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Cadmium and lead concentrations in the tissues of bottlenose dolphins (*Tursiops truncatus*) and striped dolphins (*Stenella coeruleoalba*) stranded on the Croatian Adriatic coast

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ABSTRACT

Concentrations of cadmium (Cd) and lead (Pb) were measured by atomic absorption spectrometry in the livers, kidneys and muscles of 15 bottlenose (*Tursiops truncatus*) and two striped (*Stenella coeruleoalba*) dolphins, stranded dead along the Croatian Adriatic coast from 1990 to 1999. Cd concentrations (µg/g wet weight (w.w.)) ranged from 0.004 to 0.670 in muscle, from 0.004 to 1.842 in kidney and from 0.004 to 2.548 in liver tissues. Similarly, total Pb concentrations (µg/g w.w.) ranged from 0.01 to 0.46 in muscles, from 0.01 to 0.95 in kidneys and from 0.01 to 2.38 in livers. Cd and Pb concentrations revealed no significant differences between adults ($n = 10$; >6 years) and juveniles ($n = 7$; <6 years). Mean Cd concentrations decreased in bottlenose dolphin tissues in the order: kidney>liver>muscle, which is a typical Cd distribution pattern. Significant positive correlations of Cd concentrations were found between livers and kidneys ($r = 0.63$, $P = 0.015$), and livers and muscles ($r = 0.74$, $P = 0.0008$). Furthermore, a significant positive correlation of Pb concentrations was determined between kidneys and muscles ($r = 0.75$, $P = 0.001$), opposite to the significant negative correlation between liver and muscle Pb concentrations ($r = -0.66$, $P = 0.004$). Our study reports the Cd and Pb concentrations in tissues of the most abundant delphinid species in the Adriatic Sea, sampled over a

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10-year period. These data are required for future studies on toxic metal accumulations and their dynamics in Adriatic dolphins and in the Adriatic environment.

Key words: cadmium, lead, heavy metal accumulation, *Tursiops truncatus*, *Stenella coeruleoalba*, Adriatic Sea

Introduction

One of the constant anthropogenic threats to marine ecosystem health is contamination with heavy metals and persistent organic pollutants (BOSSART, 2011). Heavy metals, such as cadmium (Cd) and lead (Pb), have a long biological half-life. They are present in the food chain and accumulate in living organisms and in ecosystems. During low-dose exposure, heavy metals are genotoxic, carcinogenic and immunosuppressive (JÄRUP, 2003; SREBOČAN and SREBOČAN, 2009; PREVENDAR CRNIĆ et al., 2015). The main source of heavy metals for dolphins is their diet, i.e. fish and cephalopods. Dolphins (Ordo: Cetacea) are predators and long living organisms at the top of the pelagic food chain, and thus they accumulate the highest concentrations of many pollutants during their lifetime in the marine environment (FRODELLO and MARCHAND, 2001; YORDY et al., 2010; SEIXAS et al., 2014). The degree to which heavy metals accumulate in an organism depends on the amount of contaminated food the animal consumes and the duration of the biological half-life (FRODELLO and MARCHAND, 2001).

Bottlenose (*Tursiops truncatus*) and striped (*Stenella coeruleoalba*) dolphins are common cetacean species of the Mediterranean Sea. Additionally, the bottlenose dolphin is considered to be the only resident marine mammal in the Adriatic Sea (ĐURAS GOMERČIĆ et al., 2009; GALOV et al., 2011), although the striped dolphin has appeared regularly over the past decade in the southern Adriatic. Since these dolphins are exposed to pollutants in coastal and offshore areas, they represent important bioindicators of marine pollution (STORELLI and MARCOTRIGIANO, 2000; GARCÍA-ALVAREZ et al., 2014; POLIZZI et al., 2014) and are sentinel species for public health (BOSSART, 2011; REIF, 2011).

Although several studies have been carried out on toxic metals in marine mammals from the Mediterranean, data on metal accumulation in dolphins from the Adriatic Sea are scarce. To date, POMPE GOTAL et al. (2009) reported on mercury concentrations in bottlenose and striped dolphins stranded from 1990 to 1999. Additionally, BILANDŽIĆ et al. (2012) determined the concentrations of toxic elements in three delphinid species stranded in the Adriatic from 2000 to 2002.

This study analyses the Cd and Pb concentrations in the tissues of the most abundant delphinid species in the Adriatic Sea, the bottlenose and striped dolphins. Archived delphinid tissues, sampled from 1990 to 1999 in the Adriatic Sea, were examined. To our knowledge, these are the first and only delphinid tissues suitable for toxicological analyses to be systematically sampled during this time period in the Adriatic. Given the importance and persistence of toxic metal concentrations in the marine environment, these historical data are important for future studies on toxic metal accumulation and dynamics in Adriatic dolphins, and in the Adriatic marine environment.

Materials and methods

From 1990 until 1999, liver, kidney and muscle samples were collected from 15 bottlenose dolphins (seven females and eight males) and two striped dolphins (one female and one male), aged between <1 and 23 years, stranded dead along the Croatian coast of the Adriatic Sea (Table 1; Fig. 1). The dolphins were examined post-mortally as part of a long-term project to investigate marine mammal stranding along the Croatian coast of the Adriatic Sea. Species, sex, body mass and external measurements were recorded. The age of animals was estimated by counting growth layer groups (GLGs) in the dentine according to HOHN et al. (1989), in teeth sections prepared according to SLOOTEN (1991). The classification was made according to the average time of sexual maturity of both studied species. The sampling was carried out with the permission of the competent authorities of the Republic of Croatia.

Liver, kidney and muscle samples for Cd and Pb analysis were stored at -20 ºC until analysis. Metals were analyzed by atomic absorption spectrometry with electrothermal atomization, as previously described in GAVRILOVIĆ et al. (2007), performed on an ATI Unicam 929 AAS at 228.8 nm for Cd and 217.0 nm for Pb, with a deuterium lamp for background correction, after digestion with 3 mL 65 % HNO_3 and 0.5 mL 30 % H_2O_2 in a Milestone 1 200 M high performance microwave oven at 300 W for 5 min, then at 600 W for 10 min. This proved satisfactory. Working standards were prepared from Titrisol solutions (Merck, Darmstadt). The Certified Standard Reference Material SRM 1566a (oyster tissue) from NIST, USA, was used to verify the procedure, yielding good agreement between the measured and verified concentrations (±10 %).

Descriptive statistics (mean, standard deviation, median, minimum and maximum values) and nonparametric analyses were performed using Statistica 9.0 software. The Mann-Whitney U-test was used to assess the significance of differences in Cd and Pb concentrations between adult (n = 10; >6 years) and juvenile (n = 7; <6 years) dolphins, and Spearman`s R coefficient was used to assess the correlation of Cd and Pb in different tissues.

Results

The individually measured Cd and Pb concentrations (μg/g wet w.w.) in liver (L), kidney (K) and muscle (M) tissues of bottlenose (Tt) and striped (Sc) dolphins sampled during the 10-year period along the Croatian Adriatic Sea are presented in Table 1, along

Table 1. Cadmium (Cd) and lead (Pb) concentrations (g/g w.w.) in liver (L), kidney (K) and muscle (M) tissues of bottlenose (*Tt*) and striped (*Sc*) dolphins, sampled from 1990 to 1999 along the Croatian Adriatic Sea.

Dolphin ID	Species	Geographical position Latitude N	Geographical position Longitude E	Date found	Body length (cm)	Body mass (kg)	Sex	Age (years)	Cd L	Cd K	Cd M	Pb L	Pb K	Pb M
01	*Tt*	45.050000	13.583333	16.10.1990	265	204	F	4	<l.o.d.	0.209	0.040	<l.o.d.	0.09	0.09
02	*Tt*	45.086929	13.640453	1.11.1990	164	52	F	<1	0.004	0.004	0.004	0.07	0.01	0.11
03	*Tt*	45.066667	13.566667	18.6.1992	263	240	M	7	0.040	0.005	0.103	0.08	0.95	0.19
06	*Tt*	44.554619	14.386917	22.9.1993	241	n.a.	M	3-4*	0.164	0.570	0.050	0.27	0.41	0.46
07	*Tt*	45.069569	13.626284	29.3.1994	219	120	F	6	0.064	0.260	0.044	0.55	0.26	0.24
08	*Tt*	44.863390	14.001785	26.5.1994	265	n.a.	F	6	0.346	0.799	0.079	2.38	0.18	0.02
10	*Tt*	42.735039	16.888750	1.9.1994	163	75	M	<1	0.043	0.056	0.042	0.09	0.88	0.12
12	*Tt*	43.729930	15.894227	21.12.1995	278	237	M	9	0.332	0.819	0.563	0.11	0.01	0.01
13	*Tt*	44.820166	13.872045	19.4.1996	240	n.a.	F	5	0.450	1.842	0.139	0.01	0.01	0.01
15	*Tt*	45.099120	13.629265	2.10.1996.	290	279	M	12	0.457	0.571	0.208	0.43	0.01	0.01
20	*Tt*	43.814485	15.678862	8.10.1997	288	241	F	21	0.181	1.132	0.068	0.12	0.09	0.13
22	*Tt*	43.491277	15.982022	17.3.1998	234	n.a.	M	3	0.256	1.219	0.034	0.14	0.10	0.12
23	*Tt*	42.640418	18.117980	12.1.1999	291	n.a.	M	11	0.292	1.015	0.060	0.44	0.10	0.18
25	*Tt*	44.261064	15.209791	27.2.1999	278	228	F	23	0.315	1.204	0.419	0.30	0.12	0.14
27	*Sc*	43.816732	15.933025	23.6.1999	198	99	M	11	2.548	<l.o.d.	0.670	0.15	<l.o.d.	0.08
28	*Tt*	43.502519	16.479775	9.7.1999	312	249	M	16	0.197	1.684	0.043	0.21	0.08	0.11
29	*Sc*	45.118622	14.517065	18.7.1999	171	29	F	5	0.805	<l.o.d.	0.232	0.13	<l.o.d.	0.06
								Descriptive statistics						
								N	16	15	17	16	15	17
								Median	0.274	0.799	0.068	0.15	0.1	0.11
								Mean ± SD	0.406 ± 0.606	0.759 ± 0.592	0.165 ± 0.199	0.34 ± 0.57	0.22 ± 0.30	0.12 ± 0.11
								Min - Max	<l.o.d. - 2.548	<l.o.d. - 1.842	0.004 - 0.670	<l.o.d. - 2.38	<l.o.d. - 0.95	0.01 - 0.46

*no teeth analyzed, age estimated according to the body length; l.o.d.= limit of detection; n.a.= not available

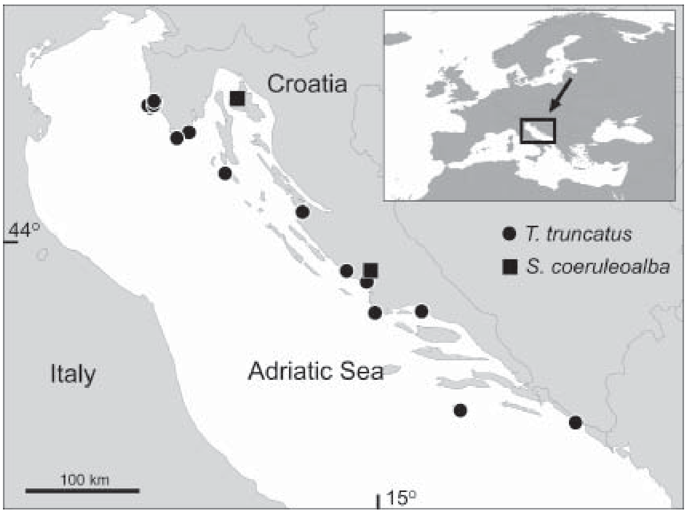

Fig. 1. Sampling areas along the Croatian Adriatic coast

with the location and year of stranding, sex and estimated age in years. Descriptive statistics of Cd and Pb concentrations (μg/g, w. w.) in liver, kidney and muscle tissues is summarized in Table 1. The wide range of Cd and Pb concentrations determined in this study showed the diverse accumulation of these toxic elements between dolphin tissues and different contamination of individuals. Cd concentrations were high in bottlenose dolphin kidneys, with values ranging from 0.004 to 1.842 and a median of 0.799 μg/g. The highest kidney Cd value was recorded in a 5 year old female bottlenose dolphin found in the Northern Adriatic. Cd concentrations in the kidneys of striped dolphins were under the limit of detection in both the examined specimens. Cd concentrations in the liver varied from 0.004 to 0.805 (median 0.274) μg/g. The highest concentrations of Cd were recorded in the livers of the two studied striped dolphins. The 5 year old striped dolphin female, found on the island of Krk in the Northern Adriatic, measured 0.805 μg/g, while the highest Cd concentration determined in our study (2.548 μg/g) was recorded in the liver of an 11 year old male striped dolphin found in Skradin in the Central Adriatic. The concentrations of Cd in the liver of the striped dolphins were 1.8 and 5.6 times higher than the highest value (0.457 μg/g) measured in the liver of a bottlenose dolphin. Cd values in muscle ranged from 0.004 to 0.670 (median 0.068) μg/g w.w. (Table 1). The highest Cd concentrations in muscle were measured in an 11 year old male striped dolphin found in the Central Adriatic (0.670 μg/g), and a 9 year old male bottlenose dolphin from the same region (0.563 μg/g). Median Pb concentrations were similar in all of the analyzed tissues, with the highest values found in the liver. In livers these concentrations ranged from 0.01

Table 2. Minimum and maximum concentrations (µg/g w.w.) of cadmium (Cd) and lead (Pb) in tissues of bottlenose dolphins from various Mediterranean locations and periods of sampling.

Location and years		Cd			Pb		
		Liver	Kidney	Muscle	Liver	Kidney	Muscle
Croatian Adriatic 1990-1999 (this study)	N Median Mean ± SD Min - Max	15 0.227 0.224 ± 0.15 <l.o.d. -0.457	15 0.799 0.759 ± 0.59 <l.o.d. -1.842	15 0.06 0.126 ± 0.158 0.004 - 0.563	15 0.175 0.37 ± 0.60 <l.o.d. - 2.38	15 0.1 0.22 ± 0.30 <l.o.d. - 0.95	15 0.12 0.129 ± 0.11 0.01 - 0.46
Eastern Adriatic 2000-2002 (BILANDŽIĆ et al., 2012)	N Median Mean ± SD Min - Max	14 0.27 0.63 ± 1.16 0.076 - 4.48	14 1.7 2.85 ± 2.88 0.12 - 10.1	14 0.008 0.011 ± 0.010 0.002 - 0.04	14 0.11 0.14 ± 0.09 0.035 - 0.38	14 0.032 0.21 ± 0.45 0.01 - 1.59	14 0.010 0.015 ± 0.009 0.01 - 0.037
Israeli Mediterranean 1993-2001 (RODITI-ELASAR et al., 2003)	N Median Mean ± SD Min - Max	14 0.41 0.49 ± 0.33 0.12 - 1.1	14 0.34 0.88 ± 1.7 0.06 - 4.2	17 0.8 0.1 ± 0.05 0.04 - 0.20	n.a.	n.a.	n.a.
Israeli Mediterranean 2004 - 2006 (SHOHAM-FRIDER et al., 2009)	N Median Mean ± SD Min - Max	7 n.a. <0.04 <0.04	7 n.a. 0.57 ± 0.47 0.5 - 1.11	7 n.a. <0.04 <0.04	n.a.	n.a.	n.a.
Corsica 1993-1998 (FRODELLO and MARCHAND, 2001)*	N Median Mean ± SD Min - Max	7 n.a. 0.184 ± n.a. 0.015 - 0.462	7 n.a. 1.07 ± n.a. 0.035 - 2.2	7 n.a. 0.05 ± n.a. 0.006 - 0.11	7 n.a. 0.814 ± n.a. 0,33-2,64	7 n.a. 0.902 ± n.a. 0.396 - 3.08	7 n.a. 0.792 ± n.a. 0.044 - 1.606
Ligurian Sea 1990 - 2004 (CAPELLI et al., 2008)*	N Median Mean ± SD Min - Max	2 n.a. n.a. <l.o.d. - 0.66	2 n.a. 1.083 ± 1.52 0.006 - 2.16	2 n.a. n.a. <l.o.d.- 0.026	2 n.a. 0.067 ± 0.04 0.034 - 0.10	2 n.a. 0.0325 ± 0.02 0.019 - 0.046	2 n.a. n.a. <l.o.d. - 0.057

* Global conversion factor of 0.22 WW/DW was used to compare our values to those reported by these authors that measured concentrations in dried samples (DW) (RODITI ELASAR et al., 2003). n.a. = not available

to 0.55 (median 0.145) μg/g, with the highest concentration (2.38 μg/g) measured in a 6 year old female from the Northern Adriatic. The values of Pb in the muscles ranged from 0.01 to 0.46 μg/g (median 0.11), with the highest value recorded in the muscle of a juvenile (estimated age 3-4 years) male bottlenose dolphin found in the Northern Adriatic. The Pb concentrations in the kidneys of the striped dolphins were under the limit of detection. The concentrations in the kidneys of bottlenose dolphins ranged from 0.01 to 0.95 μg/g (median 0.1). The highest value was determined in a 7 year old male bottlenose dolphin from the Northern Adriatic.

Cd concentrations in the livers positively correlated with Cd concentrations in the kidneys ($r = 0.63$, $P = 0.015$) and muscles ($r = 0.74$, $P = 0.0008$), while the correlation between concentrations in the kidneys and muscles was lower and not significant ($r = 0.31$, $P = 0.25$). Concurrently, the Pb concentration in the muscles correlated positively with Pb concentration in the kidneys ($r = 0.75$, $P = 0.0013$), but negatively with Pb concentration in the livers ($r = -0.66$, $P = 0.0048$). The correlation between Pb concentration in the livers and kidneys was positive, but not significant ($r = 0.24$, $P = 0.41$).

Our study did not indicate any impact of age on Cd and Pb concentrations in the examined tissues. Cd and Pb concentrations showed no statistically significant differences between adult and juvenile dolphins.

Discussion

This is the first study on Cd and Pb concentrations in the tissues of bottlenose and striped dolphins, stranded dead from 1990 to 1999 in the Adriatic Sea. We also determined differences in heavy metal accumulation between the analyzed tissues and delphinid species. As previously reported in cetaceans (BILANDŽIĆ et al., 2012), Cd concentrations recorded in bottlenose dolphins were higher in the kidneys than in the liver and muscles, which is in accordance with the fact that the kidney is the main detoxifying organ for cadmium in mammals. On the other hand, Cd concentrations in kidney tissue of the striped dolphins were under the limit of detection, while high Cd concentrations were determined in liver tissue (0.805 and 2.548 μg/g). Mean Cd concentrations decreased in bottlenose dolphin tissues in this order: kidney>liver>muscle, which is a typical Cd distribution pattern. Cd concentrations positively correlated between livers and kidneys ($r = 0.63$, $P = 0.015$), similar to bottlenose dolphins from the Mediterranean in Israel (RODITI-ELASAR et al., 2003), and livers and muscles ($r = 0.74$, $P = 0.0008$). The highest concentrations of Cd were measured in the livers of the sampled striped dolphins. It is known that striped dolphins consume more Cd accumulating prey, such as cephalopods, and therefore their Cd concentrations tend to be higher than in bottlenose dolphins (RODITI-ELASAR et al., 2003; BILANDŽIĆ et al., 2012). These findings support the previous statement that striped dolphins, like all marine mammals frequently feeding on cephalopods, accumulate Cd in the liver (MONACI et al., 1998). This study included only two carcasses of striped dolphins and therefore any further statistical analysis was inappropriate. Although expected, higher concentrations of Cd were not found in older specimens. This corresponds to findings for bottlenose dolphins reported in RODITI-ELASAR et al. (2003). Cd positively correlated with age in the muscles and livers, but not in the kidneys of the striped dolphins sampled in the study of MONACI et al. (1998).

Reports on the concentrations of Cd and Pb in the tissues of bottlenose dolphins from the Mediterranean are scarce. The published ranges (FRODELLO and MARCHAND, 2001; RODITI-ELASAR et al., 2003; CAPELLI et al., 2008; SHOHAM- FRIDER et al., 2009; BILANDŽIĆ et al., 2012) have been compiled in Table 2, together with the data for bottlenose dolphins analyzed in this study. Liver and kidney Cd concentrations from this study were lower than the concentrations reported in Israel from 1993 to 2001 (RODITI-ELASAR et al., 2003) and the Ligurian Sea (CAPELLI et al., 2008), but similar to those from Corsica (FRODELLO and MARCHAND, 2001) and Israel, reported from 2004 to 2006 (SHOHAM-FRIDER et al., 2009). The maximum muscle Cd concentrations recorded in this study were highest of the Mediterranean bottlenose dolphins, and are comparable to those from the Corsican coast (FRODELLO and MARCHAND, 2001). Our results, compared to the values reported in BILANDŽIĆ et al. (2012), show that bottlenose dolphins from the Adriatic Sea show a slight increase in tissue Cd concentrations. This finding is contrary to the continuous decrease in total Cd atmospheric emissions in Europe from 1990 to 2003 (UNEP, 2010). The sources of "new" inputs of heavy metals to the seas are: atmospheric deposition, river inputs, hydrothermal vents, sub-seafloor hot water vents (BRULAND and LOHAN, 2003), and direct anthropogenic discharges. However, Cd is transported through the air and over long distances, and is ingested through the food chain (RODITI-ELASAR et al., 2003). Since there have been no increases in industrialization on or near the Eastern Adriatic coast, remote sources of Cd in the Adriatic Sea should be considered. Namely, recent atmospheric depositions of Cd in the Mediterranean Sea have been found to originate from European, North African and Arabian aerosols (GUERZONI et al., 1999; HERUT et al., 2001). Additionally, Cd has a long residence time in the water column, as the marine reservoir is believed to be large compared to anthropogenic contributions of Cd in surface waters (BOYLE, 2001).

Concentrations of Pb in the tissues of bottlenose dolphins from the Adriatic Sea were higher than those reported from the Ligurian Sea (CAPELLI et al., 2008), but lower than those reported from the Corsican coast (FRODELLO and MARCHAND, 2001). An exceptional concentration of Pb (2.38 μg/g) was determined in the liver of a 6 year old female bottlenose dolphin found near Medulin. A significant positive correlation of Pb concentrations was determined between kidneys and muscles ($r = 0.75$, $P = 0.0013$), while there was a significant negative correlation between liver and muscle Pb concentrations ($r = -0.66$, $P = 0.0048$), which is similar to the report from BILANDŽIĆ et al. (2012).

Data on Pb concentrations from Adriatic bottlenose dolphins, stranded from 2000 until 2002, reported in BILANDŽIĆ et al. (2012), compared to data from the period 1990 to 1999 (this study), indicate a slow decrease in mean Pb concentrations in bottlenose dolphin tissues, likely as a result of the decreased contamination of the marine environment over the years. Namely, the marine environment responds to regional, remote and global changes in atmospheric Pb pollution (ANNIBALDI et al., 2009). A decrease in dissolved Pb concentrations in Adriatic coastal seawater was found to be related to the decrease in use of leaded gasoline in Italy (ANNIBALDI et al., 2009). Furthermore, atmospheric Pb in the Mediterranean region derives primarily from European emissions (VON STORCH et al., 2003), where phasing out of leaded gasoline took place during the 1990s and 2000s (ANNIBALDI et al., 2009).

In conclusion, this is the second study on Cd and Pb concentrations in dolphins stranded in the Adriatic Sea. BILANDŽIĆ et al. (2012) reported on concentrations from 2000 until 2012, while this study presents concentrations during the preceding 10-year period. In addition to other studies on pollutants in dolphins from the Mediterranean (FRODELLO and MARCHAND, 2001; RODITI-ELASAR et al., 2003; CAPELLI et al., 2008; SHOHAM- FRIDER et al., 2009; BILANDŽIĆ et al., 2012), the data presented here are a valuable source of information on heavy metal concentrations in marine mammals from this region. They also indicate a slight increase in Cd accumulation in dolphin tissues from the Adriatic Sea, as opposed to a slow decrease in Pb concentrations. Therefore, we propose systematic and long-term monitoring of heavy metal accumulations through the Adriatic food chain, in order to obtain a clear insight into their dynamics, and to ensure the effectiveness of mitigation measures.

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ŠURAN, J., M. ĐURAS, T. GOMERČIĆ, N. BILANDŽIĆ, A. PREVENDAR CRNIĆ: Koncentracije kadmija i olova u tkivima dobrog (*Tursiops truncatus*) i plavobijelog dupina (*Stenella coeruleoalba*) nasukanih na hrvatskoj obali Jadranskoga mora. Vet. arhiv 85, 677-688, 2015.

SAŽETAK

Koncentracije kadmija (Cd) i olova (Pb) određene su u uzorcima jetrenog, mišićnog i bubrežnog tkiva 15 dobrih (*Tursiops truncatus*) i 2 plavobijela (*Stenella coeruleoalba*) dupina uginulih od 1990. do 1999. godine uzduž hrvatskog dijela Jadranskoga mora. Koncentracija kadmija kretala se od 0,004 do 0,670 µg/g u mišiću, 0,004 do 1,842 µg/g u bubregu i od 0,004 do 2,548 µg/g u jetri (vlažna težina). Koncentracije olova kretale su se od 0,01 do 0,46 µg/g u mišiću, od 0,01 do 0,95 µg/g u bubregu i od 0,01 do 2,38 µg/g u jetri. Razlika u koncentracijama Cd i Pb u tkivima mladih (n = 7; <6 godina) i odraslih (n = 10; >6 godina) životinja nije bila statistički značajna. Srednje vrijednosti Cd kretale su se prema uobičajenoj distribuciji od najviše u bubrezima prema najnižoj u mišićima (bubrezi>jetra>mišići). Statistički značajnu pozitivnu korelaciju pokazuju koncentracija Cd u jetri i bubrezima (r = 0,63, P = 0,015) i koncentracija u jetri i mišiću (r = 0,74, P = 0,0008). Jednako tako statistički značajnu pozitivnu korelaciju pokazuju koncentracija Pb u bubrezima i u mišiću (r = 0,75, P = 0,001), dok je između jetre i mišića korelacija negativna (r = -0,66, P = 0,004). Ovim istraživanjem koje obuhvaća raspon od 10 godina određene su koncentracije Cd i Pb u tkivima najučestalijih vrsta dupina Jadranskoga mora. Utvrđene razine teških metala osnova su za buduća istraživanja njihove koncentracije i dinamike u jadranskim dupinima, ali i cjelokupnom jadranskom okolišu.

Ključne riječi: kadmij, olovo, zagađenje, *Tursiops truncatus*, *Stenella coeruleoalba*, Jadransko more