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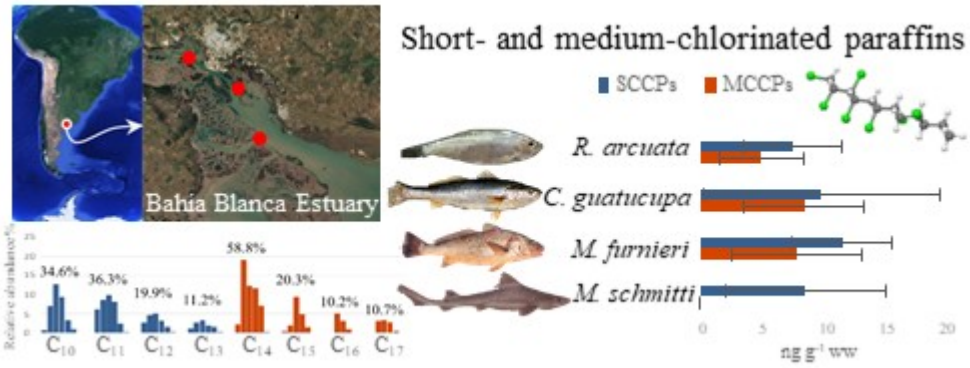


Short- and medium-chain chlorinated paraffins in fish from an anthropized south-western Atlantic estuary, Bahía Blanca, Argentina

Lautaro Girones [1], Yago Guida [2], Ana Laura Oliva [1], João Paulo Machado Torres [2], Jorge Eduardo Marcovecchio [1,3,4,5], Walter Vetter [6], Andrés Hugo Arias [1,7*]

[1] Instituto Argentino de Oceanografía (IADO – CONICET/UNS), Camino La Carrindanga km 7.5, B8000FWB Bahía Blanca, Argentina.
[2] Instituto de Biofísica Carlos Chagas Filho, Centro de Ciências da Saúde, Universidade Federal do Rio de Janeiro, Ilha do Fundão, 21941-902, Rio Janeiro, RJ, Brasil.
[3] Universidad de la Fraternidad de Agrupaciones Santo Tomás de Aquino, Gascón 3145, 7600 Mar del Plata, Argentina.
[4] Universidad Tecnológica Nacional – FRBB, 11 de Abril 445, 8000 Bahía Blanca, Argentina.
[5] Academia Nacional de Ciencias Exactas, Físicas y Naturales (ANCEFN), Av. Alvear 1711, 1014 Ciudad Autónoma de Buenos Aires, Argentina.
[6] University of Hohenheim, Institute of Food Chemistry (170b), DE-70593 Stuttgart, Germany.
[7] Departamento de Química, Universidad Nacional del Sur (UNS), Av. Alem 1253, 8000 Bahía Blanca, Argentina.

*corresponding author: aharias@iado-conicet.gov.ar

Abstract

Chlorinated paraffins (CPs) are synthetic organic compounds of growing environmental and social concern. Short-chain chlorinated paraffins (SCCPs) were listed under the Stockholm Convention on Persistent Organic Pollutants (POPs) in 2017. Further, in 2021, medium-chain chlorinated paraffins (MCCPs) were proposed to be listed as POPs. We investigated SCCP and MCCP amounts and homolog profiles in four wild fish species from Bahía Blanca Estuary, a South Atlantic Ocean coastal habitat in Argentina. SCCPs and MCCPs were detected in 41% and 36% of the samples, respectively. SCCP amounts ranged from <12 to 29 ng g^{-1} wet weight and <750 to 5887 ng g^{-1} lipid weight, whereas MCCP amounts ranged from <7 to 19 ng g^{-1} wet weight and <440 to 2848 ng g^{-1} lipid weight. Amounts were equivalent to those found in fish from the Arctic and Antarctic Oceans and from some North American and Tibetan Plateau lakes. We performed a human health risk assessment and found no direct risks to human health for SCCP or MCCP ingestion, according to present knowledge. Regarding their environmental behaviour, no significant differences were observed among SCCP amounts, sampling locations, species, sizes, lipid content, and age of the specimens. However, there were significant differences in MCCP amounts across species, which might be attributed to fish size and feeding habits. Homolog profiles in all fish were dominated by the less chlorinated (Cl_6 and Cl_7) and shorter chain length CPs were the most abundant, with $C_{10}Cl_6$ (12.8%) and $C_{11}Cl_6$ (10.1%) being the predominant SCCPs and $C_{14}Cl_6$ (19.2%) and $C_{14}Cl_7$ (12.4%) the predominant MCCPs. To the best of our knowledge, this is the first study on the presence of CPs in the environment in Argentina and the South Atlantic Ocean. CP occurrence in the environment, particularly in the food chain, promotes the need for further research on their occurrence and behavior, and the impact of CPs in marine ecosystems in Argentina.

Keywords: Environmental contamination; Chemical additives; Flame retardants; Plasticizers; South America; Bioaccumulation

1. Introduction

Chlorinated paraffins (CPs) are synthetic mixtures of polychlorinated *n*-alkanes ($C_nH_{2n+2m}Cl_m$). They have different carbon chain lengths and chlorination levels, typically between 30% and 70% by weight (Fiedler, 2010). In the scientific literature, they are generally classified as short-chain (SCCPs, C_{10}–C_{13}), medium-chain (MCCPs, C_{14}–C_{17}), and long-chain CPs (LCCPs, $C_{\geq 18}$) (Canadian Environmental Protection Agency, 2008; UNEP, 2016). Technical CP mixtures, on the other hand, are frequently manufactured, labeled, and marketed solely based on their chlorine content. These variations in carbon chain length and chlorine content provide a diverse set of physical-chemical properties that may be used to a variety of industrial goods and processes (Glüge et al., 2013).

CPs have been used as additives in paint, lubricants, metalworking fluids and fat-liquoring of leather, as well as flame retardants and plasticizers in polymers as rubber and plastics (mostly polyvinyl chloride - PVC) (Fiedler, 2010; Guida et al., 2020; Jiang et al., 2018).

From 1930 to 2014, the production and use of CP increased steadily, reaching a peak of more than 1 million tons (0.44 Mt/year of SCCPs and 0.75 Mt/year of MCCPs), with most of it being produced in China (Chen et al., 2022). Since then, production and use have remained stable, totalling a global cumulative production of ~33 million tons since 1930 (Chen et al., 2022).

In South America, information on CP production and use is scarce. The available information suggests that Brazil manufactured CPs from the 1980s until 1994, reaching a maximum annual production of 360 tons (Guida et al., 2022a). Furthermore, Guida et al. (2022a) estimated that between 5280 and 6125 tons of CPs were used in the last two decades in Brazil, whereas tens of million tons of products containing CPs may have been imported into the country. Meanwhile, Argentina reported having imported 474 tons of SCCPs between 2007 and 2010, largely for the plastic industry (UMA, 2010).

Despite their widespread manufacture and use, CPs have received increased attention due to their environmental fate and negative impacts on the environment and human health (Glüge et al., 2018; Groh et al., 2019; UNEP, 2011; UNEP, 2015; Van Mourik et al., 2016). Short-chain CPs have been shown to exhibit significant environmental persistence (Glüge et al., 2018; Yuan et al., 2017), bioaccumulative capacity (Iozza et al., 2008; Ma et al., 2014; Zeng et al., 2017), potential toxicity to animals (Cooley et al., 2001; UNEP, 2011; UNEP, 2015) and long-range transport capacity (Li et al., 2016; 2017). Despite receiving less attention, recent research reveals that medium-chain CPs, containing at least 45% chlorine by weight, exhibit similar environmental behaviour and toxicity to SCCPs (Castro et al., 2018; Cooley et al., 2001; Glüge et al., 2018; Yuan et al., 2017; Zeng et al., 2017).

SCCPs have been restricted or banned around the world. First in Europe (in 2002; Directive 2002/45/EC; Vetter et al., 2022), then in Japan (in 2005; Ministry of the Environment of Japan, 2017), Canada (in 2008; Canadian environmental Protection Agency, 2008), and the United States (in 2009; USEPA, 2009), and, finally, globally, when it was listed in the Annex A (for elimination) of the Stockholm Convention on Persistent Organic Pollutants (POPs) in May 2017 (UNEP, 2017). However, SCCPs were listed with specific exemptions for their major applications (Guida et al., 2020) and the main producer of SCCPs, China, has not yet approved a ban on these compounds (Vetter et al., 2022). Hence, SCCPs are still abundant in technical CP mixtures (Xia et al., 2021) and used in several consumer goods (Chen et al., 2021). Therefore, they are expected to impact any country importing CP-containing products or wastes (Chen et al., 2022; Guida et al., 2022a, 2022b). Meanwhile, MCCPs are still globally unregulated. But, in 2021, the UK proposed MCCPs exceeding 45% chlorine by weight to be listed under the Stockholm Convention on POPs (UNEP, 2021).

Consequently, various research on the environmental occurrence and fate of CPs have been conducted (Glüge et al., 2018; Van Mourik et al., 2016). SCCPs and MCCPs can be considered

global contaminants due to their ubiquity. They were found in almost every environmental compartment and locations investigated, including humans and biota (Basconcillo et al., 2015; Harada et al., 2011; Zeng et al., 2015; 2017) and remote areas (Ma et al., 2014; Glüge et al., 2018; Van Mourik et al., 2016).

Nevertheless, the map of the global distribution of CPs is incomplete and a huge information gap remains for the global south, mainly for South America and the South Atlantic Ocean. Moreover, estimating environmental concentrations is challenging due to the lack of detailed information on the use and production of these chemicals in South America (Chen et al., 2022). To the best of our knowledge, only two research on CPs in South American fish have been published, both on fish from the Pacific Ocean. Krätschmer et al. (2019), investigated the presence of CPs in salmon sold in Germany, including salmon farmed in Chile. In addition, Dong et al. (2019) analyzed CPs in feed material sold in Chinese markets, including Chilean and Peruvian fishmeal.

Consequently, our goal was to investigate the occurrence of SCCPs and MCCPs in four wild fish species sampled in the Bahía Blanca estuary, an anthropized Argentinean coastal environment in the South Atlantic Ocean. Furthermore, we assessed the influence of inter- (species) and intra- (size/age) specific variations on CP amounts; investigated CP homolog profiles in fish; compared the amounts found with those found in fish around the world; and assessed the health risk associated with the ingestion of SCCP-containing fish, according to current knowledge.

2. Materials and methods

2.1 Study area

This study analyzed CPs in fish from the Bahía Blanca estuary, a mesotidal system in the South Atlantic Ocean and the southeast of South America (**Figure 1**; Perillo et al., 2001). This coastal

ecosystem has great environmental and local socioeconomic importance because it is a reproduction, breeding, and feeding area for many species of fish, birds, and other animals and plants. For this reason, in 1998, Bahía Blanca, Bahía Falsa and Bahía Verde were designated as Natural Reserves (Provincial Law 12101). However, the economic development of the influence area, as well as flaws in urban planning and environmental management, endangers the health of this ecosystem. On its coasts, there is intense industrial and petrochemical activity (for example, the production of fertilizers, PVC, polyethylene, and fuel); a settlement of over 400,000 people (Bahía Blanca, General Cerri and Punta Alta cities) with poor sewage and stormwater effluents treatment and irregular solid waste disposing (Streitenberger and Baldini, 2016), as well as the main deep-water commercial port in Argentina. This ecosystem has been the subject of numerous studies on chemical pollution, including POPs such as polybrominated diphenyl ethers (PBDEs; Tombesi et al., 2017), organochlorine pesticides (OCPs; Arias et al., 2011; Menone et al., 2004; Oliva et al., 2022; Tombesi et al., 2018), and polychlorinated biphenyls (PCBs; Arias et al., 2013; Tombesi et al., 2017).

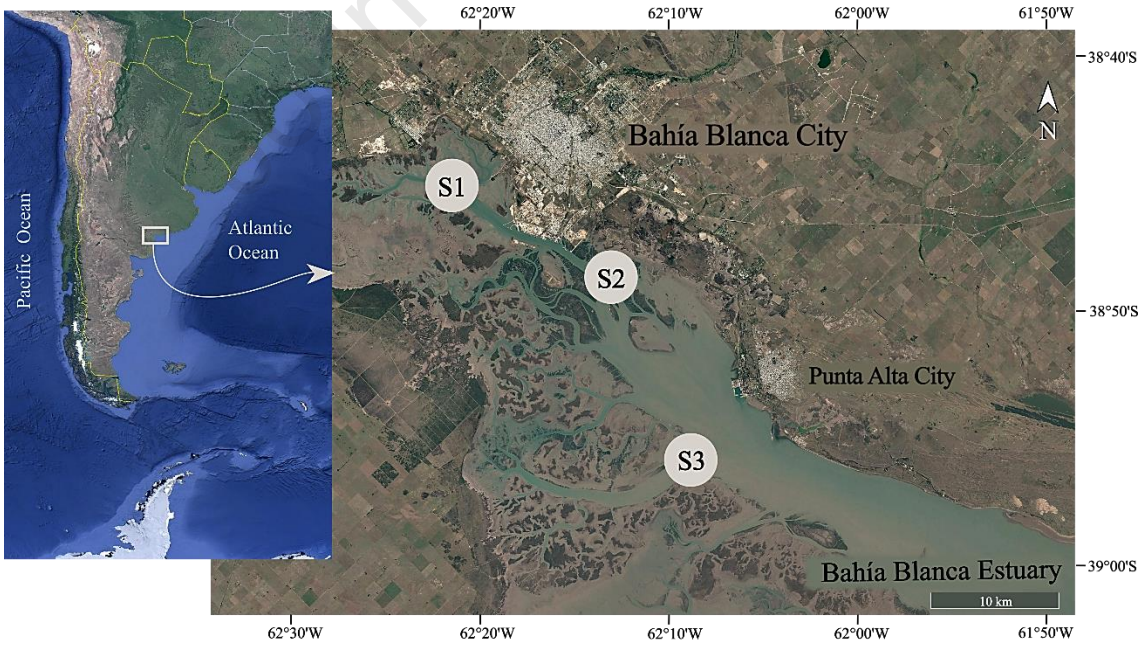


Figure 1. Satellite image of the Bahia Blanca estuary showing sampling sites (S1; S2; S3).

2.2. Sampling

Wild juvenile fish were caught by net between August and October 2017 at three sampling sites in the Bahía Blanca estuary, to ensure the representativeness of the estuary as a whole. The four fish species caught were Jenyn's sprat (*Ramnogaster arcuata*), narrownose smooth-hound (*Mustelus schmitti*), striped weakfish (*Cynoscion guatucupa*), and whitemouth croaker (*Micropogonias furnieri*). The fish were divided into classes according to their length. Only fish of the size/age that have been shown to have been in the estuary throughout their lives, i.e., they were born there and have not yet left (Cazorla and Sidorkewicj 2009; Cazorla, 2018; Molina et al., 2021), were evaluated for the information to be an indicative of the local environmental quality. Each sample was a pool of a variable number of individuals classified by class, species, and location (**Table 1**).

Table 1. Sample data, including species name, class, size range (cm), age (year), and number of individuals per composite sample grouped by sampling site.

Species	Class	Size (mm)	Age (year)	Individuals/sampling site		
				S1	S2	S3
Mustelus schmitti	C1	300-350	<1	-	3	-
Mustelus schmitti	C2	351-400	<1	3	3	4
Mustelus schmitti	C3	401-450	<1	2	2	2
Micropogonias furnieri	C1	40-70	<1	100	124	150
Micropogonias furnieri	C2	71-160	<1	60	61	-
Cynoscion guatucupa	C1	50-90	<1	-	-	150
Cynoscion guatucupa	C2	91-120	<1	14	46	62
Ramnogaster arcuata	C1	50-80	1-2	57	103	120
Ramnogaster arcuata	C2	81-110	2-3	33	32	60

2.3. Chemicals and standards

All cleaning and sample processing solvents (acetone, dichloromethane, isooctane, and *n*-hexane) were chromatographic grade, purchased from Dorwill (Buenos Aires, Argentina).

Sulfuric acid (95–97%; P.A. ACS), for acidified silica (44% w/w), was acquired from Cicarelli (Santa Fe, Argentina) and sodium sulphate and silica gel (0.063–0.2 mm) were purchased from Merck (Darmstadt, Germany). SCCP and MCCP chemical standards ($C_{10–13}$ with 51.5%, 55.5% and 63% of Cl content; and C_{14-17} with 42% 52% and 57% of Cl content) were acquired from Dr. Ehrenstorfer (Augsburg, Germany). Surrogates PCB 103 and 198 and the internal standard 6'-MeOH-BDE 66 (BCIS) were purchased from AccuStandard (New Haven, USA) and Dr. Vetter's Lab (Germany; Vetter et al., 2011), respectively.

2.4. Sample preparation

Fish muscle samples were processed using a miniaturized analytical method optimized for the simultaneous extraction and purification of organohalogenated contaminants from fatty samples (Mello et al., 2016; Roscales et al., 2017) and adapted for fish muscle (Guida et al., 2018). Briefly, 0.5 g of freeze-dried sample, 0.83 g of acidified silica gel (44% sulphuric acid, w/w), and 0.5 g of anhydrous sodium sulphate were homogenized in a mortar for 5 min and then surrogate standards (PCB 103 and 198, 20 ng) were added. The mixture was added on top of a glass column filled with 14 mL of *n*-hexane/dichloromethane (9:1) and the following co-sorbents (down to up): 1 cm of anhydrous sodium sulphate, 1.66 g of neutral silica gel, 5 g of acid silica gel (44% w/w), and 0.83 g of neutral silica gel. The analytes were then eluted in three 7-minute static extractions followed by dynamic steps with 7 mL of n-hexane/dichloromethane (9:1, v/v) (21 mL total). Extract volume was reduced closed to dryness and then washed 3 times with *n*-hexane into a glass insert for reduced vial volume. Finally, extracts were dried and then reconstituted using 100 µL of BCIS (100 ng mL^{-1}) in isooctane as injection standard. Lipid content (on dry weight basis) was determined according to Tölgyessy and Miháliková (2016).

2.5. CP´s Instrumental analysis

Instrumental analysis was based on the procedure developed by Reth et al. (2005a) with modifications described by Sprengel and Vetter (2019). The quantitative analysis was performed in a gas chromatograph coupled with electronic chemical negative ionization mass spectrometry (GC/ECNI-MS; 7890A-5975C, Agilent Technologies, Palo Alto, CA, USA), using methane as the reagent gas. The column used was a DB-5MS fused silica capillary column (15 m, 0.25 mm ID, 0.1 µm thick) from Agilent Technologies (Palo Alto, CA, USA). The injector temperature was 260 °C, and the carrier gas was helium at a constant flow rate of 1.4 mL min1. The temperature program for the oven was as follows: 80 °C for 1 minute, then raise to 270 °C at 15 °C min^{-1} and held for 5 minutes.

CP homologs with different chlorine contents were used for the calibration curve (SCCP with 51.1%, 53.3%, 55.5%, 59.25%, and 63% Cl; MCCP with 42%, 47%, 52%, 54.5%, and 57% Cl). The selected ion monitoring (SIM) mode was used for CP homolog monitoring. For quantification and confirmation, the most abundant and second most abundant ion $[M\text{-}Cl]^-$ were utilized, respectively (Reth and Oehme, 2004). To improve sensitivity and minimize interference, eight SIM runs per sample and standard were performed, selecting the seven primary and seven secondary ions from each group of homologs with the same chain length (C_{10} to C_{17}).

For the quantification, the procedure optimized by Reth et al. (2005a) was adopted. In brief, the corresponding areas were integrated based on the retention times, signal shape, and relationship between the primary and secondary ions, and the interferences were manually subtracted. The amounts in the extract were calculated based on the relationship between the relative area of each CP, the Cl content, and the calibration curve (R^2 = 0.95 for SCCPs and R^2 = 0.98 for MCCPs).

2.6. Quality assurance and quality control (QA/QC)

No plastic was used during the sampling or analytical procedure, and all material used was exposed to 450 °C for 4 h and rinsed with *n*-hexane, dichloromethane, and acetone (3-times each) before use to avoid CP contamination. A procedural blank was performed for every five samples, to monitor contamination. CPs were detected in all blanks, especially SCCPs. For this reason, the detection limit (DL) was calculated as the average sum of all blanks and three times the standard deviation. The resulting DLs were 12.2 ng g^{-1} wet weight (ww) for SCCPs and 7 ng g^{-1} ww for MCCPs. These detection limit values were similar to those shown in other studies that also analyzed CP by low-resolution mass spectrometry (Jiang et al., 2013; Huang et al., 2017; Reth et al., 2005a; Zeng et al., 2017; Zhou et al., 2018). Besides, the average CP amounts in the analytical blanks were subtracted from those in samples. The method was previously tested by spiking SCCP and MCCP standards into three triplicate samples and a triplicate blank and analyzing them together with the same triplicate samples and blank without standard fortification. The difference of SCCP and MCCP amounts between the enriched and non-enriched samples resulted in a 80% ± 16% recovery of CPs. Furthermore, the recovery of the surrogate standards, PCB 103 and 198, added to each sample was between 80 and 110%.

2.7. Statistical analysis

Data was tested for normal distribution by the Tuckey test. Since normality was not observed in the dataset, the non-parametric Kruskal-Wallis test was used to analyze the significant difference between groups ($p < 0.05$) and Spearman's correlation coefficient to evaluate the association between multiple variables (Camacho-Sandoval, 2008). All statistical analyses were performed using InfoStat 2018 software (InfoStat Group, Córdoba, Argentina). The moisture content of each sample was used for the conversion of CP concentrations to wet weight basis; firstly, because that represents fish consumption and secondly as a way of data normalization to facilitate their comparison with other studies.

3. Results

3.1. SCCP and MCCP amounts

Total amounts of SCCPs and MCCPs grouped by species and size are summarized in **Table 1** and **Figure 2**, while the detailed information of all the samples is shown in **Table S1**.

SCCP amounts were below the detection limit (12.2 ng g^{-1} ww) in 13 samples and were detected in 9 samples, ranging from 12.7 ng g^{-1} to 29.4 ng g^{-1} ww and 889.5 to 5887.7 ng g^{-1} lipid weight (lw; **Table S1**). Meanwhile, MCCPs were below the detection limit (7 ng g^{-1} ww) in 14 samples, including all *M. schmitti* samples, and were detected in 8 samples with levels ranging from 8.1 ng g^{-1} to 18.7 ng g^{-1} ww and 657.4 to 2848.5 ng g^{-1} lw.

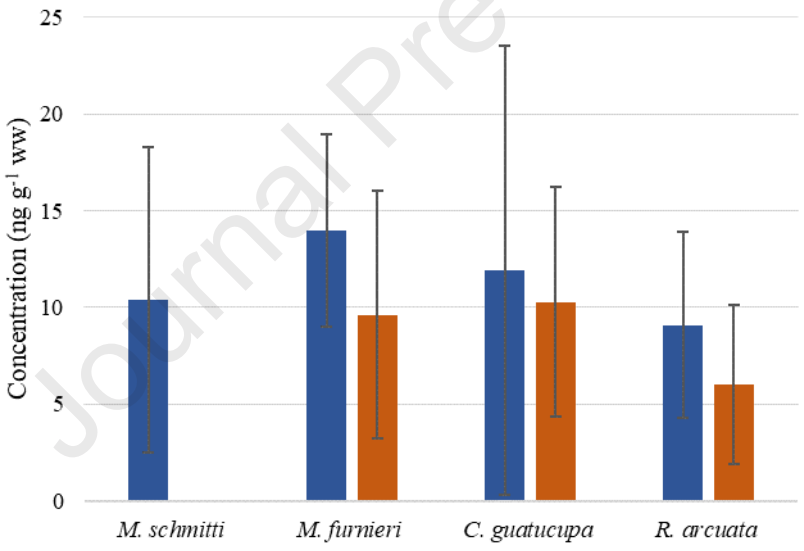
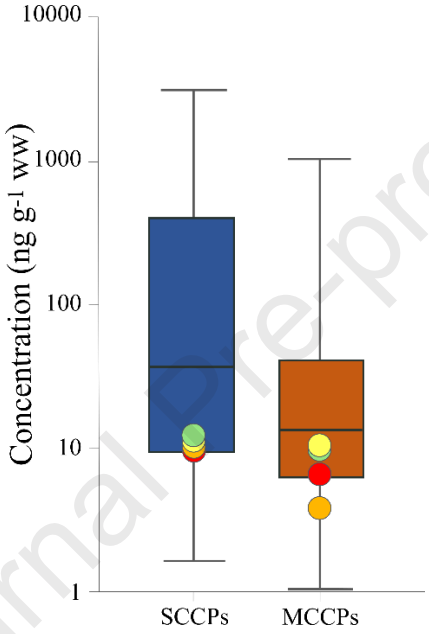


Figure 2. Levels (mean and SD) of SCCPs (blue bars) and MCCPs (orange bars) in fish grouped by species.

3.2. Comparison with worldwide CP amounts

Compared to fish from other regions, the CP amounts in this study were lower than the median and in the first or second quartile of the studies examined (**Table S2**; **Figure 3**). These levels were comparable to those found in fish from the Arctic (Dick et al., 2010) and Antarctica Oceans (Li et al., 2016), Great Lakes of North America (Basconcillo et al., 2015), and Chilean

240 and Scandinavian fisheries (Krätschmer et al., 2019). They were much lower than those found
241 in fish from China (Du et al., 2018; Huang et al., 2017; 2019; Zhou et al., 2018) and Lake
242 Michigan, North America (Basconcillo et al., 2015) and in fishmeal from different fisheries
243 around the world (Dong et al., 2019). These results could be expected since there is no evident
244 direct input of CPs into the studied environment nor Argentina is expected to be an important
245 player regarding CP production and application.



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247 **Figure 3.** Box plot for SCCP and MCCP amounts in fish worldwide based on data in Table S2.
248 The middle hinge represents the median, the lower and upper hinges represent the first (Q1)
249 and third (Q3) quartiles, and the whiskers reflect the minimum and maximum value. The
250 colored circles represent the mean amount in each fish species in the Bahía Blanca estuary: *M.*
251 *schmitti* (Orange), *M. furnieri* (Green), *C. guatucupa* (Yellow), and *R. arcuata* (Red).

252 **3.3. Potential factors influencing CP accumulation in fish**

253 Regarding capture sites, the innermost sampling site of the estuary (S1) showed higher
254 average SCCP levels, followed by the outermost (S3) and middle (S2) sites, while MCCP average
255 amounts were higher in S3, followed by S2 and S1 (**Figure S1**). However, there were no
256 significant differences between the three sites ($p > 0.05$). This could be explained because the
257 target fish circulate throughout the estuary and do not represent a punctual site (Cazorla,

2018). Furthermore, the physical-chemical properties of the water in the study area are relatively uniform (Arena et al., 2022; Piccolo and Perillo, 1990), as is the distance to pollution sources. As a result, fish in the three sampling sites might be similarly exposed to CPs, but further studies in this area should be conducted to confirm this.

Regarding the species, there were no statistically significant differences between SCCP amounts in the four studied species ($p > 0.05$). Furthermore, Spearman's correlation analysis showed no significant correlations between variables such as age, size, feeding habits, lipid contents and SCCP amounts.

It has been well documented that lipid content is a key variable in the bioaccumulation of chemicals with high octanol-water partition coefficients, such as SCCPs (Arnot and Gobas, 2006; Mackay and Fraser, 2000). Indeed, this trend has been documented in studies on SCCPs in fish around the world (Du et al, 2018; Huang et al., 2017; Labadie et al., 2019; Ma et al., 2014). In this study, we found no correlation between lipid content and SCPPs amounts; however, the average levels of SCCPs were higher in the species with the highest lipid content, *M. furnieri* (Table S1). Further, there were significant differences in MCCP amounts (on wet weight basis) between species, particularly between *M. schmitti* and *M. furnieri* ($p < 0.05$). These differences seem to be related to the size of the fish (Spearman's coefficients, $r = -0.6$, $p = 0.018$, n = 15) and their feeding habits (i.e., zooplankton intake: Spearman's coefficients, $r = 0.44$, $p = 0.10$, n = 15; crab intake: Spearman's coefficients, $r = -0.47$, $p = 0.08$, n = 15; Table S3). In particular, between this two species, those differences could be explained by lipid content, since *M. furnieri* showed a three times higher lipid content than *M. schmitti*. Regarding the rest of the species, the concentrations did not correlate with the lipid content, which is consistent with prior studies on these fish species (Huang et al., 2017; Labadie et al., 2019). Overall, these results suggested that lipid content was not the main factor influencing the distribution of CPs in fish of the BBE.

3.4. CP homolog profiles

Homolog profiles of SCCPs and MCCPs in fish from the Bahía Blanca estuary are provided in **Figure 4**. Regarding SCCPs, the most abundant alkane-chain length were C_{11} and C_{10}, with averages of 36% and 35% and maximums of 53% and 48%, respectively (**Figure 4**).

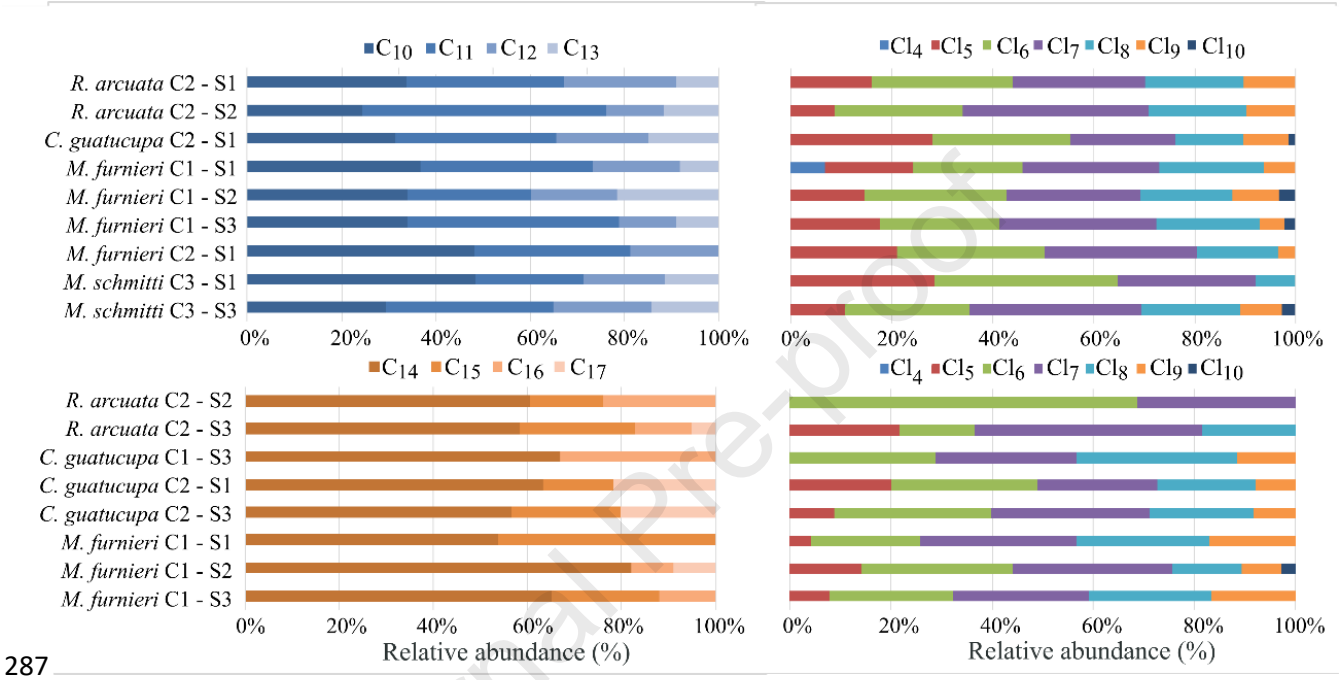

Figure 4. SCCP and MCCP homolog profiles in the Bahía Blanca estuary fish. Size class: C1, C2, C3; sampling site: innermost site (S1), middle site (S2), outermost site (S3). The X-axes represent relative abundance (%).

The predominance of C_{11}-CPs has also been observed in animals from different parts of the world, including coastal, urban, and e-waste dismantling areas (Borgen et al., 2002; Houde et al., 2008; Ma et al., 2014; Reth et al., 2006; Sun et al., 2017; Yuan et al., 2017; Zeng et al., 2011). Other studies, however, found a higher abundance of the C_{10}-CP group, particularly in remote areas such as the Arctic (Li et al., 2017; Tomy et al., 2000) and Antarctic Oceans (Li et al., 2016) and Tibetan Plateau (Du et al., 2019). On the other hand, the highest relative abundance of C_{12}-CPs (e.g., Basconcillo et al., 2015, in Canada) or C_{13}-CPs (e.g., Du et al., 2018, in China) were common in other studies. Our findings were consistent with those reported in fish and fishmeal from Chilean and Peruvian fisheries in the Pacific Ocean (Dong et al., 2019;

Krätschmer et al., 2019) where shorter carbon chains predominated; however, in these studies, C_{10}-CPs were more abundant.

Meanwhile, MCCPs were largely dominated by the C_{14}-CPs with relative abundances between 45% and 67% and an average of 59%, followed by the C_{15}-CP group with an average of 18%. These patterns were consistent with studies on fish elsewhere (Basconcillo et al., 2015; Du et al., 2018; Zeng et al., 2015; Reth et al., 2005b), including studies on Chilean and Peruvian fish and fishmeal in the Pacific Ocean (Dong et al., 2019; Krätschmer et al., 2019). Some authors suggested in the early 2000s that samples near urbanized and industrialized regions exhibit a higher relative abundance of less volatile congeners and a pattern comparable to commercial CP mixtures (Marvin et al., 2003; Reth et al., 2005b; Tomy et al., 2000). However, commercial CP mixtures have diversified, and as a result, they contribute differently to the contamination of environmental samples, making correlation of CP homolog profiles with commercial CP mixtures extremely challenging (Vetter et al., 2022).

Concerning the Cl content, the SCCPs had between 58.5% and 61.4% (60.31% on average) and the MCCPs had between 51.2% and 56.4% (54.1% on average). Moreover, the most abundant homologs among the SCCPs were $C_{10}Cl_6$-CPs (12.8%) and $C_{11}Cl_6$-CPs (10.1%) and those among the MCCPs were $C_{14}Cl_6$-CPs (19.2%) and $C_{14}Cl_7$-CPs (12.4%). Cl_6 and Cl_7 were the most abundant groups overall, with averages of 27% and 29% for SCCPs and 31% and 31% for MCCPs, respectively (Figure S2). The predominance of shorter chain groups (C_{10}-/C_{11}- and C_{14}-CPs) and lower chlorinated groups (Cl_6 and Cl_7) is common in aquatic animals since those compounds present the highest capacity for migration towards biological matrices. Finally, these results matched with those reported by other researchers worldwide (Du et al., 2019; Guida et al., 2020; Li et al., 2016; Lino et al., 2005; Ma et al., 2014; Reth et al., 2005b; Wang et al., 2018; Yuan et al., 2017).

3.5. Health risk assessment of CPs

325 The health risk associated with consuming fish containing SCCPs and MCCPs from the BBE was
326 determined using the margins of exposure (MOEs). This is calculated as the ratio between the
327 no-observed-adverse-effect level (NOAEL) and the estimated daily intake (EDI) of CPs. NOAEL is
328 a limit of acceptable daily exposure determined by the European Chemicals Bureau based on
329 toxicity experiments in mammals (ECB, 2000; 2007), being 100 mg/kg/d and 6 mg/kg/d for
330 SCCPs and MCCPs, respectively (Wang et al., 2021). Meanwhile, EDI is calculated using the
331 following equation:

332 $$Estimated\ daily\ intake\ (EDI) = \frac{Ci \times DFI}{BW}$$

333 Where, Ci is the SCCP or MCCP amounts in each fish sample (ng g^{-1} ww), DFI is the daily fish
334 intake of Argentines (13 g/d; FAO, 2016), and BW is the average adult body weight in
335 Argentina (70kg).

336 MOE values >1000 are considered to indicate that exposure to SCCP and MCCP does not pose
337 significant risks to human health (Wang et al., 2018; Wang et al., 2021). This value was
338 determined as a total uncertainty factor for the NOAEL, given an uncertainty factor of 10 to
339 the interspecific, intraspecific and interannual differences (Lino et al., 2005).

340 The resulting EDI of SCCPs ranged from 1.14 to 3.70 ng/kg/d and the EDI of MCCPs from 0.65
341 to 3.24 ng/kg/d. While the MOEs of SCCPs ranged from 18,350 to 87,900 and those of MCCPs
342 ranged from 1,720 to 9,260. Consequently, all MOEs of SCCP and MCCP were >1,000,
343 suggesting no significant risk from consumption of fish from the BBE. However, these
344 parameters are calculated based on the average daily fish consumption of Argentines and may
345 be higher in populations linked to fishing and habitual fish consumers. In these cases, the
346 MOEs may be lower and consequently be close to the safety limits or even exceed them,
347 especially the MOEs of MCCPs.

348 ## 4. Conclusions

This study demonstrates, for the first time, the environmental occurrence and bioavailability of SCCP and MCCP in Argentina and the South Atlantic Ocean.

CP amounts found in this study were lower than in fish from highly industrialized/urbanized areas of the world, such as Chinese estuaries or some North American Great Lakes, but comparable to those found in fish from Chile, the Arctic and Antarctic Oceans, and some North American and Tibetan Plateau lakes. Moreover, the consumption of the analysed fish would not represent a health risk associated with the SCCPs and MCCPs. There were no significant differences in CP amounts between sampling sites. SCCP amounts were similar between and within species. Rather, there were significant differences in MCCP amounts between species, which were related to feeding habits, fish size, and lipid content.

Regarding CP homolog profiles, C_{10}-CPs and C_{11}-CPs with Cl_6 and Cl_7 predominated among SCCPs, whereas C_{14}-CPs with Cl_6 and Cl_7 predominated among MCCPs. These patterns matched those found in other studies, particularly those conducted in urban/industrial areas.

Finally, the authors suggest that future research should be conducted to assess the environmental occurrence, behavior, fate, and impacts of CPs in other South American ecosystems influenced by humans where CPs may endanger ecosystems and human health.

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6. References

Arena, M., Pratolongo, P., Delgado, A.L., Celleri, C., Vitale, A., 2022. Spatial and temporal distribution of satellite turbidity in response to different environmental variables in the Bahía Blanca Estuary, South-Western Atlantic. Int. J. Remote Sens. 43(10), 3714-3743. https://doi.org/10.1080/01431161.2022.2105175

Arias, A.H., Pereyra, M.T., Marcovecchio, J.E., 2011. Multi-year monitoring of estuarine sediments as ultimate sink for DDT, HCH, and other organochlorinated pesticides in Argentina. Environ. Monit. Assess. 172(1), 17-32. https://doi.org/10.1007/s10661-010-1315-9

Arias, A.H., Vazquez-Botello, A., Diaz, G., Marcovecchio, J.E., 2013. Accumulation of polychlorinated biphenyls (PCBs) in navigation channels, harbors and industrial areas of the Bahia Blanca Estuary, Argentina. Int. J. Environ. Res. 7(4), 925-936.

Arnot, J.A., Gobas, F.A., 2006. A review of bioconcentration factor (BCF) and bioaccumulation factor (BAF) assessments for organic chemicals in aquatic organisms. Environ. Rev. 14(4), 257-297. https://doi.org/10.1139/a06-005

Basconcillo, L.S., Backus, S.M., McGoldrick, D.J., Zaruk, D., Sverko, E., Muir, D.C., 2015. Current status of short-and medium chain polychlorinated n-alkanes in top predatory fish across Canada. Chemosphere 127, 93-100. https://doi.org/10.1016/j.chemosphere.2015.01.016

Borgen, A.R., Schlabach, M., Kallenborn, R., Fjeld, E., 2002. Polychlorinated alkanes in fish from Norwegian freshwater. Sci. World J. 2, 136-140. https://doi.org/10.1100/tsw.2002.82

Camacho-Sandoval, J., 2008. Asociación entre variables: correlación no paramétrica. Acta Med. Costarric. 50(3), 144-146.

Castro, M., Breitholtz, M., Yuan, B., Athanassiadis, I., Asplund, L., Sobek, A., 2018. Partitioning of chlorinated paraffins (CPs) to Daphnia magna overlaps between restricted and in-use categories. Environ. Sci. Technol. 52(17), 9713−9721. https://doi.org/10.1021/acs.est.8b00865

Cazorla, L.A., Sidorkewicj, N., 2009. Some biological parameters of Jenyns' sprat *Ramnogaster arcuata* (Pisces: Clupeidae) in south-western Atlantic waters. Mar. Biodivers. Rec. 2. https://doi.org/10.1017/S1755267209001286

Cazorla, L.A., 2018. Sección II.1. Aspectos biológicos de cuatro especies de peces del estuario de Bahía Blanca. Programa de Monitoreo de la Calidad Ambiental de la Zona Interior del Estuario de Bahía Blanca. Final report 2017-2018. https://www.bahia.gob.ar/cte/informes/

Chen, C., Chen, A., Li, L., Peng, W., Weber, R., Liu, J., 2021. Distribution and emission estimation of short- and medium-chain chlorinated paraffins in Chinese products through detection-based mass balancing. Environ. Sci. Technol. 55(11), 7335–7343. https://doi.org/10.1021/acs.est.0c07058

Chen, C., Chen, A., Zhan, F., Wania, F., Zhang, S., Li, L., Liu, J., 2022. Global historical production, use, in-use stocks, and emissions of short-, medium-, and long-chain chlorinated paraffins. Environ. Sci. Technol. 56, 7895−7904. https://doi.org/10.1021/acs.est.2c00264

Cooley, H.M., Fisk, A.T., Wiens, S.C., Tomy, G.T., Evans, R.E., Muir, D.C.G., 2001. Examination of the behavior and liver and thyroid histology of juvenile rainbow trout (*Oncorhynchus mykiss*) exposed to high dietary concentrations of C_{10}-, C_{11}-, C_{12}- and C_{14}-polychlorinated *n*-alkanes. Aquat. Toxicol. 54(1-2), 81-99. https://doi.org/10.1016/S0166-445X(00)00172-7

Dick, T.A., Gallagher, C.P., Tomy, G.T., 2010. Short-and medium-chain chlorinated paraffins in fish, water and soils from the Iqaluit, Nunavut (Canada), area. World Review of Science, Technology and Sustainable Development 7(4), 387-401. Http://doi.org/10.1504/WRSTSD.2010.032747

Dong, S., Li, X., Su, X., Wang, P., 2019. Concentrations and congener group profiles of short-and medium-chain chlorinated paraffins in animal feed materials. Sci. Total Environ. 647, 676-681. https://doi.org/10.1016/j.scitotenv.2018.08.017

Du, X., Yuan, B., Zhou, Y., Benskin, J. P., Qiu, Y., Yin, G., Zhao, J., 2018. Short-, medium-, and long-chain chlorinated paraffins in wildlife from paddy fields in the Yangtze River Delta. Environ. Sci. Technol. 52(3), 1072-1080. https://doi.org/10.1021/acs.est.7b05595

Du, B., Ge, J., Yang, R., Han, X., Chen, H., Li, J., Zeng, L., 2019. Altitude-dependent accumulation of short chain chlorinated paraffins in fish from alpine lakes and Lhasa river on the Tibetan Plateau. Environ. Pollut. 250, 594-600. https://doi.org/10.1016/j.envpol.2019.04.059

Canadian environmental Protection Agency, 2008. Chlorinated Paraffins. Follow-up report on a PSL1 assessment for which data were insufficient to conclude whether the substances were “toxic” to the environment and to the human health. Canadian environmental Protection Agency, Ottawa. https://www.ec.gc.ca/lcpe-cepa/documents/substances/pc-cp/cps_followup-eng.pdf

ECB (European Chemicals Bureau), 2000. European Union Risk Assessment Report, Alkanes, C10–13, chloro (SCCPs). European Commission, Devon, England.

ECB (European Chemicals Bureau), 2007. European Union Risk Assessment Report, Alkanes, C14–17, chloro (MCCPs). European Commission, Devon, England (2007)

FAO, 2016. Food and Agriculture Organization of the United Nations. El estado mundial de la pesca y la acuicultura 2016. Contribución a la seguridad alimentaria y la nutrición para todos. Roma. 224 pp.

Fiedler, H., 2010. Short-chain chlorinated paraffins: production, use and international regulations. In: de Boer, J. (Ed.), Chlorinated Paraffins. The Handbook of Environmental Chemistry, Vol. 10. Springer, Berlin Heidelberg, Germany, 1-40. https://doi.org/10.1007/698_2010_58

Glüge, J., Bogdal, C., Scheringer, M., Buser, A.M., Hungerbühler, K., 2013. Calculation of physicochemical properties for short-and medium-chain chlorinated paraffins. J. Phys. Chem. Ref. Data. 42(2), 023103. https://doi.org/10.1063/1.4802693

Glüge, J., Schinkel, L., Hungerbühler, K., Cariou, R., Bogdal, C., 2018. Environmental risks of medium-chain chlorinated paraffins (MCCPs): a review. Environ. Sci. Technol. 52(12), 6743-6760. https://doi.org/10.1021/acs.est.7b06459

Groh, K.J., Backhaus, T., Carney-Almroth, B., Geueke, B., Inostroza, P.A., Lennquist, A., Leslie, H.A., Maffini, M., Slunge, D., Trasande, L., Warhurst, A.M., Muncke, J., 2019. Overview of known plastic packaging-associated chemicals and their hazards. Sci. Total Environ. 651, 3253-3268. https://doi.org/10.1016/j.scitotenv.2018.10.015

Guida, Y., Capella, R., Weber, R., 2020. Chlorinated paraffins in the technosphere: A review of available information and data gaps demonstrating the need to support the Stockholm Convention implementation. Emerg. Contam. 6, 143-154. https://doi.org/10.1016/j.emcon.2020.03.003

Guida, Y., Capella, R., Kajiwara, N., Babayemi, J.O., Torres, J.P.M., Weber, R., 2022a. Inventory approach for short-chain chlorinated paraffins for the Stockholm Convention implementation in Brazil. Chemosphere 287, 132344. https://doi.org/10.1016/j.chemosphere.2021.132344

Guida, Y., Lino, A.S., Capella, R., Meire, R.O., Torres, J.P.M., Malm, O., 2018. Amazon Riparian People's Exposure to Legacy Organochlorine Pesticides and Methylmercury from Catfish (Ageneiosus brevifilis) Intake. Orbital: Electron. J. Chem. 10 (4), 320-326. http://dx.doi.org/10.17807/orbital.v10i4.1071

Guida, Y., Matsukami, H., Kajiwara, N., 2022b. Short-and medium-chain chlorinated paraffins in polyvinyl chloride consumer goods available in the Japanese market. Sci. Total Environ. 849, 157762. http://dx.doi.org/10.1016/j.scitotenv.2022.157762

Harada, K.H., Takasuga, T., Hitomi, T., Wang, P., Matsukami, H., Koizumi, A., 2011. Dietary exposure to short-chain chlorinated paraffins has increased in Beijing, China. Environ. Sci. Technol. 45, 7019-7027. https://doi.org/10.1021/es200576d

Houde, M., Muir, D.C., Tomy, G.T., Whittle, D.M., Teixeira, C., Moore, S., 2008. Bioaccumulation and trophic magnification of short-and medium-chain chlorinated paraffins in food webs from Lake Ontario and Lake Michigan. Environ. Sci. Technol. 42(10), 3893-3899. https://doi.org/10.1021/es703184s

Huang, H., Gao, L., Xia, D., Qiao, L., 2017. Bioaccumulation and biomagnification of short and medium chain polychlorinated paraffins in different species of fish from Liaodong Bay, North China. Sci. Rep. 7(1), 1-9. https://doi.org/10.1038/s41598-017-06148-5

Huang, Y., Qing, X., Jiang, G., Chen, L., He, Q., Meng, X.Z., Gao, B., 2019. Short-chain chlorinated paraffins in fish from two developed regions of China: occurrence, influencing factors and implication for human exposure via consumption. Chemosphere 236, 124317. https://doi.org/10.1016/j.chemosphere.2019.07.048

Iozza, S., Müller, C.E., Schmid, P., Bogdal, C., Oehme, M., 2008. Historical profiles of chlorinated paraffins and polychlorinated biphenyls in a dated sediment core from Lake Thun (Switzerland). Environ. Sci. Technol. 42, 1045-1050. https://doi.org/10.1021/es702383t

Jiang, G., Chen, L.G., He, Q.S., Meng, X.Z., Feng, Y.B., Huang, Y.M., Tang, C.M., 2013. Contamination characteristics of short-chain chlorinated paraffins in edible fish of Shanghai. Environ. Sci. 34(9), 3374-3380. In Chinese. Http://doi.org/10.13227/j.hjkx.2013.09.017

Jiang, W., Huang, T., Chen, H., Lian, L., Liang, X., Jia, C., Gao, H., Mao, X., Zhao, Y. and Ma, J., 2018. Contamination of short-chain chlorinated paraffins to the biotic and abiotic environments in the Bohai Sea. Environ. Pollut. 233, 114-124. https://doi.org/10.1016/j.envpol.2017.10.034

Krätschmer, K., Schächtele, A., Malisch, R., Vetter, W., 2019. Chlorinated paraffins (CPs) in salmon sold in southern Germany: Concentrations, homologue patterns and relation to other persistent organic pollutants. Chemosphere 227, 630-637. https://doi.org/10.1016/j.chemosphere.2019.04.016

Krätschmer, K., Malisch, R., Vetter, W., 2021. Chlorinated paraffin levels in relation to other persistent organic pollutants found in pooled human milk samples from primiparous mothers in 53 countries. Environ. Health Perspect. 129(8), 087004. https://doi.org/10.1289/EHP7696

Labadie, P., Blasi, C., Le Menach, K., Geneste, E., Babut, M., Perceval, O., Budzinski, H., 2019. Evidence for the widespread occurrence of short-and medium-chain chlorinated paraffins in fish collected from the Rhône River basin (France). Chemosphere 223, 232-239. https://doi.org/10.1016/j.chemosphere.2019.02.069

Li, H., Fu, J., Zhang, A., Zhang, Q., Wang, Y., 2016. Occurrence, bioaccumulation and long-range transport of short-chain chlorinated paraffins on the Fildes Peninsula at King George Island, Antarctica. Environ. Int. 94, 408-414. https://doi.org/10.1016/j.envint.2016.05.005

Li, H., Fu, J., Pan, W., Wang, P., Li, Y., Zhang, Q., Wang, Y., Zhang, A., Liang, Y., Jiang, G., 2017. Environmental behaviour of short-chain chlorinated paraffins in aquatic and terrestrial ecosystems of Ny-Ålesund and London Island, Svalbard, in the Arctic. Sci. Total Environ. 590, 163-170. https://doi.org/10.1016/j.scitotenv.2017.02.192

Lino, F., Takasuga, T., Senthilkumar, K., Nakamura, N., Nakanishi, J., 2005. Risk assessment of short-chain chlorinated paraffins in Japan based on the first market basket study and species sensitivity distributions. Environ. Sci. Technol. 39(3), 859-866. https://doi.org/10.1021/es049221l

Ma, X., Zhang, H., Wang, Z., Yao, Z., Chen, J., Chen, J., 2014. Bioaccumulation and trophic transfer of short chain chlorinated paraffins in a marine food web from Liaodong Bay, North China. Environ. Sci. Technol. 48(10), 5964-5971. https://doi.org/10.1021/es500940p

Mackay, D., Fraser, A., 2000. Bioaccumulation of persistent organic chemicals: mechanisms and models. Environ. Pollut. 110(3), 375-391. https://doi.org/10.1016/S0269-7491(00)00162-7

Mello, F.V., Roscales, J.L., Guida, Y. Menezes, J.F.S., Vicente, A., Costa, E.S. Jiménez, B., Torres, J.P.M., 2016. Relationship between legacy and emerging organic pollutants in Antarctic seabirds and their foraging ecology as shown by δ13C and δ15N. Sci. Total Environ., 573 (2016), pp. 1380-1389. https://doi.org/10.1016/j.scitotenv.2016.07.080

Ministry of the Environment of Japan, 2017. The environmental risk assessment of decabromodiphenyl ether and short chained chlorinated paraffins. 18–20. In Japanese. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiVhKW_7p73AhUDK6YKHaq4DYcQFnoECBAQAQ&url=https%3A%2F%2Fwww.env.go.jp%2Fcouncil%2F05hoken%2Fy051-177-1b%2Fref04.pdf&usg=AOvVaw3X0p-dD0TfiRnDn3Rw7vRj

Menone, M.L., Miglioranza, K.S., Iribarne, O., de Moreno, J.E.A., Moreno, V.J., 2004. The role of burrowing beds and burrows of the SW Atlantic intertidal crab *Chasmagnathus granulata* in trapping organochlorine pesticides. Mar. Pollut. Bull. 48(3-4), 240-247. https://doi.org/10.1016/S0025-326X(03)00394-1

Molina, J.M., Blasina, G., Cazorla, A.L., 2021. Ecology and Biology of Fish Assemblages. In: Fiori, S.M., Pratolongo, P.D. (eds) The Bahía Blanca Estuary. Springer, Cham. https://doi.org/10.1007/978-3-030-66486-2_11

Perillo, G.M.E., Piccolo, M.C., Parodi, E., Freije, R.H., 2001. The Bahía Blanca Estuary, Argentina. In: SEELIGER, U. & KJERFVE, B. (Eds.), Coastal marine ecosystems of Latin America. Berlin, Springer, p. 205-217.

Piccolo, M.C., Perillo, G.M., 1990. Physical characteristics of the Bahía Blanca estuary (Argentina). Estuar. Coast. Shelf Sci. 31(3), 303-317. https://doi.org/10.1016/0272-7714(90)90106-2

Reth, M., Oehme, M., 2004. Limitations of low resolution mass spectrometry in the electron capture negative ionization mode for the analysis of short-and medium-chain chlorinated paraffins. Anal. Bioanal. Chem. 378(7), 1741-1747. https://doi.org/10.1007/s00216-004-2546-9

Reth, M., Zencak, Z., Oehme, M., 2005a. New quantification procedure for the analysis of chlorinated paraffins using electron capture negative ionization mass spectrometry. J. Chromatogr. A 1081(2), 225-231. https://doi.org/10.1016/j.chroma.2005.05.061

Reth, M., Zencak, Z., Oehme, M., 2005b. First study of congener group patterns and concentrations of short-and medium-chain chlorinated paraffins in fish from the North and Baltic Sea. Chemosphere 58(7), 847-854. https://doi.org/10.1016/j.chemosphere.2004.09.036

Reth, M., Ciric, A., Christensen, G.N., Heimstad, E.S., Oehme, M., 2006. Short-and medium-chain chlorinated paraffins in biota from the European Arctic—differences in homologue group patterns. Sci. Total Environ. 367(1), 252-260. https://doi.org/10.1016/j.scitotenv.2005.12.014

Roscales, J.L., Vicente, A., Ramos, L., Jiménez, B., 2017. Miniaturised sample preparation method for the multiresidual determination of regulated organohalogenated pollutants and related compounds in wild bird eggs. Analytical and bioanalytical chemistry 409(20), 4905-4913. https://doi.org/10.1007/s00216-017-0432-5

Sprengel, J. and Vetter, W., 2019. Synthesis and characterization of eight single chain length chlorinated paraffin standards and their use for quantification. Rapid Commun. Mass Spectrom., 33 (1) (2019), pp. 49-56. https://doi.org/10.1002/rcm.8310

Sprengel, J. and Vetter, W., 2020. NMR and GC/MS analysis of industrial chloroparaffin mixtures. Analytical and bioanalytical chemistry, 412(19), 4669-4679. https://doi.org/10.1007/s00216-020-02720-7

Streitenberger, M.E., Baldini, M.D., 2016. Contribution of the tributaries to the fecal contamination of the Bahía Blanca Estuary, Argentina. Revista internacional de contaminación ambiental 32(2), 243-248. https://doi.org/10.20937/RICA.2016.32.02.10

Sun, R., Luo, X., Tang, B., Chen, L., Liu, Y., Mai, B., 2017. Bioaccumulation of short chain chlorinated paraffins in a typical freshwater food web contaminated by e-waste in south china: Bioaccumulation factors, tissue distribution, and trophic transfer. Environmental Pollution 222, 165-174. https://doi.org/10.1016/j.envpol.2016.12.060

Tombesi, N., Pozo, K., Álvarez, M., Přibylová, P., Kukučka, P., Audy, O., Klánová, J., 2017. Tracking polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) in sediments and soils from the southwest of Buenos Aires Province, Argentina (South eastern part of the GRULAC region). Science of the Total Environment 575, 1470-1476. https://doi.org/10.1016/j.scitotenv.2016.10.013

Tombesi, N., Pozo, K., Arias, A., Alvarez, M., Pribylova, P., Audy, O., Klánová, J., 2018. Records of organochlorine pesticides in soils and sediments on the southwest of Buenos Aires Province, Argentina. Environmental Earth Sciences 77(11), 1-11. https://doi.org/10.1007/s12665-018-7582-4

Tomy, G.T., Muir, D.C.G., Stern, G.A., Westmore, J.B., 2000. Levels of C10-C13 polychloro-n-alkanes in marine mammals from the Arctic and the St. Lawrence River estuary. Environ. Sci. Technol. 34, 1615-1619. https://doi.org/10.1021/es990976f

UMA (Unidad de Medio Ambiente, Argentina), 2010. Annex E of the Stockholm Convention on short-chained chlorinated paraffins to the POPs Review Committee. UNEP-POPS-POPRC5FU-SUBM-SCCP-E-Argentina-100715. http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC5/SCCPsAnnexESupplementalInformation/tabid/711/Default.aspx

UNEP, 2011. Case study on toxicological interactions of chlorinated paraffins. Information document for seventh meeting of the Persistent Organic Pollutants Review Committee, United Nations Environment Programme. UNEP-POPS-POPRC.7-INF-15. http://www.pops.int/Convention/POPsReviewCommittee/POPRCMeetings/POPRC7/POPRC7Documents/tabid/2267/language/en-US/Default.aspx

566 UNEP, 2015. Report of the Persistent Organic Pollutants Review Committee on the work of its eleventh meeting.
567 UNEP/POPS/POPRC.11/10/Add.2
568 http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC11/Overview/tabid/4558/mctl/Vi
569 ewDetails/EventModID/871/EventID/553/xmid/13837/Default.aspx

570 UNEP, 2016. Report of the Persistent Organic Pollutants Review Committee on the Work of its Twelfth Meeting.
571 UNEP/POPS/POPRC.12/11/Add.3
572 http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC12/MeetingDocuments/tabid/51
573 91/Default.aspx

574 UNEP, 2017. Decision SC-8/11: Listing of Short-Chain Chlorinated Paraffins.
575 http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

576 UNEP, 2021. Technical work: consideration of chemicals proposed for listing in Annexes A, B and/or C to the
577 Convention: chlorinated paraffins with carbon chain lengths in the range C14-17 and chlorination levels at or
578 exceeding 45 per cent chlorine by weight. UNEP/POPS/POPRC.17/6
579 http://www.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/Default.aspx

580 Van Mourik, L.M., Gaus, C., Leonards, P.E., de Boer, J., 2016. Chlorinated paraffins in the environment: a review on
581 their production, fate, levels and trends between 2010 and 2015. Chemosphere 155, 415-428.
582 https://doi.org/10.1016/j.chemosphere.2016.04.037

583 Vetter, W., Kirres, J., Bendig, P., 2011. Bromination of 2-methoxydiphenyl ether to an average of tetrabrominated 2-
584 methoxydiphenyl ethers. Chemosphere, 84 (8), pp. 1117-1124.
585 https://doi.org/10.1016/j.chemosphere.2011.04.039

586 Vetter, W., Sprengel, J., Krätschmer, K., 2022. Chlorinated paraffins – A historical consideration including remarks on
587 their complexity. Chemosphere. 287. 132032. https://doi.org/10.1016/j.chemosphere.2021.132032

588 Wang, R., Gao, L., Zheng, M., Tian, Y., Li, J., Zhang, L., Wu, Y., Huang, H., Qiao, L., Liu, W., Su, G., Liu, G., Liu, Y., 2018.
589 Short-and medium-chain chlorinated paraffins in aquatic foods from 18 Chinese provinces: occurrence, spatial
590 distributions, and risk assessment. Science of the Total Environment 615, 1199-1206.
591 https://doi.org/10.1016/j.scitotenv.2017.09.327

592 Wang, S., Gao, L., Zheng, M., Qiao, L., Xu, C., Wang, K., Huang, D., 2021. Occurrences, congener group profiles, and
593 risk assessment of short-and medium-chain chlorinated paraffins in cup instant noodles from China.
594 Chemosphere 279, 130503. https://doi.org/10.1016/j.chemosphere.2021.130503

595 WHO/IPCS (World Health Organization/International Programme on Chemical Safety), 1996. Environmental Health
596 Criteria 181. Chlorinated Paraffins. International Programme on Chemical Safety. Available online:
597 http://www.inchem.org/documents/ehc/ehc/ehc181.htm

598 Xia, D., Vaye, O., Lu, R., Sun, Y., 2021. Resolving mass fractions and homolog group patterns of C8– C17 chlorinated
599 paraffins in commercial products: associations with source characterization. Sci. Total Environ. 769, 144701.
600 https://doi.org/10.1016/j.scitotenv.2020.144701

601 Yuan, B., Fu, J., Wang, Y., Jiang, G., 2017. Short-chain chlorinated paraffins in soil, paddy seeds (*Oryza sativa*) and
602 snails (Ampullariidae) in an e-waste dismantling area in China: Homologue group pattern, spatial distribution
603 and risk assessment. Environ. Pollut. 220, 608-615. https://doi.org/10.1016/j.envpol.2016.10.009

604 Zeng, L., Wang, T., Wang, P., Liu, Q., Han, S., Yuan, B., Zhu, N., Wang, Y., Jiang, G., 2011. Distribution and trophic
605 transfer of short-chain chlorinated paraffins in an aquatic ecosystem receiving effluents from a sewage
606 treatment plant. Environ. Sci. Technol. 45(13), 5529-5535. https://doi.org/10.1021/es200895b

607 Zeng, L., Lam, J.C.W., Wang, Y., Jiang, G., Lam, P.K.S., 2015. Temporal trends and pattern changes of short- and
608 medium-chain chlorinated paraffins in marine mammals from the South China sea over the past decade.
609 Environ. Sci. Technol. 49, 11348-11355. https://doi.org/10.1021/acs.est.5b02473

610 Zeng, L., Lam, J.C., Chen, H., Du, B., Leung, K.M., Lam, P.K., 2017. Tracking dietary sources of short-and medium-
611 chain chlorinated paraffins in marine mammals through a subtropical marine food web. Environ. Sci. Technol.
612 51(17), 9543-9552. https://doi.org/10.1021/acs.est.7b02210

613 Zhou, Y., Yin, G., Du, X., Xu, M., Qiu, Y., Ahlqvist, P., Chen, Q., Zhao, J., 2018. Short-chain chlorinated paraffins
614 (SCCPs) in a freshwater food web from Dianshan Lake: Occurrence level, congener pattern and trophic transfer.
615 Sci. Total Environ. 615, 1010-1018. https://doi.org/10.1016/j.scitotenv.2017.10.026

616 Zhou, Y., de Wit, C.A., Yin, G., Du, X., Yuan, B., 2019. Shorter than short-chain: Very short-chain chlorinated paraffins
617 (vSCCPs) found in wildlife from the Yangtze River Delta. Environ. Int. 130, 104955.
618 https://doi.org/10.1016/j.envint.2019.104955

Highlights

- First report on the occurrence of SCCPs and MCCPs in fish from the South Atlantic Ocean in Argentina
- SCCP and MCCP amounts were considered low or moderate, compared to other studies
- Analysed fish are safe for human consumption regarding SCCP amounts
- SCCPs amounts showed no inter- or intra-specific significative differences
- MCCP interspecific differences were explained by feeding habits and fish size

Short- and medium-chain chlorinated paraffins in fish from an anthropized south-western Atlantic estuary, Bahía Blanca, Argentina

Lautaro Girones , Yago Guida, Ana Laura Oliva , João Paulo Machado Torres , Jorge Eduardo Marcovecchio, Walter Vetter , Andrés Hugo Arias

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: