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RESEARCH ARTICLE

Mercury in the feathers of bird scavengers from two areas of Patagonia (Argentina) under the influence of different anthropogenic activities: a preliminary study

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Abstract
Mercury (Hg) is a global pollutant that bioaccumulates and biomagnifies in food chains and is associated with adverse effects in both humans and wildlife. We used feather samples from bird scavengers to evaluate Hg concentrations in two different areas of Northern Patagonia. Hg concentrations were analyzed in feathers obtained from turkey vultures (*Cathartes aura*), Black Vultures (*Coragyps atratus*), and southern crested caracaras (*Caracara plancus*) from the two areas of Northern Patagonia (Argentina): Bariloche and El Valle. Hg was detected in all the samples analyzed, but the concentrations can be considered low for the three species in both sampling areas. The mean concentration of Hg in Bariloche was 0.22 ± 0.16 mg/kg dry weight (d.w.) in black vulture, 0.13 ± 0.06 mg/kg d.w. in turkey vulture, and 0.13 ± 0.09 mg/kg d.w. in southern crested caracara; in El Valle, the mean concentration of Hg was 1.02 ± 0.89 mg/kg d.w. in black vulture, 0.53 ± 0.82 mg/kg d.w. in turkey vulture, and 0.54 ± 0.74 mg/kg d.w. in southern crested caracara. Hg concentrations in feathers were explained by the sampling area but not by the species. The concentrations of Hg contamination were comparable to those obtained in other studies of terrestrial raptors and aquatic bioindicator raptors. The species of the present study occur throughout much of North and South America. Thus, they may be appropriate bioindicators across the species' range, which is particularly useful as a surrogate, especially in distribution areas shared with endangered scavengers such as the California condor (*Gymnopsys californianus*) and the Andean Condor (*Vultur gryphus*).

Keywords Heavy metals · Non-invasive sampling · *Cathartidae* · *Caracara plancus* · Northern Patagonia · Mercury

Introduction

Mercury (Hg) is a persistent, toxic heavy metal, with a tendency of bioaccumulation and biomagnification across food chains (Eisler 1985). Primary sources of anthropogenic Hg emissions include the combustion of fossil fuels, mining and reprocessing of ores (gold, copper, lead, and zinc), iron, and steel, and cement production, operation of chlor-alkali plants, and waste incineration and disposal (Pacyna et al. 2006; Driscoll et al. 2007). Hg poisoning can result in reproductive, neurological, hematologic, and cellular disorders (Solonen and Lodenius 1984; Wolfe et al. 1998; Nichols et al. 1999; Espín et al. 2014a, b). Several studies indicate that Hg has immunotoxic effects (dose-dependent stimulation/suppression of lymphocyte response) (Ortega et al. 1997; Fallacara et al. 2011). Inorganic Hg is biotransformed by methylation processes (biotic and abiotic) to organomercury (i.e., methylmercury), becoming more toxic than inorganic Hg (Morel et al. 1998). Both paths have not been fully investigated, but the existing evidence indicates that the biotic pathway is the most common, as it is related to sulfate-reducing bacteria present in aquatic environments,

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which are responsible for 95% of the biomethylation (Broo and Odsjo 1981; Eisler 1985; Burger and Gochfeld 1997; PNUMA 2002; Rigét et al. 2007).

Birds have been widely used for assessing the levels of certain contaminants, especially metals (Furness and Greenwood 1993; García-Fernández et al. 2008; Lodenius and Solonen 2013; García-Fernández 2014). Due to their feeding habits, waterbirds present higher Hg concentrations compared to other birds as shown in many waterfowl contamination studies (Cahill et al. 1998; Monteiro and Furness 2001; Champoux et al. 2006; Sanpera et al. 2007; Rattner et al. 2008; Ribeiro et al. 2009; Espín et al. 2012). Therefore, aquatic ecosystems have been most frequently studied. However, there is evidence that the methylation process applies to terrestrial ecosystems as well, and some studies have found significant concentrations of this metal in terrestrial birds of prey (Broo and Odsjo 1981; Palma et al. 2005; Zolfaghari et al. 2007; Espín et al. 2014a, b). In this sense, several authors have reported significantly higher metal concentrations in birds inhabiting mining areas than in those from unpolluted or reference sites (Henny et al. 1994; García-Fernández et al. 2005; Gómez-Ramírez et al. 2011). Besides the pollution from mining areas, one of the main sources of anthropogenic Hg in the environment is chlor-alkali plants, and the effects can be observed long after the plants have ceased operation (Parks et al. 1984).

The analyses of Hg in feathers have been widely used, demonstrating that they are very useful as a non-invasive and non-lethal alternative to internal tissues (Martínez-López et al. 2004, 2005; Garitano-Zavala et al. 2010; Espín et al. 2012, 2014a, 2014b). Their collection and storage are fast and low-cost. In addition, Hg can also be analyzed in feathers from museums, which may offer valuable information about the temporal trends of contamination (Furness and Greenwood 1993; Ansara-Ross et al. 2013; García-Fernández et al. 2013). Hg is accumulated in the feathers during their growth by binding to disulphide bonds (Leonzio et al. 2009; Zolfaghari et al. 2009; García-Fernández et al. 2013), and Hg concentration in the feathers is correlated to its concentration in the blood (Solonen and Lodenius 1990; Monteiro and Furness 2001; Ansara-Ross et al. 2013; Lodenius and Solonen 2013). Once the growth process is completed and vascular connections that feed the feather atrophy, Hg concentrations do not vary significantly over time (García-Fernández et al. 2013).

Between 2005 and 2010, global industrial use of Hg cell chlorine has decreased by 30%. Although in Argentina, and other South American countries, regulations on the use of products, substances, and residues that contain Hg have been established in order to protect health and biodiversity, there is no regulation regarding the treatment of Hg waste (CRBAS 2012). Moreover, studies evaluating Hg in sediments and biota of the upper Negro River basin (Northern Patagonia, Argentina; Arribére et al. 2003) showed the probable influence of a chlor-alkali plant long after its closure in 1999. In this study, we use feather samples of scavenger birds in two contrasting areas of Northern Patagonia—one with a history of Hg contamination due to the presence of a chlor-alkali plant and the other with no history of contamination. We then compare our results with several other species of birds of prey with different feeding habits (including scavengers, hunters, and fishers) and discuss their implications for highly threatened scavenger species, which share the same areas with our focal species.

Materials and methods

Study area

The sampling was conducted during the austral spring of 2011 (October to December), as part of a preliminary study to determine the distribution of nests and roosts of the three species of this study in two previously not studied areas of Patagonia (Argentina) (Fig. 1), carried out by an interdisciplinary team formed by researchers from the University of Murcia (Spain) and CONICET-Universidad Nacional del Comahue de Bariloche (Argentina). The first study area (El Valle) includes the Rio Negro Valley (Cipolletti and Allen cities) (Fig. 1), an area of 100,000 ha (over 40,000 ha are used for agriculture) (Pozo 2013; Romero Gámez 2013). The average elevation of the area is 270 m above mean sea level (amsl); the climate is dry and cold desert (climatic classification of Köppen), with an average annual temperature of 14.5 °C and annual rainfall of 186.9 mm (Bustos and Rocchi 2008). The ecotone represented is the steppe. As already mentioned above, there was a chlor-alkali plant, active from 1950 to 1995 (Arribére et al. 2003) in the city of Neuquén (Fig. 1), and contamination by Hg in rivers has been detected more than 100 km downstream from the point of emission (Jackson et al. 2011). Thus, the presence of a gold and silver mining area of Andacollo in the area of Huaracu stream, Neuquén River tributary, between the towns of Andacollo and Huinganco should be taken into account. This area has a long mining tradition, which has been used by the Chilean-Canadian mining company “Andacollo Gold” since 2001. This company has received complaints from the inhabitants of Andacollo who accuse it of polluting the Huaraco stream (Ortiz 2008; Bellotti 2011). The second study area (Bariloche) was nearby San Carlos de Bariloche city, between the provinces of Neuquén and Rio Negro (Fig. 1), a rural area with low human population density (Rizzo et al. 2011). The average elevation of the area is 893 amsl; the climate is humid continental (climatic classification of Köppen), with an average annual temperature of 8.1 °C and total rainfall of 782.6 mm. The ecotone represented is the subantarctic forest (Bustos and Rocchi 2008). The area includes the Nahuel Huapi National Park with its main lake

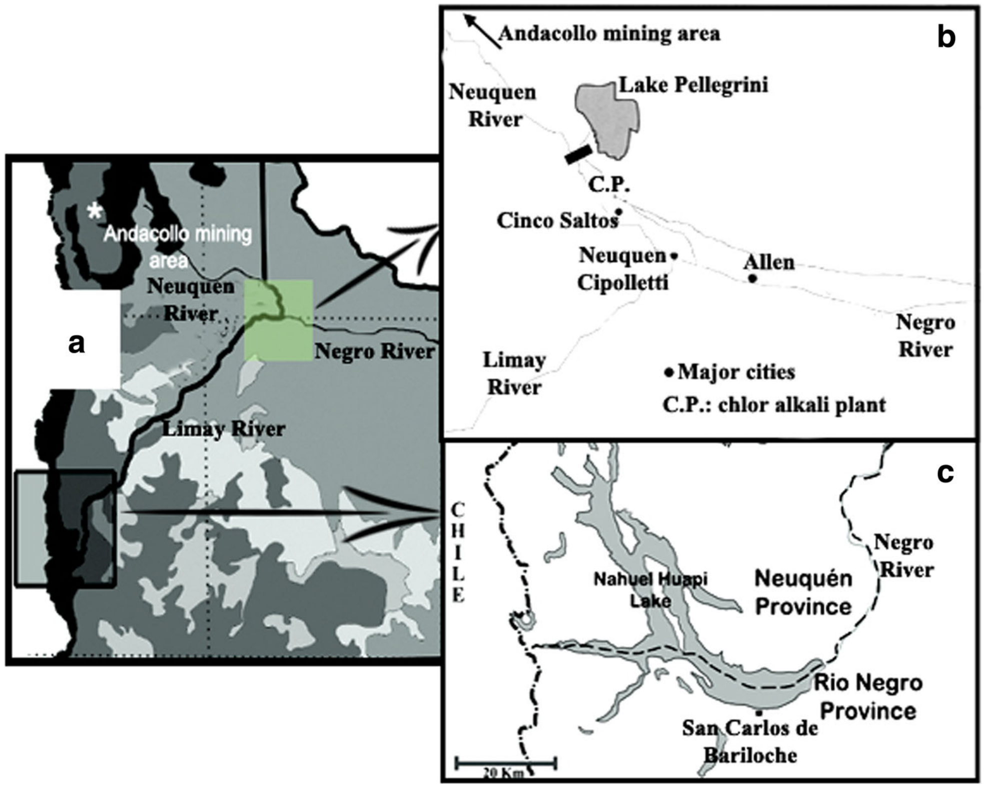

Fig. 1 Geographical representation of the study area. **a** Sampling areas (* represent the location of Andacollo mining ares, Huarachu stream, and Andacollo village). **b** Sampling area "El Valle." **c** Sampling area "Bariloche"

Nahuel Huapi and several other lakes. The main economic activity of the area is represented by nature tourism.

Species

The species studied were the turkey vulture (*Cathartes aura*) and black vulture (*Coragys atratus*), both species belonging to the family Cathartidae, plus another species of facultative scavenger bird of the American continent, the southern crested varacara (*Caracara plancus*). This species, unlike the previous two, belongs to the family Falconidae (Ferguson-Lees and Christie 2001). Turkey vulture is the most widely distributed New World vulture species. Its distribution area ranges from South Canada to Tierra del Fuego (Argentina/Chile) (Ferguson-Lees and Christie 2001). The distribution area of black vulture covers the majority of Central and South America, including the Atlantic states of USA (Ferguson-Lees and Christie 2001). The distribution of this species has been expanding, following the expansion of human settlements (Evans 2013, Novaes and Cintra 2013; Barbar et al. 2015; Ballejo et al. 2017). The distribution area of southern crested caracara includes South America (except Amazonia, Colombia, Peru, and high Andes), several Caribbean islands, Mexico, and is rarely encountered in the southern USA. (Ferguson-Lees and Christie 2001).

Black vulture and turkey vulture are scavenger birds, while southern crested caracara is an opportunistic scavenger (Ferguson-Lees and Christie 2001). The diet of black vulture and turkey vulture consists of carcasses of mammals, dead or stranded fish, insects, scraps from waste dumps and seabird colonies, occasionally reptiles, and eggs, and nestlings of herons (Ardeidae) and seabirds (Ferguson-Lees and Christie 2001; Haskins et al. 2013). A recent study conducted in Mexico shows the reliance of turkey vulture on the remains of fish (Blázquez et al. 2016). The diet of southern crested caracara is primarily carcasses, juveniles, injured, slow-moving birds, little rodents, reptiles, amphibians, fish, and arthropods (Ferguson-Lees and Christie 2001). Although we have no complete information on the feeding patterns of the three species in our study area, it has been found that the main food source of black vultures in "Bariloche" are the remains of slaughterhouse and exotic wildlife hunting, followed by arthropods (Ballejo and De Santis 2013). Both species of vultures are scavengers, but while black vultures mainly feed on remains of domestic animals, the diet of turkey vulture includes reptiles, fishes, and small rodents (Ballejo et al. 2017). As the three species also consume aquatic animals, they can be exposed to Hg from the aquatic environment in addition to Hg from terrestrial ecosystems. Another possible way to accumulate Hg from the aquatic environment can be the consumption of arthropods (Cristol et al. 2008). In this part of Patagonia, the black vulture is the most abundant species in urbanized areas, feeding from landfills and fishing areas (Bellati 2000; Ferguson-Lees and Christie 2001; Ballejo and De Santis 2013), while the southern crested caracara and especially the turkey vulture are species that prefer countryside (Bellati 2000; Ferguson-Lees and Christie 2001).

The black vulture and the southern crested caracara are resident birds, while the turkey vulture is migratory (Bildstein 2004). The northwestern Patagonian population of turkey vulture migrates to northern South America in winter (Graña Grilli et al. 2017). Black vulture can be considered site faithful. Several studies show that the home range of this species is approximately 30–40 km. In the case of turkey vulture, this range can reach 60–70 km (Coleman and Fraser 1989; De Vault et al. 2004; Holland et al. 2017). Site faithfulness can also be justified by the strong social bond and the aggressiveness of black vulture community that reduce the number of non-local vultures in the communal roosts (Buckley 1999).

There is scarce information on the molting patterns of the species under study. Southern crested caracara, as other medium-small-sized Falconidae, undergoes a complete molt each year (Ferguson-Lees and Christie 2001). As phylogenetic relationships of Cathartidae to other avian groups remain unresolved, it is difficult to compare with other species, and direct studies are insufficient (Chandler et al. 2010). Thus, the interpretation of molt patterns of Cathartidae is more complex. It is known that the molt of turkey vulture is serial. It starts by molting of the primary feathers (P1–P10). The molt of P1–P4 is completed before the reproductive period, followed by a suspension during the reproductive period, a resumption before the winter migration and suspended again during winter (Chandler et al. 2010). This strategy is similar to the California condor (*Gymnopsys californianus*), which lasts 2 years (Snyder et al. 1987).

Due to the limited number of Hg studies in scavenger birds, a bibliographic search including other birds of prey was done. Thus, both aquatic- and terrestrial-based raptor species were chosen, in order to compare Hg concentrations in birds living in the same area, but foraging in different ecosystems. To check whether our Hg contamination results from both sampling areas could be considered contaminated, they were compared with other studies in the same species from other areas (Fig. 2).

Sample collection

Only fresh-molted primary flight feathers (P1–P10) of adult individuals collected from the roosting areas were used in this study. The sampling was conducted during the austral spring of 2011 (October to December); this time of year covers the courtship, mating, and breeding periods of the species studied in the sampling region. Due to the type of sample and the sampling methodology, age or sex of the individuals is unknown. To reduce the possibility of pseudoreplication, only one feather per sampling point (or more than one if it was the same primary feather from the same wing) was collected. Each sample was kept in an individual plastic bag, labeled (study area, day, and species), and stored at room temperature in a dry place until analysis. A total of 90 primary feathers were collected: 44 in "Bariloche" from black vultures ($n = 20$), turkey vultures ($n = 14$), and southern crested caracaras ($n = 10$) and 46 in "El Valle" from black vultures ($n = 5$), turkey vultures ($n = 30$), and southern crested caracaras ($n = 11$) (see more details in Martínez-López et al. 2015).

Hg analysis

In order to remove external contamination from the surface of the feathers, a washing process was performed prior to analytical determination sequentially using tap water, distilled water, and Milli-Q® water (ISO 3696). The feathers were subsequently dried at room temperature overnight (Espín et al. 2012). Total Hg was analyzed in a Milestone DMA-8 Direct Hg Analyzer by atomic absorption spectrophotometry, with a detection limit of 0.005 ng. The whole feathers were individually cut, mixed shaft and vane, and stored in sterile bottles. Then the subsamples (0.5 g dry weight for vane and shaft) were loaded in nickel boats and analyzed, following USEPA Method 7473 (sediments, soils, and sludges). The applicability of this method to the analysis of biotic samples has been previously demonstrated (Haynes et al. 2006). The calibration curve was calculated with 11 points (in duplicate) from 0 to 1004 ng of Hg. The precision and accuracy of the method were tested using certified reference material (CRM) ($n = 11$; Hg standard for AAS, Fluka, 1000 mg/L Hg in 12% nitric acid). Recovery of total Hg from seven replicates of CRM diluted to 1 ppm was $98.14 \pm 3.52\%$ (mean ± standard deviation). The coefficient of variation for repeatability was 3.58%.

Statistical analysis

All analyses were carried out using the SPSS v.15.0 statistical package. Reported Hg concentrations represent median, mean ± standard deviation, and range. We used the Mann-Whitney test for the comparison between species. We used generalized linear models (GLM, normal distribution) to analyze the concentrations of Hg in each sample, using Hg concentration in each sample as the response variable. The explanatory variables considered were the study area and species. Four models were compared: (a) the null model, (b) the model with the variable "study area," (c) the model with the variable "species," (d) the model with two variables (study area + species), and finally, (e) the model with the interaction of both variables (study area × species). The level of significance for these tests was set at $\alpha = 0.05$. Furthermore, the quality of each model relative to each of the other models

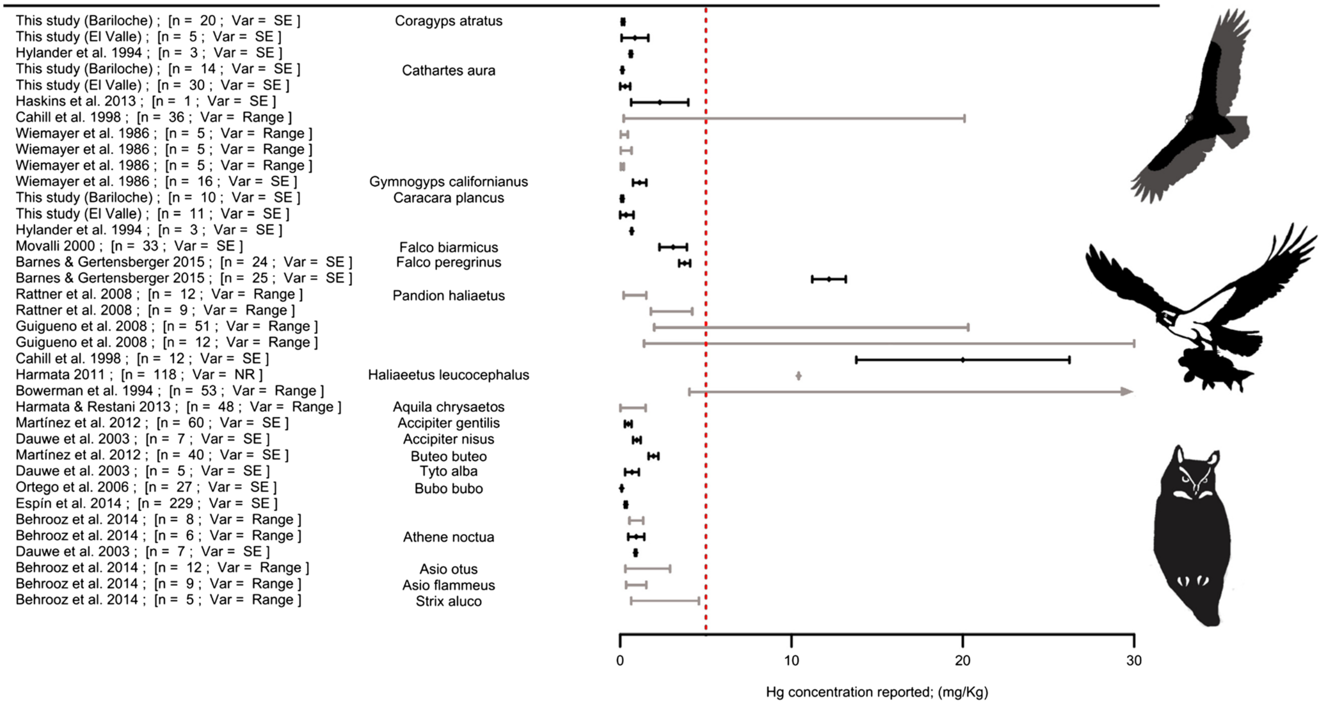

Fig. 2 Summary of Hg studies in feathers from different species, including scavengers around the world

was estimated by applying the Akaike information criterion (AIC) on the collection of model data (Burnham and Anderson 2002).

Results and discussion

Hg concentrations in feathers

Hg concentrations were detected in all feather samples. In "Bariloche" area, Hg concentrations were similar between species; but in "El Valle", the highest mean and median concentrations (1.02 mg/kg and 0.86 mg/kg, respectively) were found in the black vulture. The two highest concentrations of Hg feather concentrations were found in a turkey vulture (4.20 mg/kg) and in a southern crested caracara (2.61 mg/kg) (Table 1). However, no significant differences among species were found. In fact, the application of GLM to study the effect of the sampling area and species on concentrations of Hg in feathers shows that the model including only the variable "study area" was significant ($D^2 = 72.89$, $p = 0.005$) and with the best Akaike index (AIC = 1225.12). The value was significantly higher in "El Valle" than "Bariloche" for the three species (Table 1). As mentioned above, "El Valle" is considered contaminated by Hg as a result of the activity of a chlor-alkali plant (Arribére et al. 2003). These results are consistent with the data from several Hg and heavy metal contamination studies, carried out using samples of sludge and biota from rivers and lakes from the same area (Guevara et al. 2002; Arribére et al. 2003; Rizzo et al. 2011).

We compared our results with other studies in feathers of different bird species, including scavengers, from different areas around the world (Fig. 2). The study of black vulture and southern crested caracara (Hylander et al. 1994) in Alto Pantanal (Brazil) was used to represent a contaminated area. Alto Pantanal has a large history of Hg pollution due to the gold mining activities (Alho et al. 1988). There seem to be certain parallels between the environmental history of Alto Pantanal and "El Valle," as reflected in Hg concentrations detected in fish tissues (mean 0.2 mg/kg wet weight "El Valle"; 0.29 mg/kg wet weight "Alto Pantanal"; Hylander et al. 1994; Arribére et al. 2003). The mean concentration of Hg in feathers of black vulture and southern crested caracara from Alto Pantanal was 0.62 mg/kg and 0.67 mg/kg, respectively (Hylander et al. 1994). Those concentrations are similar to the mean concentrations of turkey vulture (0.53 mg/kg; $n = 30$) and southern crested caracara (0.54 mg/kg; $n = 11$) detected in "El Valle." The distance between both areas is more than 3000 km, and they represent two different ecoregions (Patagonian steppe vs. Tropical wetland) (Olson et al. 2001). However, the similarities between the results obtained in the analysis of Hg in feathers show that these results may reflect the level of contamination of the area.

Some considerations need to be made regarding the interpretation of the black vulture results. Due to the lack of previous information regarding the area and species, only five samples of black vulture feathers were obtained for our study. In addition, one of these five samples showed a high Hg concentration (2.44 mg/kg). If this outlier was not considered, the mean Hg concentration of this species (0.66 mg/kg of Hg)

Table 1 Concentrations of mercury for the three species of the study in the two sampling areas (median (in bold), mean ± standard deviation (SD), between parenthesis range (minimum/maximum) (*n* = number of samples)

Hg (mg/kg)	Bariloche	El Valle	All areas
Black vulture (*Coragyps atratus*)	0.17 0.22 ± 0.16 (SD) (*R* 0.09–0.65) (*n* = 20)	0.86 1.02 ± 0.89 (SD) (*R* 0.23–2.44) (*n* = 5)	0.18 0.38 ± 0.51 (SD) (*R* 0.09–2.44) (*n* = 25)
Turkey vulture (*Cathartes aura*)	0.13 0.13 ± 0.06 (SD) (*R* 0.06–0.25) (*n* = 14)	0.29 0.53 ± 0.82 (SD) (*R* 0.04–4.2) (*n* = 30)	0.17 0.4 ± 0.7 (SD) (*R* 0.04–4.2) (*n* = 44)
Southern crested caracara (*Caracara plancus*)	0.12 0.13 ± 0.09 (SD) (*R* 0.03–0.36) (*n* = 10)	0.34 0.54 ± 0.74 (SD) (*R* 0.09–2.61) (*n* = 11)	0.15 0.35 ± 0.56 (SD) (*R* 0.03–2.61) (*n* = 21)
All species	0.14 0.17 ± 0.12 (SD) (*R* 0.03–0.65) (*n* = 44)	0.33 0.59 ± 0.81 (SD) (*R* 0.04–4.2) (*n* = 46)	0.17 0.39 ± 0.62 (SD) (*R* 0.03–4.2) (*n* = 90)

remained similar to the values of turkey vultures and southern crested caracaras from "El Valle" and black vultures from Alto Pantanal. Nevertheless, due to a scarce number of samples of black vulture in "El Valle," these data must be considered relative.

Our results could not be compared with those found by Haskins et al. (2013), as primary and secondary flight, and tail feathers from a single specimen of turkey vulture were analyzed, with the aim to determine the element composition of vane and rachis structures. On the other hand, Cahill et al. (1998) found an average of 1.26 mg/kg Hg (*n* = 36) in turkey vulture feathers, higher than in the same species from "El Valle" (0.53 mg/kg Hg, *n* = 30), found in our study. In this case, the difference could be due to the different degree of contamination of the two areas. Clear Lake (California) has a history of contamination due to the activities of now abandoned Sulphur Bank Hg Mine that poured 100 tons of Hg into the lake between 1872 and 1957 (Suchanek et al. 1993, 1998). The contamination of "El Valle" is mainly due to the activity of an alkali chlorine plant. The plant, built on an island within the Neuquén River, poured its wastewaters into a series of drainage pools from 1951 to 1979 (Arribére et al. 2003). After 1979, until its closure in 1995, water was stored in settling and drying pools (Arribére et al. 2003). The estimated annual discharge value of the plant is approximately 500 kg/Hg/year (CRBAS 2012). This difference is reflected by the Hg concentrations detected in the sediment samples (18.3 mg/kg in Clear Lake; 1.3 mg/kg in the nearest sampling point to the area of higher contamination "El Valle") (Suchanek et al. 1998; Arribére et al. 2003).

In the case of "Bariloche," we can assume that this is a less polluted area than "El Valle," with mean concentrations and range of Hg lower than those detected in "El Valle" (mean Hg concentration "Bariloche" 0.6 mg/kg, range 0.49–0.6 mg/kg; mean Hg concentration "El Valle" 1.2 mg/kg, range 0.75–5.1 mg/kg) (Arriberé et al. 2003; Guevara et al. 2002). The levels found in "Bariloche" are similar to those found in areas considered to have received low levels of pollution and are similar to the study of turkey vulture in California, USA, by Wiemeyer et al. (1986), with mean concentrations of 0.11 mg/kg (*n* = 5, female breeding), 0.12 mg/kg (*n* = 5, male non-breeding), and 0.098 mg/kg (*n* = 5, female non-breeding). Due to the scarcity of research on these species, no further studies have been found to contrast our results in an area of low contamination.

Risk assessment

The scarce number of studies relating Hg concentrations in feathers and their corresponding effects (e.g., toxic effects levels) makes further interpretation difficult. According to a study on black-headed gull chicks (*Chroicocephalus ridibundus*), concentrations of Hg from 5 to 40 mg/kg in feathers were associated with reproductive disorders (Lewis and Furness 1991). Studies with several bird species indicate that 40 mg/kg of Hg in feathers is associated with fertility problems, reproductive disorders, low hatching rate, and survival of chicks (Finley and Stendell 1978; Solonen and Lodenius 1984; Eisler 1985). Eisler (1985) indicates that Hg concentrations of 9–11 mg/kg in feathers cause reproductive and behavioral deficits in domestic mallards (*Anas platyrhynchos*). However, Bowerman et al. (1994) detected Hg concentration between 13 and 20 mg/kg in bald eagles (*Haliaeetus leucocephalus*) without associated signs of reproductive problems or decreasing population size. Scheuhammer (1991) hypothesizes that Hg concentrations above 20 mg/kg (dry weight) in feathers of growing piscivorous birds can result from diets containing Hg concentrations greater than 1 mg/kg (dry weight) and that these concentrations should be considered as indicative of a wetland habitat that may pose a significant threat to the reproductive success of piscivorous wildlife breeding there. In any case, Scheuhammer (1991) considered Hg concentrations of 1–5 mg/kg (dry weight) in feathers of raptor birds as "normal." Other authors consider Hg concentrations greater than 5 mg/kg in feathers as "dangerous to birds" (Burger and Gochfeld 1997; Palma et al. 2005; Eisler 2006; Albuja et al. 2012). No concentrations higher than 5 mg/kg were detected in this study. If we take the concentration of 5 mg/kg in this study as a reference, only one sample of turkey vulture from the El Valle area is close to this concentration (4.2 mg/kg).

On the other hand, it should be pointed out that any of these studies quantify the possible sub-lethal effects at these concentrations, which might be relevant for long-living species, such as the scavenger birds in our study. In addition, as mentioned above, feathers trap Hg during their growth phase and are molted every year. Therefore, the results obtained from the analysis of the feathers must take this aspect into account.

Conclusions

This study brings together the concentrations of Hg in feathers of 69 samples of family Cathartidae and 21 *Caracara plancus*, and this is the first study of this magnitude of birds from Patagonia. The results of this study regarding the contamination of Hg coincide with the results of different studies in the same areas, suggesting higher concentrations of Hg contamination in "El Valle" than in "Bariloche." The three species are common throughout the American continent (North, Central, and South), have a high position in the trophic chain and the few studies where they have been used to determine Hg contamination in different environments of the American continent have some consistency of results. Therefore, we can consider valid the hypothesis that black vulture, turkey vulture, and southern crested caracara are good candidates for future biomonitoring studies. However, more studies are needed to assess more relationships between the values obtained. Another relevant aspect is that the three species share habitats with two endangered scavenger birds, the Californian condor and the Andean condor. Therefore, the results obtained with the species of this study might be relevant to evaluate risk to these endangered condors. This study is an important step in the collection of data on North Patagonia, the phenomena of Hg contamination in terrestrial ecosystems and the New World scavenger species, all of which have been little studied. Our results can be used as a comparison with future studies and geographic areas. This and other research on ethology and phenology, developed from the joint sampling of 2011, have provided us with new information, which has been used for new sampling that will try to shed light on some of the questions arisen from this preliminary study.

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