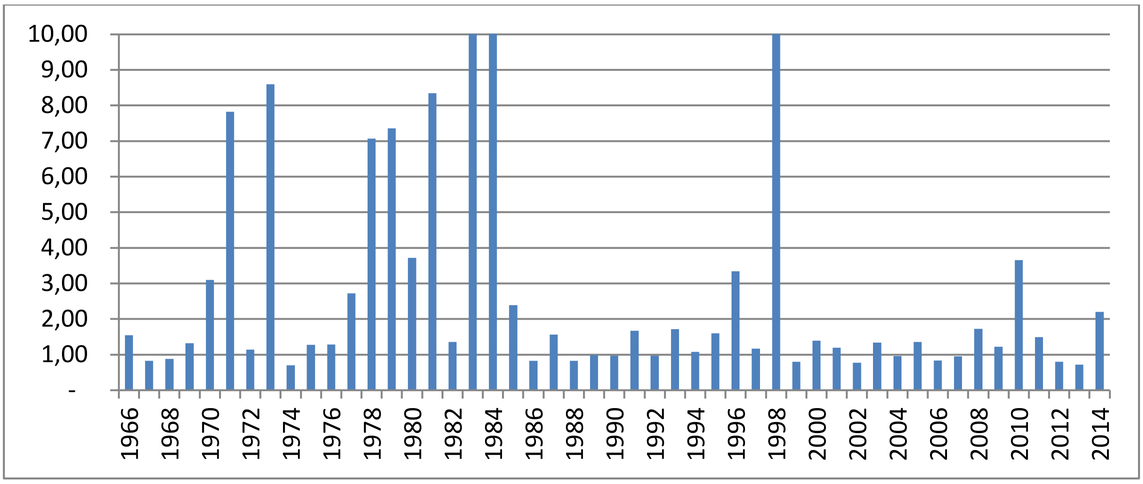

Chart 18. Indicator of "environmental exploitation". 1966-2014. The ideal value equals 1 being 1.15 acceptable.

As observed in Chart 18, according to this indicator, there would have been years of extreme over-exploitation in the past (years 1971, 1973, 1978, 1979, 1981, 1983, 1984 and 1998). This would have occurred due to the lack of knowledge about the correlation between the upwelling strength and the resource abundance. There are three years that stand out in the series because they have less than 5 cold days: 1984, 1998 and 2010. It is noticeable that after these "warm" years, the successive "cold"periods do not have an immediate impact in the stock recovery. In the future, when this type of years would appear, a special approach should be taken for the development of the fishery during that year.

A global view of Chart 18 indicates that the 1970s and first half of the 1980s were probably characterized by an over-exploitation of the resource, whereas from 1985 till date, an average fully exploitation would have occurred with some exceptional moments of overfishing.

Now we can create a table indicating annual environmentally advisable catch depending on the number of cold days in the dry season each year (See Table 5). This advisable catch should be considered within a range of ±15%., which is the average deviation from the determined linear equation.

After this study was completed, a data base was found containing daily water temperatures taken in the Puerto Caimito pier by the Quality Laboratory of Promarina during high diurnal tide from 1994 till date. With great satisfaction, we verified a high correlation between these data and those of the satellite NOAA (R=0.757). It was also proven that the relation found between cold days (temperature under 25.4°C[1]) and recommended catch was still valid, therefore we have at hand a simple and accessible tool to estimate a priori anchoveta recommended catch for each year, while some other abundance studies that will require a longer timeframe, follow their course.

[1] A test was performed using several threshold temperatures and 25.4°C was the best one matching the catch data; it was almost the same as the one determined with NOAA data (25.35°C)

Dias frios	CER	Dias frios	CER
0	15.000	26	46.200
1	16.200	27	47.400
2	17.400	28	48.600
3	18.600	29	49.800
4	19.800	30	51.000
5	21.000	31	52.200
6	22.200	32	53.400
7	23.400	33	54.600
8	24.600	34	55.800
9	25.800	35	57.000
10	27.000	36	58.200
11	28.200	37	59.400
12	29.400	38	60.600
13	30.600	39	61.800
14	31.800	40	63.000
15	33.000	41	64.200
16	34.200	42	65.400
17	35.400	43	66.600
18	36.600	44	67.800
19	37.800	45	69.000
20	39.000	46	70.200
21	40.200	47	71.400
22	41.400	48	72.600
23	42.600	49	73.800
24	43.800	50	75.000
25	45.000	51	76.200

Table 5. Determination of Environmentally Recommendable Catch (CER) ±15% from the number of cold days (días fríos) of the previous dry season.

Flows of rivers feeding the Gulf of Panama as a predictor

The same as with temperatures, we work with a data base supplied by ETESA with the flows of rivers of the Pacific watershed between 1995 and 2012. A significant negative correlation was found (-0.39) between high flows of the last quarter of the year and anchoveta catches the year after.

It was remarkable that when establishing an index directly proportional to the number of cold days of the current year and inversely proportional to the high flows of the previous year, the correlation between the combination of environmental factors and catches climbed up to 0.623. The same as with temperature, an "environmental exploitation index" was created whose results are shown in Chart 19.

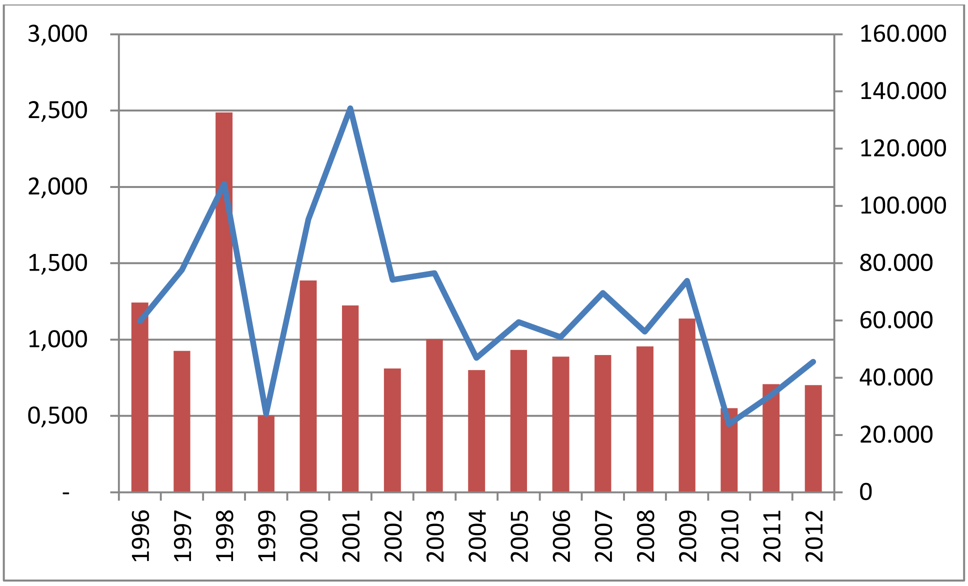

Chart 19. Relation between anchoveta catches (blue line) and "environmental exploitation index" (red bars) depending on cold days of the current year and river flows from the previous year. 1996-2012.

As illustrated in Chart 19, the combination of these two factors offers a slightly different scenario, maybe less striking, where we can see with certain exceptions such as the year 1998, that anchoveta catches follow a pattern controlled by environmental factors.

Consequently, it is **necessary to have available data bases of river flows updated in real time for a better assessment of this interaction.** The latter would be used, in turn, as a predictor to determine allowable catches per year. Probably rainfall data could be a good substitute. This certainly needs more follow up to create a practical tool.

Likewise, **these efforts should also be applied to the herring abundance and availability analyses**.

Other indicators

Small pelagic species play a key role in the general health of marine ecosystems, as they feed from plankton and become the food source for other fish, birds, reptiles and marine mammals. In the case of the Gulf of Panama, it is important to consider the evolution of bird populations as an indicator both of the health of the ecosystem in general and of the small pelagic stocks in particular.

It should be noted that the Gulf of Panama has been highlighted by very important institutions such as the Smithsonian Institute and the Audubon Society as a place of global and national importance for numerous species of marine, aquatic and migratory birds.

In 2005 and 2006, a mission from STRI and the Audubon Society of Panama carried out a complete survey of marine and wading birds using air, water and land resources, estimating the total population of birds in more than 50,000 individuals that belong to 20 species, nesting in 57 places. Among them, the pelican is predominant.

Species	Population	Nests
Brown pelican	21,000	4,800
Cormorant		3,600
Frigates		2,200

Table 6: Marine bird populations and nests 2005-2006. Source: Angehr et al, 2007

It should be highlighted that the nesting and feeding period of marine young birds coincide with the dry season and the upwelling in the Gulf of Panama, just before the opening of the fishing season. Therefore, the interaction between the fleet and birds looking for food for their young is very low. Moreover, during the fishing season, the fleet operates around the coastal area, as has already been mentioned, whereas the birds move in a much wider radio inside the Gulf, moving in several islands and islets in many cases without anthropogenic intervention whatsoever.

During the fishing activities, the interaction is mostly positive, making available a large amount of food within the net circle from which the birds take advantage fishing at their leisure. In the final stages of the pump aboard operations, a pelican might occasionally end up entangled in the fishing gear despite the efforts of the fishermen to scare them off, as they pay no heed to the imminent danger. In general they are released although sometimes they end up severely damaged. However, according to the survey mentioned, "there is no evidence in the long run of declining marine or wading birds in the Gulf of Panama" (Angehr et al, 2007) and fishing is not among the potential threats listed at that paper.

This conclusion of the scientist of the STRI and the Audubon Society is a key indicator to conclude that the small pelagic populations are not in a "declining situation"

Bycatch analysis

In 2013 and 2014 around 250 sets were sampled. These samplings reveal that the Pacific bumper catch represents, in average, less than 5% of the total catch and that no other species represents even more than 0.5% of the total volume caught, adding in total less than 2% of total catches (see Table 7)

Species	%	Species	%
Cynoscion phoxocephalus	0.336	Peprilus snyder	0.008
Selene peruviana	0.147	Oligoplites altus	0.006
Pomadasys panamensis	0.127	Isopisthus remifer	0.006
Bardiela armata	0.123	Polydactylus approximans	0.006
Bagre panamensis	0.086	Pseudupeneus grandisquamis	0.005
Caranx vinctus	0.082	Diapterus peruvianus	0.004
Oligoplites refulgens	0.040	Cynoscion squamipinni	0.004
Larimus acclivis	0.037	Lutjanus guttatus	0.002
Larimus argenteus	0.035	Selene brevoortii	0.002
Nebris occidentalis	0.029	Eucinostomus gracilis	0.002
Peprilus medius	0.027	Occidentarius platypogon	0.001
Odontognathus panamensis	0.026	Caranx caballus	0.001
Ariopsis guatemalensis	0.019	Polydactylus opercularis	0.001
Sphyraena ensis	0.017	Hemicaranx zelotes	0.001
Mugil curema	0.014	Eucinostomus currani	0.001
Centropomus robalito	0.013	Diapterus aureolus	0.001
Cyclopsetta querma	0.012		

Table 7: Percentages of bycatch per species compared to total volume landed by the small pelagic fleet. Source: Observers Program CeDePesca-Promarina

The most frequent species, with 0.336% (that could mean around 300 tons per year) was cachema weakfish (*Cynoscion phoxocephalus*) with average sizes per set between 23 and 36 cm. This figure represents less than 10% of the national landing estimated for this species (very popular in the local market). In the red list of the UICN this species is classified as Least Concern (LC), the same as the following 10 species appearing in Table 7.

In conclusion, the impact of the different bycatch species is of little significance, in coincidence with previous results of the Productivity-Susceptibility Analysis, carried out in 2012 (See below).

Regarding the interaction with protected species, in the 250 sets only one sea turtle was spotted and she was not caught. No shark species were caught either.

The only management recommendation possible is to maintain the permanent monitoring of onboard observers.

Habitats

The composition of by-catch species, including elements from the demersal and pelagic environment, confirms that when operating in shallow areas, purse seines reach the seabed. Nevertheless the bottoms with hard structures are carefully avoided to prevent fishing gear damages, and the fishery operates only in muddy bottoms.

There are several rules creating non take zones to protect mangroves and river mouths, thus creating additional protection to important portions of seabed where mud is prevalent (see Chart 20).

Bahía Chame	Resolución AG #364 de 2009
Manglares de la Bahía de Panamá	Ley #1 de 2015
Panamá Viejo	Decreto Ejecutivo #210 de 1965
Puerto Aguadulce	Decreto Ejecutivo #210 de 1965
San Carlos - Río Hato	Decreto Ejecutivo #210 de 1965

Chart 20. Non take coastal zones to protect mangroves and high productivity areas.

Compliance with these rules has not been very good some years ago but has been improving recently since VMS is mandatory.

Productivity-Susceptibility Analysis

The PSA was applied to the target species of the fishery (in this case anchoveta and herring), to bycatch species retained onboard (for instance, Pacific bumper and cachema weakfish, among others) and to bycatch species that are discarded or considered vulnerable (for instance, turtles and pelicans).

The use of the Productivity-Susceptibility Analysis requires a deep literature review about each one of the species involved in the fishery, to determine certain features that indicate their biological “productivity”. More precisely, the following variables related to productivity are studied: average age and average size at first maturity, average maximum size and age, fecundity, reproductive strategy and trophic level (place in the food web). Each item receives a score. There are three possible scores: low productivity (3), medium productivity (2) or high productivity (1). The scores received by each item are added and the average indicates the risk level presented by the productivity of each species.

Likewise, the “susceptibility” of species towards fishing is estimated according to four items, namely: accessibility (relation between the geographical deployment of the fleets and the distribution of the species); vulnerability (the distribution of the species and the depth reached by the fishing gear); selectivity (related to the efficiency of the fishing gear); and post-catch mortality of the species. Each one of these items receives a score, representing a risk scale with three levels: high (3), medium (2) or low (1). The scores received by each item are multiplied and the average indicates the susceptibility level of each species.

The methodology is precautory, meaning that if there are no definite data for giving a score to the risk of the items included in productivity and susceptibility, those items should receive a high risk score.

The combined productivity and susceptibility scores (Table 8) give as a result the total risk level (high, medium or low) faced by each species, as shown in Chart 21.

Referring to Chart 21, it was estimated that the flathead grey mullet, Pacific bumper and herring face low risk of being negatively affected by the fishery of small pelagic with purse seines in the Gulf of Panama; whereas anchoveta, red sea catfish, cachema weakfish, Pacific sierra, yellow bobo and the pelicans face medium risk of being negatively affected by the fishery. For most of these species, productivity was considered medium to high, except in the case of pelicans and the red sea catfish that received a low to medium score.

		Productivity Scores [1 3]								Susceptibility Scores [1 3]						PSA scores (automatic)	
SCIENTIFIC_NAME	COMMON_NAME	Edad promedio madurez	Edad maxima promedio	Fecundidad relativa	Talla maxima promedio	Talla promedio madurez	Estrategia reproductiva	Nivel trofico	Productividad promedio	Solapamiento horizontal	Solapamiento vertical	Selectividad	Mortalidad post-captura	Susceptibilidad	Color en el PLOT	Puntaje PSA	Categoria de riesgo
Cetengraulis mysticetus	Anchoveta	1	1	1	1	1	1	1	1,00	3	3	3	3	3,00		3,16	Med
Opisthonema libertate	Arenque	1	1	1	1	1	1	2	1,14	2	3	3	3	2,33		2,59	Low
Chloroscombrus orqueta	Orqueta	1	1	1	1	1	1	1	1,00	2	3	3	3	2,33		2,53	Low
Cynoscion phoxocephalus	Corvina rolliza	1	2	1	1	1	1	3	1,43	2	3	3	3	2,33		2,73	Med
Polydactilus opercularis	Bobo amarillo	1	1	2	1	1	2	3	1,57	2	3	3	3	2,33		2,81	Med
Sphyraena ensis	Barracuda	1	2	1	2	2	1	3	1,71	2	3	3	3	2,33		2,89	Med
Scomberomorus sierra	Sierra	1	2	1	1	1	1	3	1,43	2	3	3	3	2,33		2,73	Med
Penaeus vanammei	Camaron	1	1	1			1	1	1,00	2	3	3	3	2,33		2,53	Low
Bagre panamensis	Alguacil	2	2	2	1	2	2	3	2,00	2	3	3	3	2,33		3,07	Med
Cynoscion albus	Corvina amarilla	2	3	1	2	2	1	3	2,00	2	3	3	3	2,33		3,07	Med
Larimus acclivis	Cirila roja	1	2	2	1	1	1	3	1,57	2	3	3	3	2,33		2,81	Med
Nebris occidentalis	Guabina	1	3	2	1	1	1	3	1,71	2	3	3	3	2,33		2,89	Med
Pelecanus occidentalis murp	Pelicano	1	3	3	2	2	3	3	2,43	2	3	3	2	1,88		3,07	Med
Chelonia mida	Tortuga verde	3	3	2	1	2	2	2	2,14	1	3	3	2	1,43		2,57	Low

Table 8. Productivity-Susceptibility Analysis results for a group of species related to the small pelagic fishery in Panama

Anchoveta: Anchoveta Arenque: Herring Orqueta: Pacific bumper Corvina rolliza: Cachema weakfish Bobo amarillo: Yellow bobo Barracuda: Great barracuda Sierra: Pacific sierra	Camaron: Shrimp Alguacil: Red sea catfish Corvina amarilla: Whitefin weakfish Cirila roja: Steeplined drum Guabina: Twospot lebiasina Pelícano: Pelican Tortuga verde: Green turtle

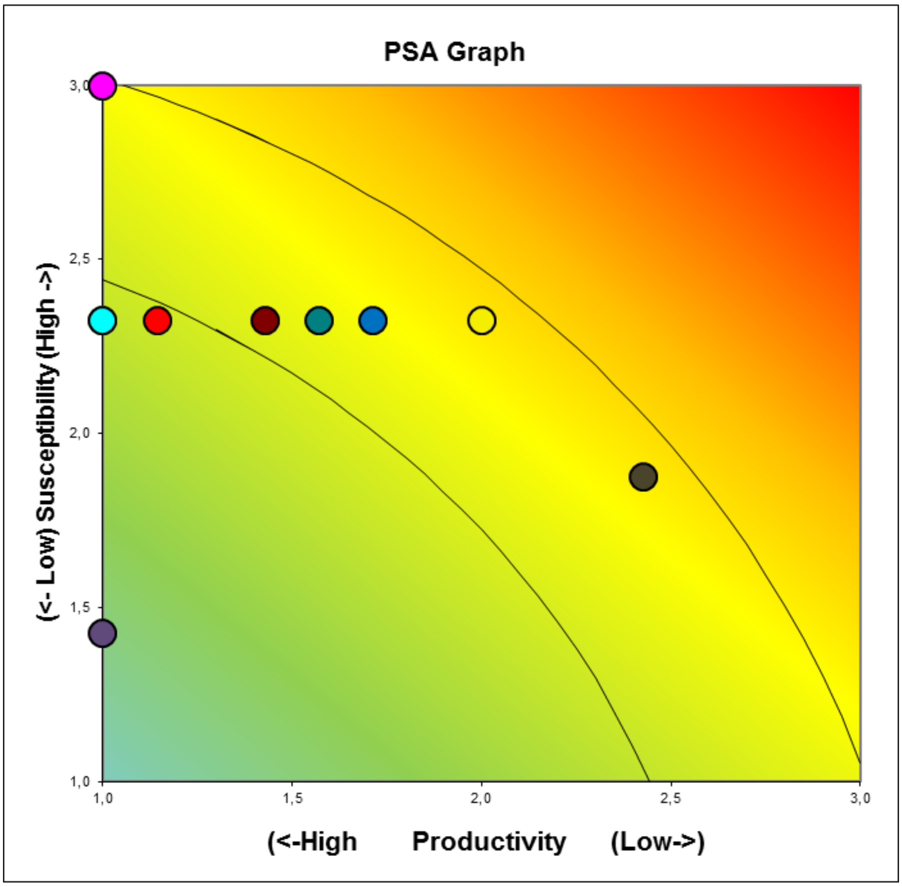

Chart 21. Plot of the results of the PSA analysis for species

Also a Consequence Spatial Analysis was conducted for soft habitats resulting in a low risk:

	Productivity Scores [1 3]			Susceptibility Scores [1 3]						PSA scores (automatic)	
Habitat	RF	ED	Rr	A	E	CI	E	Rq	Color	Puntaje PSA	Categoria de Riesgo
Fangoso	1	2	1,50	3	3	1	1	1,20		1,92	Low
Arenoso	1	2	1,50	2	3	1	1	1,13		1,88	Low

Table 9. CSA analysis for habitats impacted by the small pelagics fishery

Recommendations for a Management Plan

So far, it would be advisable to maintain the current features of the fishery, with some adjustments:

1. Maintain the catch and effort data base updated
2. Maintain the criterion that the average size of the sampling must be ABOVE 13 cm for anchoveta before opening the fishing season in April.
3. Avoid the catch of herring schools whose average size would be under 17.4 cm, changing the area when noticing mostly small fish.
4. Establish a range of Environmentally Advisable Catch for anchoveta at the opening of the season, once the data of cold days for the first four-month period of the year are available. This Environmentally Advisable Catch will be experimented while more extensive studies for this population will become available.
5. Maintain the criterion of suspending anchoveta fishing when its reproductive period starts by the middle of the year.
6. While there are no new results coming from the work of the herring stock analysis, it seems wise to maintain catches around its recent average (around 35 thousand tons) and never above 38 thousand tons.

According to these limits, it seems advisable not to increase under any circumstance the current level of effort, establishing that when vessels are replaced, the current fishing capacity should be maintained.

These recommendations are dependent on the results of the research work on course that will allow for more precise limits.

The necessary research lines include the following:

- Maintain systemic gathering of data regarding search time between successful sets once arriving to the fishing ground
- Maintain data gathering about size structures of the catch of target species, as well as their maturity stages, in relation to space distribution and individual weight of those specimens sampled.
- Incorporate a program to identify herring species, using samples from the Observers Program.
- Include an analysis of the age of sampled specimens by means of reading of scales or other hard parts, using samples from the Observers Program.
- It would be highly advisable to put in practice hydroacustic prospecting each two years in the whole area of the Gulf of Panama. The most cost-effective solution should be found.
- Include a systematic abundance assessment of the phytoplankton in coastal areas of the Gulf of Panama
- Continue the systematic data gathering of surface temperature of the sea water
- Put in practice an efficient mechanism to obtain updated information about the flow of rivers feeding the Gulf of Panama or rainfall levels.
- Maintain the assessment of bycatches.
- Systematically gather data about birds nesting areas as an indicator of the health of the ecosystem and of the small pelagic stocks.

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