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Ontogenic and seasonal variations of metal content in a small pelagic fish (*Trachurus picturatus*) in northwestern African waters

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A B S T R A C T

Marine organisms are exposed to great changes induced by human beings due, among others, to discharges into the oceans, increasing marine pollution. For this study, 294 specimens of *Trachurus picturatus* from the Canary Islands were analyzed during a period of 2 years. The concentration of 11 anthropic metals and trace elements was determined in each individual using the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique. Statistical analyses were carried out considering the following factors: oceanographic season, maturity of the gonads, size of the specimens, season. Immature specimens had higher concentration in more metals than the mature specimens. This fact may be due to the fact that these specimens require a much higher metabolic rate due to their growth and do not detoxify like mature specimens.

1. Introduction

The Canary Islands archipelago is located off the northwest coast of Africa, with a distance from the continent of between 100 and 450 km depending on the island (Fig. 1). Their volcanic origin explains the reduced coastal shelf, especially in the western islands, which affects the oceanographic conditions and limits abundance and distribution of marine organisms, also influenced by the NW African upwelling that contributes nutrients to the oligotrophic waters (Coca et al., 2014; García-Mederos et al., 2015; Landaeta et al., 2012). The Canary archipelago is a place of great tourism throughout the year, especially in the summer months, this increase in population leads to more coastal pollution in these months. The emission of underwater sewage outfalls, water runoff from crop plants that discharge harmful compounds and metals into the ocean mean that coastal pollution in the archipelago has increased in recent years (Lozano-Bilbao et al., 2018a, 2019b).

Fish species are highly affected by overfishing, meaning that fishing grounds in some areas of the world are currently overexploited (Fujiwara, 2012). In the Canary Islands, the artisanal purse-seine fleet targeting small pelagics (mainly *Scomber colias*, *Trachurus picturatus*, *Sardinella aurita* and *Sardina pilchardus*) produces around 70% of the fishing landings, constituting the second most important fishing resource in the archipelago, after tuna (Jurado-Ruzafa et al., 2019).

Coastal and marine systems are critical areas for global food security and for the economic well-being of nations, particularly in developing countries (Ruilian et al., 2008; Topcuo, 2003). There is growing concern about the direct or indirect introduction of pollutants into the marine environment. In recent years, marine ecosystems have been contaminated by heavy metals coming from various anthropomorphic sources such as industry, agriculture, domestic waste, mining, as well as other sources of natural origin (Rubio et al., 2018). About 70% of the contamination comes from anthropogenic land-based activities, in which domestic, industrial and agricultural waste ends up dumped in coastal water, generally by means of submarine outlets (Fort et al., 2016; Lozano-Bilbao et al., 2018a; Žvab Rožič et al., 2012).

These pollutants constitute a serious risk to the environment, since they are highly stable chemical substances in terms of biodegradation processes, what means that living beings are unable to metabolize them. This fact promotes the bioaccumulation phenomena and a multiplier effect on the concentration of these elements in the trophic network (Bustamante et al., 2016a, 2016b; Carravieri et al., 2014). On one hand, toxic heavy metals (such as Hg, Pb or Cd) have harmful

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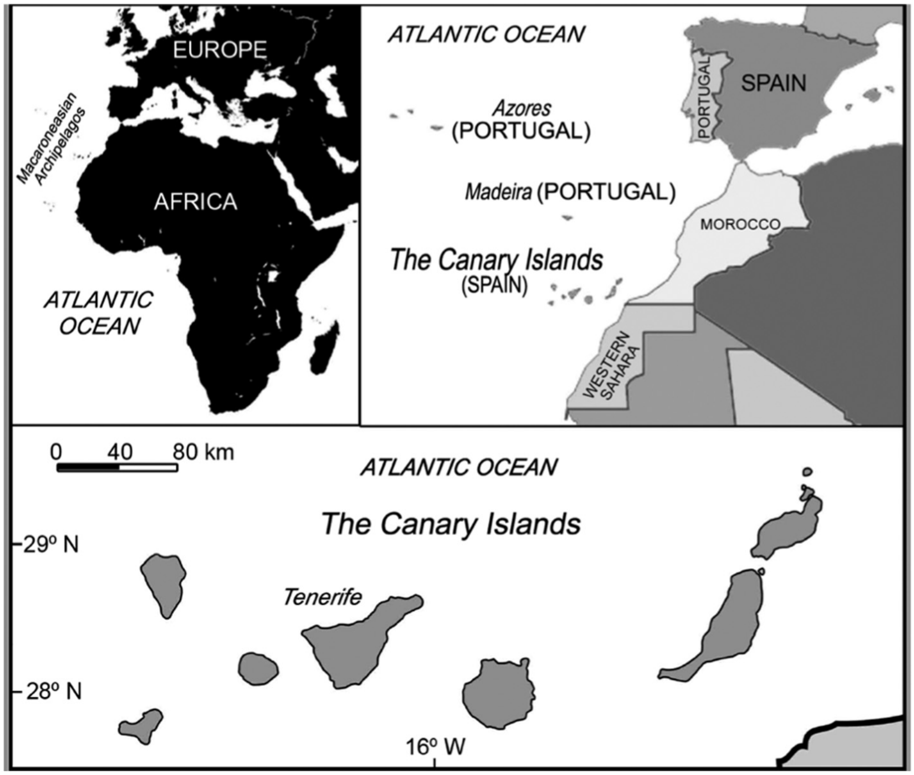

Fig. 1. Map of the study area (from Lozano-Bilbao et al., 2019b).

effects on the organisms. On the other hand, macro- and micronutrients (or trace elements) are required by the organism for the proper functioning of metabolic processes (Lozano-Bilbao et al., 2020). However, trace elements can have beneficial or harmful properties in plants, animals and humans depending on their concentration (Bustamante et al., 2016a, 2016b; Carravieri et al., 2014; Dorta et al., 2015; Hosono et al., 2011; Lozano-Bilbao et al., 2020, 2019a, 2018a, 2018b, 2018c; Raimundo et al., 2013). Although several studies have addressed the content of metals and trace elements in commercial marine species in the area (Lozano-Bilbao et al., 2019b; Rubio et al., 2018), the possible seasonal and ontogenic variations have not been analyzed. Therefore, the aim of this study is to analyze possible linkage between the metal and trace elements content in the blue jack mackerel (*Trachurus picturatus* (Bowdich, 1825) and seasonal variation and biology stage).

2. Material and methods

When possible, monthly samples were analyzed from commercial catches by the artisanal purse-seine fleet of Canary. The samples were acquired in the island of Tenerife, where > 70% of the small pelagic fish catches of the Canary Archipelago are landed (Fig. 1). A total of 294 blue jack mackerel specimens were sampled from June 2016 to May 2018, with total lengths between 12.0 and 30.2 cm (mean length = 19.52 ± 2.39 cm).

Biological sampling consisted on recording next data of each specimen: the total length, total weight, sex, and sexual maturity state of each specimen by macroscopic observation of the gonads, according to a general scale of 5 states of maturity (1, virgin, 2, immature or in recovery, 3: maturing, 4: spawning, 5: post-spawning).

2.1. Sample preparation

The analytical sample consisted of a portion of muscle of around 10–15 g. The samples were placed in porcelain crucibles and dried in an oven at a temperature of 70 °C for 24 h. They were then incinerated in a muffle furnace for 48 h at 450 °C ± 25 °C, until obtaining white ashes. If after this time, the total mineralization of the samples had not been achieved (white or gray-white ash), a few drops of 65% HNO_3 were added to the samples under the gas hood, and they were later evaporated on a heating plate at 70–90 °C. Once treated, they were re-incinerated in a muffle-furnace at 450 °C ± 25 °C until white ashes were obtained.

Once the white ashes were obtained, they were filtered with a 1.5% HNO_3 solution, made up to 25 ml for the subsequent determination of the metal content by means of Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), to determine the metal concentration of the samples. Table 1 shows the limits of detection and wavelengths used to measure the metals (Afonso et al., 2018).

Table 2 shows the number of tourists, temperature stations and chlorophyll concentration data in the Canary Islands for the months of study, the chlorophyll values (Chl-a, mg/m^3) were chosen because in the Canary Islands it is closely related to the upwellin, it is in the winter months where this effect has more incidence, it is observed in Table 2 that is also where there is more concentration of Chlorophyll. The

Table 1
Limits of detection and quantification of the toxic heavy metals (*) and trace elements analyzed by ICP-OES.

Metal	Detection wavelength (nm)	Limit of detection (LD) (mg/L)	Limit of quantification (LQ) (mg/L)
Al*	167.0	0.004	0.012
B	249.7	0.003	0.012
Cd*	226.5	0.0003	0.001
Cr	267.7	0.003	0.008
Cu	327.3	0.004	0.012
Fe	259.9	0.003	0.009
Li	670.8	0.005	0.013
Ni	231.6	0.0007	0.003
Pb*	220.3	0.0003	0.001
V	310.2	0.001	0.005
Zn	206.2	0.002	0.007

Table 2
Seasons, chlorophyll concentration, temperature and number of tourists for each month in the Canary Islands.

Month	Season	2016			2017			2018		
		Chl-a (mg/m^3)	(T°)	Tourists	Chl-a (mg/m^3)	(T°)	Tourists	Chl-a (mg/m^3)	(T°)	Tourists
January	Cold				0.269	19 °C	1.1 M	0.275	19 °C	1.2 M
February	Cold				0.246	19 °C	1 M	0.312	18 °C	1 M
March	Cold				0.235	18 °C	1 M	0.251	18 °C	1.3 M
April	Cold				0.153	19 °C	1 M	0.187	19 °C	0.9 M
May	Cold				0.121	21 °C	0.9 M	0.164	19 °C	0.9 M
June	Cold	0.163	21 °C	1.1 M	0.118	21 °C	0.9 M			
July	Hot	0.144	22 °C	1.3 M	0.132	22 °C	1.2 M			
August	Hot	0.138	23 °C	1.3 M	0.152	23 °C	1.1 M			
September	Hot	0.152	23 °C	1.1 M	0.161	24 °C	1.1 M			
October	Hot	0.153	23 °C	1.2 M	0.139	24 °C	1.3 M			
November	Hot	0.145	22 °C	1.1 M	0.154	22 °C	1.2 M			
December	Hot	0.156	20 °C	1.2 M	0.231	21 °C	1.2 M			

monthly values from June 2016 to May 2018 were downloaded for the geographical area that makes up the Canary Islands (27–30° N, 13–18.5° W), from the GIOVANNI database (Acker and Leptoukh, 2007) and the tourist data has been collected from the Canarian Institute of Statistics (www.gobiernodecanarias.org/).

2.2. Statistical analysis

In order to know whether there were significant differences in the content of heavy metals and trace elements among the analyzed samples, multivariate permutational analyses of variances (PERMANOVA) were performed with euclidean distances (Anderson and Braak, 2003).

In all analyses, 4999 interchangeable unit permutations and a posteriori comparisons were used to determine the differences between the levels of the significant factors (p-value < 0.05) (Anderson, 2004). The PRIMER 7 and PERMANOVA + v.1.0.1 statistical packages were used for the statistical analyses.

The variables included in the analyses were the concentration in mg/kg of the following heavy metals and trace elements due to their anthropic character: Al, B, Cd, Cr, Cu, Fe, Li, Ni, Pb, V and Zn (Hosono et al., 2011; Qing et al., 2015; Temsch et al., 2010).

2.3. Seasonal variation of the metal concentration study

A one-way design with the fixed factor “Season” with two levels of variation was used, bearing in mind that in the Canary Archipelago two seasons can be considered based on variations in the concentration of chlorophyll *a*, the surface temperature of seawater and its anomalies (Jurado-Ruzafa et al., 2019): a cold season (from January to June) and a hot season (from July to December), using also these levels of the “Season” factor for the pairwise tests (Jurado-Ruzafa et al., 2019).

2.4. Comparison of the metal concentration depending on the size of the specimens

A one-way design with the fixed factor “Length” was used considering the following size groups as levels of variation: small (< 13.8 cm), medium (13.9–17.4 cm) and large (> 17.5 cm).

2.5. Comparison of the metal concentration between sex and by stage of maturity of the specimens

One-way designs with the fixed factor “Sex” and “Maturity” were used with two levels of variation: male/female, and immature (stage 1 and stage 2 immature) and mature (stage 2 at rest and stages 3, 4 and 5), respectively.

2.6. Interannual comparison of the metal concentration for each season

To prove possible variations caused by interannual differences, a two-way design was used with the fixed factors “Year” with two levels of variation: first year (from June 2016 to May 2017) and second year (from June 2017 to May 2018) and “Season” with the two levels of variation: cold season/hot season, using the levels of the “Season” factor in the pairwise tests.

2.7. Seasonal comparison of the metal concentration for each maturity level in each season

A two-way design was used with the fixed factors “Season” (with the two levels of variation: cold season/hot season) and “Maturity” (with two levels of variation: immature/mature (stage 2-which exceeded the size of first spawning and stages 3, 4 and 5), using the levels of the “Season” factor in the pairwise tests.

3. Results and discussion

Table 3 shows the mean values obtained and the standard deviation in the analysis of the variations in the content of heavy metals and trace elements in the blue jack mackerel *T. picturatus* from the Canary Islands.

Statistically significant differences were observed, with higher concentration of Al, B and Li in the individuals caught during the hot season (Table 4). In the cold season, Cd and Pb (Fig. 2) resulted statistically significant different, with higher concentrations in the specimens collected during the same season. This phenomenon may be due to the effect of African upwelling, which has a greater presence and influence on the Canary waters during the cold season (Table 2) (Auger et al., 2015; Barton et al., 1998; Marcello et al., 2011; Pérez-Matus et al., 2017). The second year, which is from June 2017 to May 2018,

Table 3
Mean and standard deviation of the concentration in toxic heavy metals (*) and trace elements obtained in *T. picturatus* from the Canary Islands. sd: standar deviation.

	Mean concentration (mg/kg wet weight) ± sd
Al*	7.577 ± 5.083
B	0.200 ± 0.131
Cd*	0.018 ± 0.012
Cr	0.217 ± 0.433
Cu	1.233 ± 0.644
Fe	13.601 ± 7.747
Li	0.453 ± 0.472
Ni	2.122 ± 2.959
Pb*	0.131 ± 0.216
V	0.050 ± 0.076
Zn	8.299 ± 3.424

Table 4
Results of pairwise tests of the two stations and mean and standard deviation in the content of heavy metals and trace elements (mg/kg wet weight) in *Trachurus picturatus* by seasons.

	Cold season	Hot season	Cold vs. hot
Al	8.060 ± 4.569	6.835 ± 5.726	0.003*
B	0.219 ± 0.138	0.171 ± 0.114	0.003*
Cd	0.016 ± 0.009	0.021 ± 0.015	0.006*
Cr	0.181 ± 0.185	0.274 ± 0.648	0.445
Cu	1.245 ± 0.504	1.215 ± 0.817	0.131
Fe	13.172 ± 7.782	14.257 ± 7.680	0.191
Li	0.496 ± 0.513	0.387 ± 0.396	0.013*
Ni	2.284 ± 3.131	1.873 ± 2.668	0.066
Pb	0.095 ± 0.088	0.186 ± 0.32	0.001*
V	0.052 ± 0.087	0.048 ± 0.055	0.994
Zn	8.309 ± 3.732	0.284 ± 2.904	0.761

* p-value < 0.05.

the oceanographic parameters deviated a lot from normal since there were no trade winds in the summer months in the archipelago, a phenomenon that led to very high temperatures reaching even to appear on the coasts blooms of *Trichodesmium erythraeum*, a dinoflagellate concurrent in the Islands but which due to meteorological conditions accumulated in large concentrations near the coasts (Ramos et al., 2005). According to Kumar et al. (2015) phytoplankton fish and algae species change their distribution due to a *T. erythraeum* bloom, which is why the change in feeding distribution of these species could induce lower metal concentrations. It should also be noted that in the summer months there is an increase in population due to foreign tourism, that although there is a lot of tourism throughout the year in the Canary archipelago, it is in the summer months that there is a greater spike, due to this contamination increases. Cd and Pb also have a markedly anthropic character (Castro-González and Méndez-Armenta, 2008; Zhou et al., 2016), and their increase during the cold season could be related to a higher foreign tourism in the islands during this season.

The analysis depending on the size of the specimens showed that the smallest specimens had the highest concentrations of B and Cd; the medium specimens had the greatest concentration of Al, Cr, Cu and V; and the biggest specimens showed the highest concentrations of Fe, Li, Ni, Pb and Zn (Table 6). In the case of Al (Fig. 3), Cr, Cu, Pb and V, the highest concentrations were found in the medium sized specimens (Table 5). It should be mentioned that the largest specimens in the present study (30 cm) were much smaller than the maximum length recorded for this species, which reaches 60 cm (Fowler, 1936). As mentioned, fish bioaccumulate substances from the environment and this phenomenon leads directly to a biomagnification process, so that if the analyzed size range was wider, larger specimens not present in the sample probably content higher concentrations of the studied elements (Abdul-Wahab et al., 2013; Catsiki and Strogyloudi, 1999; Çogun et al., 2006; Keil et al., 2008; Man et al., 2014). The higher concentration of B and Cd in smaller specimens could be due to a higher metabolic rate in young specimens (Metcalfe et al., 2016) and a less effective detoxification mechanism of these metals (Alak et al., 2019; Ando et al., 2020).

Regarding the relationship between the maturity stage of the specimens and the metal concentration, the mature specimens presented higher metal concentrations of Al, B, Li, Ni and Zn, while in the immature specimens had the highest concentrations of Cd, Cr, Cu, Fe, Pb and V (Table 7) (Fig. 4). In the pre-reproductive period, there is an increase in energy investment towards the production of reproductive products, with a progressive increase in gonads biomass (Lockwood et al., 1981; Techetach et al., 2019; Vasconcelos et al., 2012), and the metals accumulated in the fat pass to the gonads. The latter may explain a higher concentration of some of the metals in the muscle tissue of immature specimens (Kadri et al., 1996), such as Cd that tends to become fixed in the bones (Shirkhanloo et al., 2016).

The analysis with the factors "maturity" and "season" revealed significant differences (Table 8), with higher concentrations of Cd, Cr, Cu and Fe for the hot season in immature specimens. Immature specimens also presented a higher concentration of V during the cold season, and mature specimens had higher concentrations of Al and Pb for the hot season (Fig. 4). It should be taken into account that they are two closely related factors, since the sexual maturation of the species depends directly on oceanographic conditions, especially on ocean temperature (Cury et al., 2000; Gordo et al., 2008; Murta et al., 2008). The fact that oceanographic conditions were heterogeneous between the two years may explain the difference found between mature specimens with the highest concentration of metals in the cold season. As regards the immature specimens, they had higher concentrations of metals during the hot season. In the Canary Islands, the blue jack mackerel spawns between January and April (Jurado-Ruzafa and García Santamaría, 2013), which matches with the cold season and could

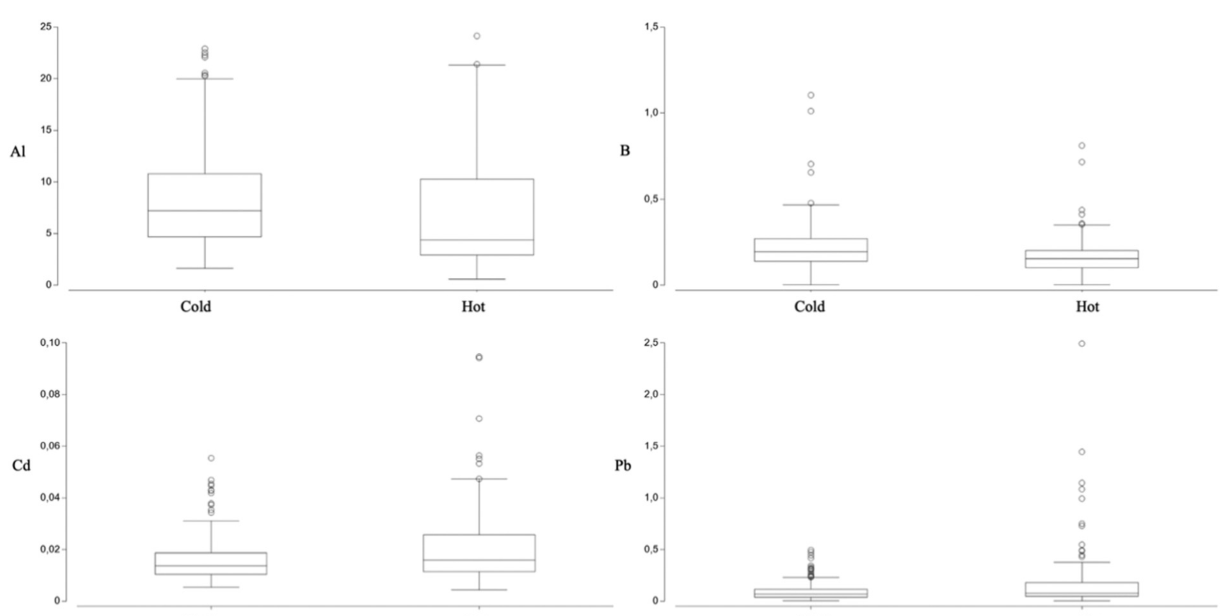

Fig. 2. Box Plot graphs for Al, B, Cd and Pb content (mg/kg wet weight) in *T. picturatus* for each season. Cold: January to June; Hot: July to December.

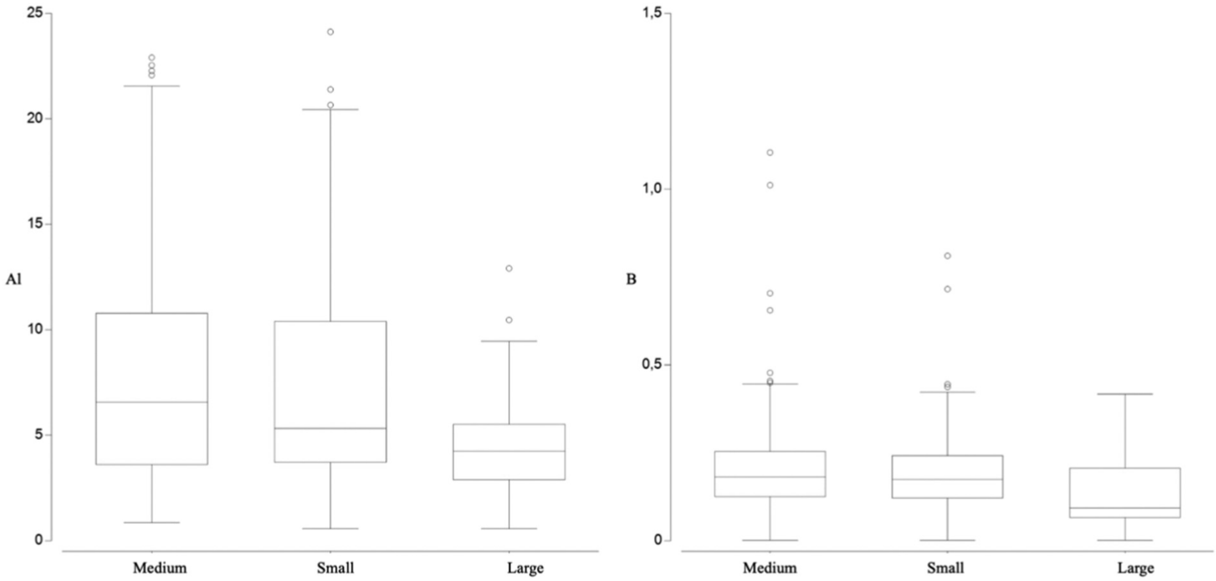

Fig. 3. Box Plot graphs for Al and Cd content (mg/kg wet weight) according to the degree of sexual maturity of *T. picturatus*.

Table 5
Mean ± standard deviation (mg/kg wet weight) in *Trachurus picturatus* for each size group.

	Large	Medium	Small
Al	6.188 ± 3.077	6.685 ± 3.726	6.587 ± 3.723
B	0.145 ± 0.070	0.139 ± 0.072	0.152 ± 0.087
Cd	0.018 ± 0.028	0.020 ± 0.013	0.021 ± 0.017
Cr	0.222 ± 0.349	0.245 ± 0.318	0.165 ± 0.210
Cu	1.314 ± 0.640	1.409 ± 0.73	1.309 ± 0.631
Fe	16.304 ± 6.409	13.963 ± 5.836	13.528 ± 5.355
Li	0.541 ± 0.689	0.464 ± 0.691	0.519 ± 0.067
Ni	2.849 ± 7.140	2.480 ± 3.535	2.450 ± 4.889
Pb	0.138 ± 0.193	0.146 ± 0.189	0.101 ± 0.104
V	0.023 ± 0.016	0.119 ± 0.801	0.041 ± 0.060
Zn	9.656 ± 3.626	8.262 ± 2.930	8.350 ± 3.269

Table 6
Results of pairwise tests comparing metal and trace element content between size groups of *T. picturatus*.

	Small vs. medium	Small vs. large	Medium vs. large
Al	0.636	0.086	0.027*
B	0.984	0.029*	0.032*
Cd	0.002*	0.026*	0.161
Cr	0.001*	0.512	0.244
Cu	0.001*	0.692	0.178
Fe	0.037*	0.064	0.418
Li	0.631	0.301	0.932
Ni	0.138	0.330	0.705
Pb	0.006*	0.478	0.663
V	0.001*	0.004*	0.246
Zn	0.052	0.480	0.779

* p-value < 0.05.

Table 7
Results of pairwise tests of the two degrees of maturity and mean and standard deviation (mg/kg wet weight) for the stages of maturity.

	Immature vs. mature	Immature	Mature
Al	0.004*	6.736 ± 5.082	8.280 ± 4.992
B	0.108	0.189 ± 0.122	0.209 ± 0.139
Cd	0.037*	0.020 ± 0.015	0.017 ± 0.009
Cr	0.007*	0.284 ± 0.605	0.161 ± 0.182
Cu	0.008*	1.362 ± 0.762	1.125 ± 0.505
Fe	0.072	14.414 ± 7.635	12.911 ± 7.797
Li	0.396	0.434 ± 0.461	0.469 ± 0.483
Ni	0.076	1.927 ± 2.896	2.285 ± 3.011
Pb	0.141	0.159 ± 0.300	0.108 ± 0.100
V	0.001*	0.065 ± 0.072	0.039 ± 0.078
Zn	0.981	8.275 ± 3.311	8.319 ± 3.527

* p-value < 0.05.

Table 8
Results of pairwise tests examining the significant factor of "Season and Maturity".

	Cold season	Hot season
	Mature vs. immature	Mature vs. immature
Al	0.001*	0.387
B	0.072	0.071
Cd	0.028*	0.001*
Cr	0.442	0.012*
Cu	0.244	0.001*
Fe	0.540	0.005*
Li	0.453	0.382
Ni	0.286	0.002*
Pb	0.023*	0.104
V	0.003*	0.001*
Zn	0.359	0.653

* p-Value < 0.05.

explain why the mature specimens loss a high percentage of the weight and the consequent reduction in their concentration of metals in the hot season (Jurado-Ruzafa et al., 2019).

Table 9 summarizes the results of the concentration of heavy metals and trace elements reported by different studies on species of the genus *Trachurus*. In the Canary Islands, Rubio et al. (2018) obtained similar results in the concentration of Cd in *T. picturatus*, but the values in the rest of the metals in the present study were higher. This fact may be due to the large number of samples analyzed along two years for the present study since, the metal content in this species varies depending on many factors, as verified above. Therefore, punctual analyses could result biased if temporal and ontogenic variations are not considered.

Raimundo et al. (2013) studied the metal content in *T. trachurus* in Azores waters. With the exception of Ni (present in a lower concentration than in the present study), all the metals studied in their work were present in higher concentrations than those reported here.

Table 9
Concentration of heavy metals and trace elements in *Trachurus* spp. (mg/kg).

Ocean/sea	Atlantic Ocean							Mediterranean Sea	Marmara Sea		
Country	Spain (Canary Islands)		Portugal (Azores)	Morocco	Mauritania	Ghana	South Africa	Spain (Granada)	Turkey (Winter)	Turkey (Summer)	Turkey
Species	*T. picturatus*	*T. picturatus*	*T. trachurus*	*T. trachurus*	*T. trachurus*	*T. trachurus*	*T. trachurus*	*T. picturatus*	*T. trachurus*	*T. trachurus*	*T. trachurus*
Al	7.577	8.76						5.81			
B	0.2	0.07									
Cd	0.018	0.01	0.012	0.077	0.02	0.08		0.31	0.74	0.86	0.05
Cr	0.217	0.14	0.25	0.13			1.8	0.09			
Cu	1.233	1.51	1.7	2.13	2.8	5.58	6.83	1.78	2.65	2.83	
Fe	13.601	7.33		37.07				14.52	56.48	84.32	
Li	0.453	1.08									
Ni	2.122	0.11	0.08	0.148			3.17	0.15	1.52	1.66	
Pb	0.131	0.004	0.043	0.029		0.08	8.44	0.96	0.7	0.78	0.66
V	0.05	0.01	0.16								
Zn	8.299	4.69	12		23	1.7	56.71	23.17	93.19	106.02	
Studies	Present study	(Rubio et al., 2018)	(Raimundo et al., 2013)	(Afandi et al., 2018)	(Roméo et al., 1999)	(Kwaansa-Ansah et al., 2019)	(Debipersadh et al., 2018)	(Rivas et al., 2014)	(Durmus, 2018)		(Cucu et al., 2019)

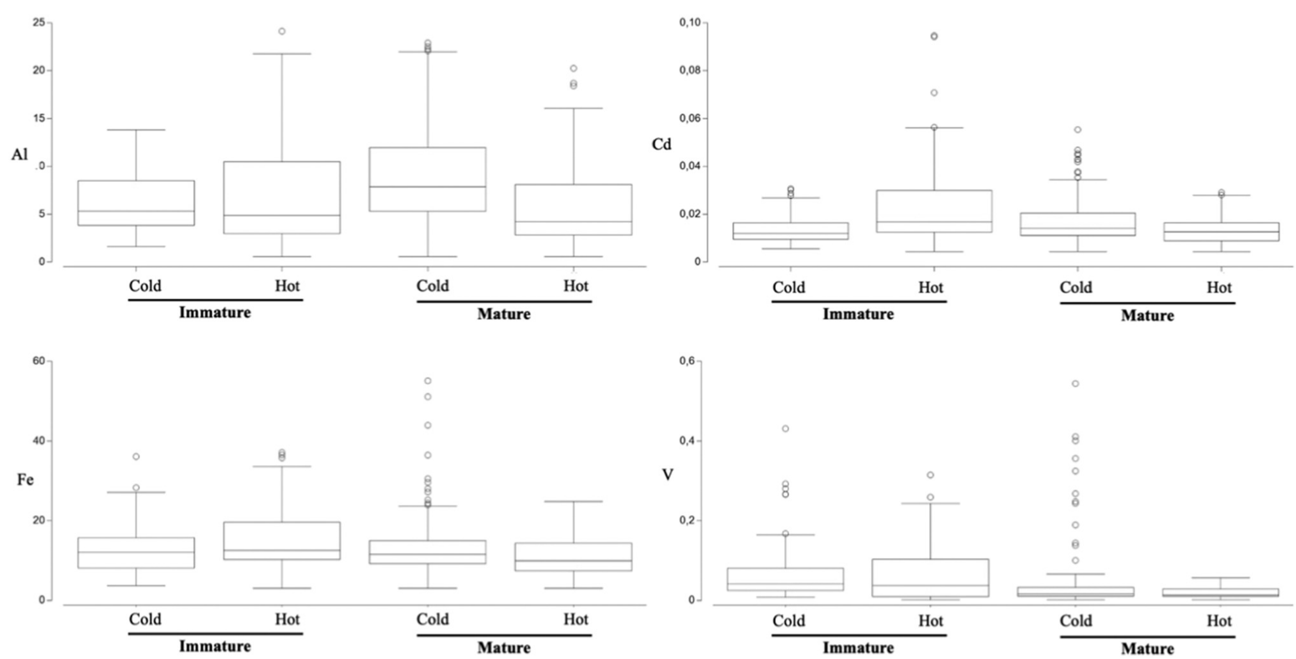

Fig. 4. Box Plot graphs for Al, Cd, Fe and V content (mg/kg wet weight) in each season and maturity group.

Afandi et al. (2018), for the Moroccan coast, and Roméo et al. (1999), for the coast of Mauritania, also analyzed the metal content in *T. trachurus*, and found lower concentrations of Ni and Pb than in the present study, and higher values of Cu, Fe and Zn. These elements are abundant in the sand of the Sahara Desert, which has a greater fertilizing influence on African coasts than on the Canary Islands waters (Al-Taani et al., 2015; Brochier et al., 2018; Lozano-Bilbao et al., 2019b; Ohde and Siegel, 2010).

As for the central and southern Atlantic part of Africa, in South Africa *T. trachurus* has higher concentrations of metals than those in the present study. Rivas et al. (2014) observed that the blue jack mackerel had a higher concentration of Cd and Pb in the Atlantic Ocean, which is probably because this area of the Atlantic is one of the most polluted areas in the Atlantic, and the metal concentrations probably have increased as a result of bioaccumulation through the trophic network (Alomar et al., 2017; Alós et al., 2011; Benedicto et al., 2008; Canli and Atli, 2003; Huang et al., 2013; Markus and Sánchez, 2018) In the Adriatic Sea, Durmus (2018) found that concentrations of metals in *T. trachurus* were higher in summer compared to winter values, Conversely, in the present study, higher concentrations were observed for the cold season with the exception of Cd, Cr, Fe and Pb. The Sea of Marmara, being a highly polluted sea and which includes the large port of Istanbul that introduces high concentrations of polluting elements into the sea, especially in the high summer local tourist season (Aslan et al., 2019; Aydin-Önen and Öztürk, 2017; Dural et al., 2007; Keskin et al., 2007; Korkmaz et al., 2017; Morar et al., 2011; Signa et al., 2017).

4. Conclusions

The high concentrations of Al, B, Li, Ni and especially Zn in the cold season may be due to the effect that upwelling has in the Canary Islands, amounting to shallower bodies of nutrients, it is especially in the months winter when it has more incidence in the Canary archipelago, being demonstrated with the chlorophyll concentrations.

The Canary Islands are very close to the Sahara Desert, whose sand is very rich in Fe, Cu and Zn minerals. In the "calima" phenomena, the dust rich in these metals reaches the Canary Islands Archipelago enriching the waters and entering the trophic network.

The summer months are those that have the highest concentration for Cd and Pb, which are two heavy metals of great anthropic character, it is in the summer months when the number of tourists increases, due to this, the pollution produced by hotels, factories and water treatment places, which pour tons of compounds into the sea, accumulating in organisms.

The higher concentration in more metals in immature specimens than the mature specimens could be due to a much higher metabolic rate (needed for their somatic growth), and a less effective detoxification precesses than mature specimens.

In general, the studied specimens of *T. picturatus* presented lower mean metal concentrations than in other studies conducted in the Atlantic Ocean, with the values from the Moroccan coasts probably linked to the effects of the reach upwelling waters and in the input of sand from the Sahara Desert. The studies conducted on this species in the Mediterranean Sea and showed higher concentrations than those found here because they are highly polluted seas.

CRediT authorship contribution statement

Enrique Lozano-Bilbao: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Validation, Writing - original draft, Writing - review & editing. **Gonzalo Lozano:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Writing - original draft, Writing - review & editing. **Sebastián Jiménez:** Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Validation, Writing - original draft, Writing - review & editing. **Alba Jurado-Ruzafa:** Data curation, Funding acquisition, Validation, Writing - review & editing. **Arturo Hardisson:** Funding acquisition, Methodology, Resources, Validation, Writing - review & editing. **Carmen Rubio:** Funding acquisition, Methodology, Validation, Writing - review & editing. **Dailos González Weller:** Funding acquisition, Validation, Writing - review & editing. **Soraya Paz:** Funding acquisition, Methodology, Validation, Writing - review & editing. **Ángel J. Gutiérrez:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Writing - original draft, Writing - review & editing.

Declaration of competing interest

All authors of this manuscript affirm that there is no conflict of interest.

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