Electronic Supplementary Material (ESI) for Environmental Science: Processes & Impacts.

Supplementary materials

Ecotoxicology of Persistent Organic Pollutants in Birds

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Captions

Fig. S1 Spatial distribution of the reported DDTs concentrations in birds around the world.

Fig. S2 Spatial distribution of the reported HCHs concentrations in birds around the world.

Fig. S3 Spatial distribution of the reported PCDD/Fs concentrations in birds around the world.

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Fig. S5 Spatial distribution of the reported PBDEs concentrations in birds around the world.

Fig. S6 Spatial distribution of the reported TEQ values of PCDD/Fs, dioxin-like PCBs and ∑(PCDD/Fs + dioxin-like PCBs) in birds around the world (pg TEQ g^{-1} lw).

Fig. S7 Global distribution of the publications on POPs related to avian species.

Fig. S8 Publications on investigated orders of avian species and the percentages of investigated species numbers in each order.

Fig. S9 Publications on investigated bird species.

Fig. S10 Publications on the different employed matrices.

Table S1 Associations between POP exposure and thyroid hormones.

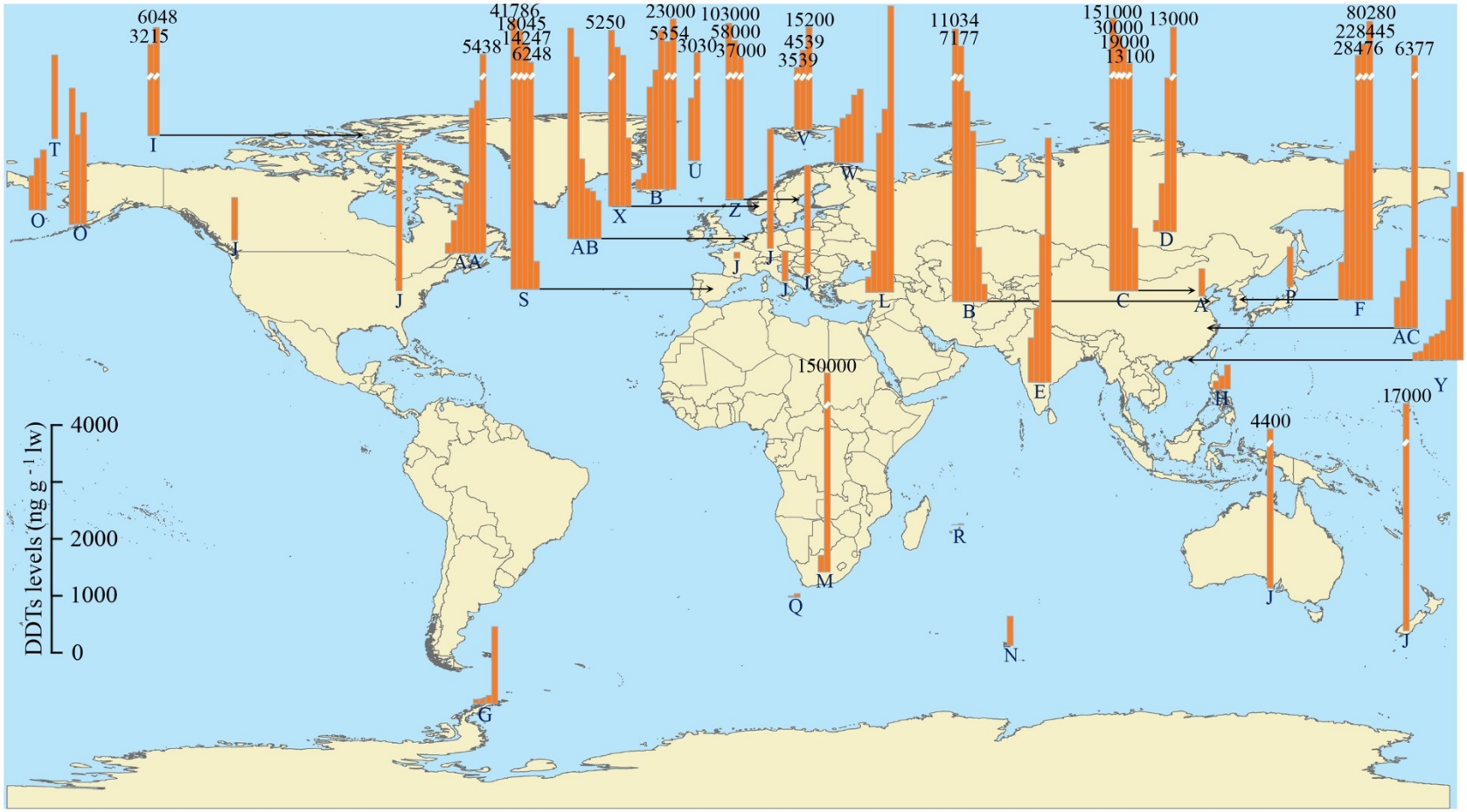

Fig. S1 Spatial distribution of the reported DDTs concentrations in birds around the world. The concentrations were obtained from a: A: Kentish

Plover (Zheng et al., 2018); B: Saunders's Gull, Black-winged Stilt, Common Tern, Oriental Pratincole, Kentish Plover, Eurasian Coot (Gao et al., 2009); C: Eurasian Sparrowhawk, Little Owl, Oriental Scops Owl, Common Kestrel (Chen et al., 2009), Long-eared Owl (Luzardo et al., 2014); D: House Sparrow, Grey Heron, Carrion Crow (Kunisue et al., 2003), Herring Gull (Kunisue et al., 2002); E: Kentish Plover, Common Myna, Black Drongo, White-throated Kingfisher (Kunisue et al., 2003); F: Pacific Loon, Grey Heron, Little Egret (Hong et al., 2014), Herring Gull (Choi et al., 2001), Great Egret (Hong et al., 2014), Bar-tailed Godwit (Choi et al., 2001); G: Gentoo Penguin, Adelie Penguin, Chinstrap Penguin, South Polar Skua (Mello et al., 2016); H: Von Schrenck's Bittern, Yellow Bittern, Striated Heron (Kunisue et al., 2003); I: Thick-billed Murre, Northern Fulmar (Braune et al., 2014); J: Common Starling (Eens et al., 2013); K: Common Eider, Arctic Tern, Common Murre, Lesser Black-backed Gull, Northern Fulmar, Great Black-backed Gull, Great Skua (Jorundsdottir et al., 2010); L: Yellow-legged Gull, Eurasian Coot, Mediterranean Gull, Grey Heron, Dalmatian Pelican (Kocagoz et al., 2014); M: Eastern Cattle Egret, Grey Heron(Bouwman et al., 2013); N: Antarctic Prion (Fromant et al., 2016); O: Common Murre, Thick-billed Murre(Vander Pol et al., 2004), Glaucous-winged Gull (Vander Pol et al., 2009); P: Streaked Shearwater(Ito et al., 2013); Q: African Penguin (Bouwman et al., 2015); R: Brown Noddy, Sooty Tern (Bouwman et al., 2012); S: Eurasian Sparrowhawk, Barbary Falcon, Common Kestrel, Eurasian Eagle-Owl (Luzardo et al., 2014), Common Starling (Eens et al., 2013); T: Glaucous Gull (Vander Pol et al., 2009); U: Common Murre (Jorundsdottir et al., 2009), Northern Fulmar (Fangstrom et al., 2005); V: Glaucous Gull (Verreault et al., 2005), Black-legged Kittiwake (Murvoll et al., 2006b), Ivory Gull (Miljeteig et al., 2009); W: Black Guillemot, Little Auk, Thick-billed Murre, Black-legged Kittiwake (Borga et al., 2007), Northern Fulmar (Knudsen et al., 2007); X: European Shag (Murvoll et al., 2006a), Black-legged Kittiwake (Murvoll et al., 2006b), Tawny Owl (Bustnes et al., 2015), Common Murre (Jorundsdottir et al., 2009); Y: Light-vented Bulbul (Peng et al., 2015), Eurasian Tree Sparrow (Yu et al., 2014), Oriental Magpie-Robin (Peng et al., 2015), Ruddy-

breasted Crake, White-breasted Waterhen, Slaty-breasted Rail (Luo et al., 2009), Great Tit (Peng et al., 2015), Chinese Pond Heron, Common Snipe (Luo et al., 2009); Z: White-tailed Eagle (Nordlof et al., 2012a), Peregrine Falcon, Golden Eagle (Helander et al., 2008); AA: Common Eider, Velvet Scoter (Kelly et al., 2008), Black-legged Kittiwake, Black Guillemot, Razorbill, Herring Gull, Great Black-backed Gull (Lavoie et al., 2010); AB: Common Starling (Eens et al., 2013), Little Owl (Jaspers et al., 2005), Western Barn Owl, Eastern Buzzard, Long-eared Owl (Jaspers et al., 2006), Great Cormorant (Covaci et al., 2006); AC: Black-crowned Night Heron (Zhou et al., 2016b), Peregrine Falcon (Zhou et al., 2016a), Eurasian Tree Sparrow (Yu et al., 2014), Chinese Pond Heron(Zhou et al., 2016a).

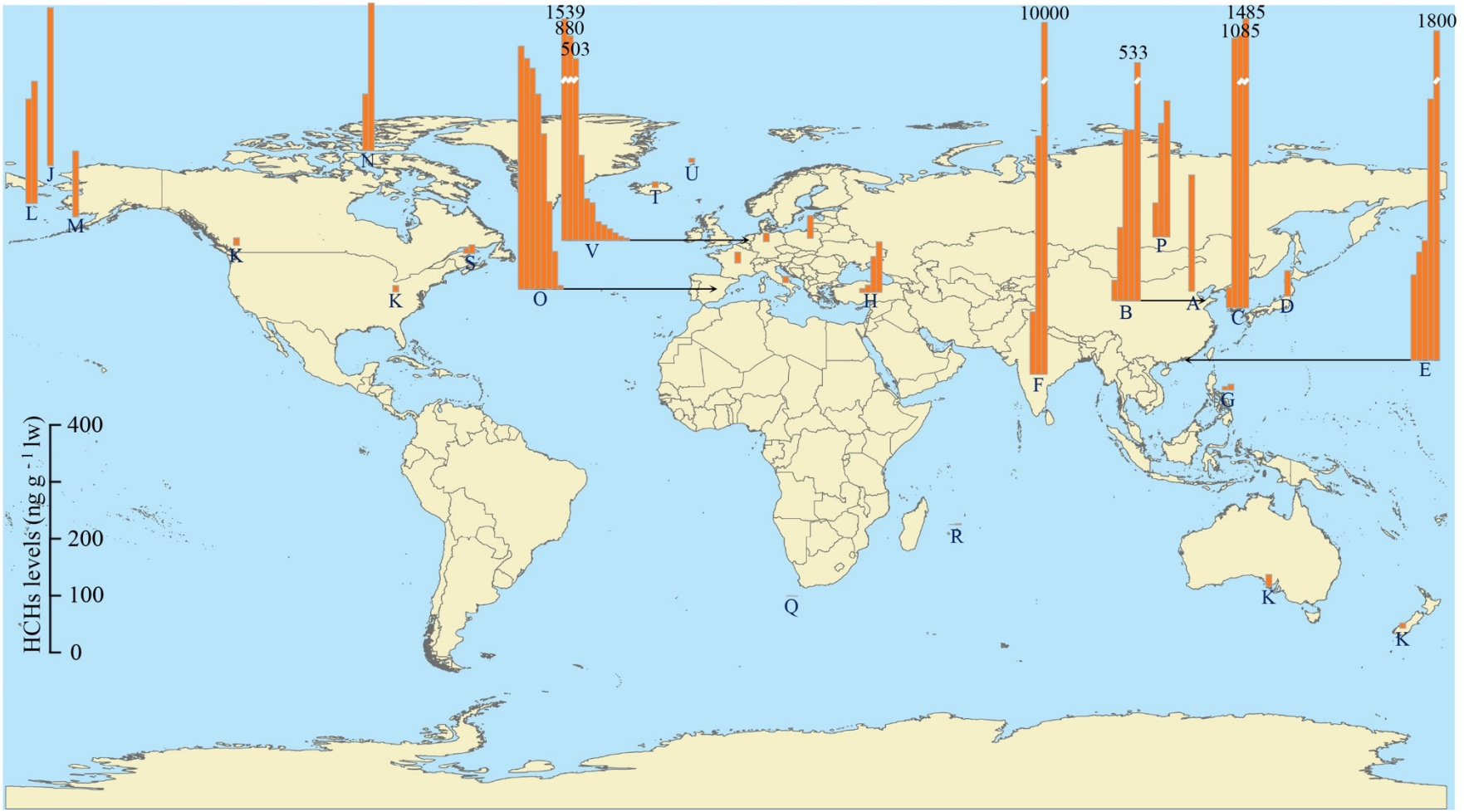

Fig. S2 Spatial distribution of the reported HCHs concentrations in birds around the world. The concentrations were obtained from A: Kentish

Plover (Zheng et al., 2018); B: Eurasian Coot, Oriental Pratincole, Common Tern, Black-winged Stilt, Saunders's Gull (Gao et al., 2009); C: Bar-tailed Godwit, Black-necked Grebe (Choi et al., 2001), Black-tailed Gull, Pacific Loon (Hong et al., 2014); D: Streaked Shearwater(Ito et al., 2013); E: Ruddy-breasted Crake, Common Snipe, White-breasted Waterhen, Slaty-breasted Rail, Chinese Pond Heron (Luo et al., 2009); F: Kentish Plover, Common Myna, Black Drongo (Kunisue et al., 2003); G: Yellow Bittern, Von Schrenck's Bittern (Kunisue et al., 2003); H: Mediterranean Gull, Eurasian Coot, Grey Heron, Dalmatian Pelican (Kocagoz et al., 2014); J: Glaucous Gull (Vander Pol et al., 2009); K: Common Starling (Eens et al., 2013); L: Glaucous-winged Gull, Glaucous Gull (Vander Pol et al., 2009); M: Glaucous-winged Gull (Vander Pol et al., 2009); N: Northern Fulmar, Thick-billed Murre (Braune et al., 2014); O: Common Kestrel, Eurasian Sparrowhawk, Barbary Falcon, Long-eared Owl, Common Buzzard, Western Barn Owl (Luzardo et al., 2014), Eurasian Eagle-Owl (Gomez-Ramirez et al., 2012), Common Starling (Eens et al., 2013); P: House Sparrow, Herring Gull, Carrion Crow (Kunisue et al., 2002); Q: African Penguin(Bouwman et al., 2015); R: Sooty Tern, Brown Noddy (Bouwman et al., 2012); S: Velvet Scoter, Common Eider (Kelly et al., 2008); T: Common Murre (Jorundsdottir et al., 2010); U: Common Murre (Jorundsdottir et al., 2009); V: Western Barn Owl, Besra (Jaspers et al., 2006), Great Cormorant(Covaci et al., 2006), Grey Heron, Great Crested Grebe, Long-eared Owl, Eastern Buzzard (Jaspers et al., 2006), Little Owl (Jaspers et al., 2005), Common Kestrel (Jaspers et al., 2006) Common Starling (Eens et al., 2013), Northern Lapwing, Great Tit (Dauwe et al., 2009).

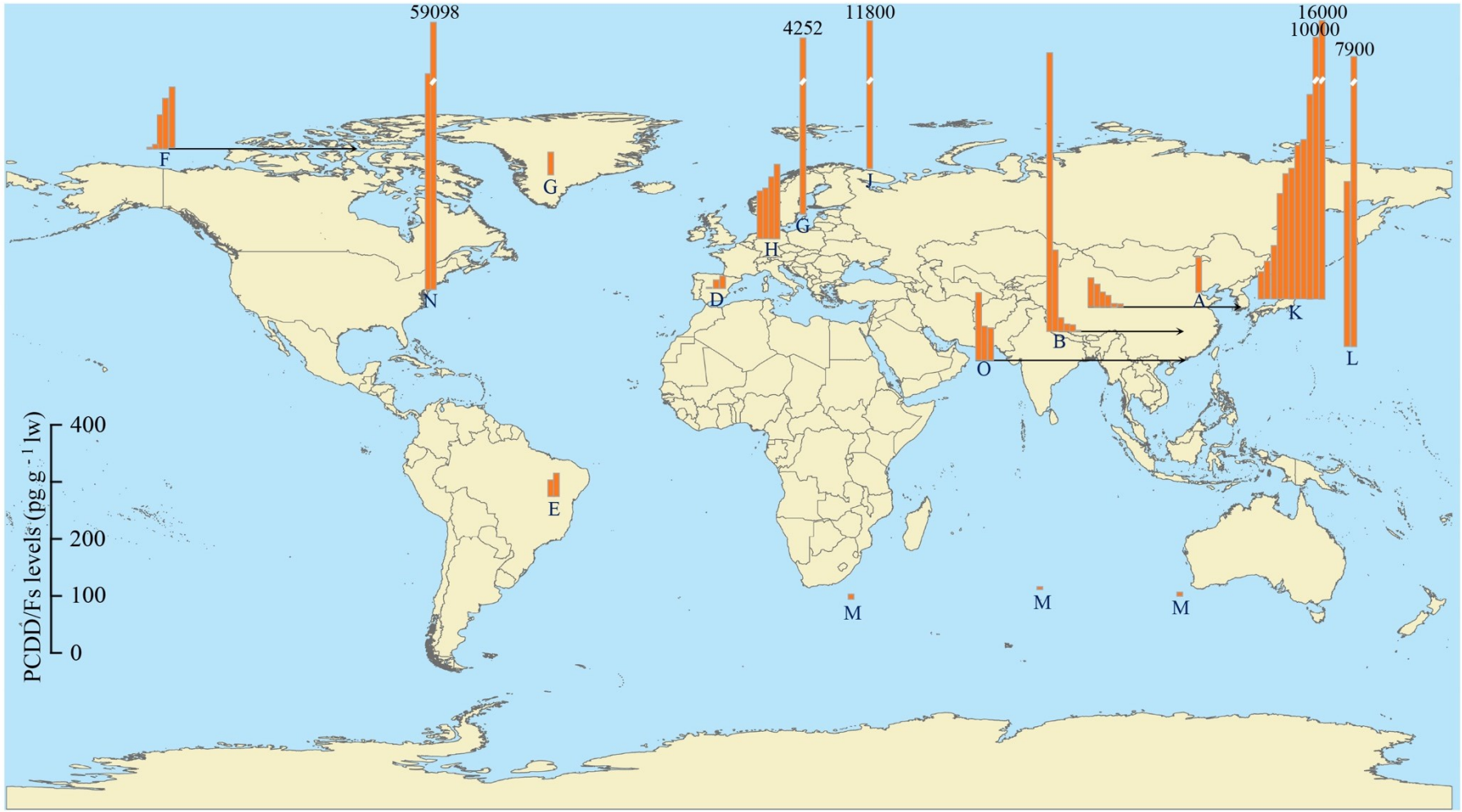

Fig. S3 Spatial distribution of the reported PCDD/Fs concentrations in birds around the world. The concentrations were obtained from A:

Kentish Plover (Zheng et al., 2018); B: Great Egret (Fang et al., 2007), Great Cormorant (Gao et al., 2011), Mallard, Tundra Bean Goose, Northern Pintail, Indian Spot-billed Duck (Fang et al., 2007); C: Common Tern, Great Knot, Common Greenshank, Little Tern, Sanderling, Black-tailed Gull, Bar-tailed Godwit (Choi et al., 2001); D: Red Kite (Gomara et al., 2008), Yellow-legged Gull, Audouin's Gull (Morales et al., 2016); E: Manx Shearwater, Great Egret (Ferreira, 2012); F: Short-tailed Shearwater (Senthilkumar et al., 2002), Columba (Braune et al., 2007), Thick-billed Murre, Northern Fulmar, Black-legged Kittiwake (Braune and Simon, 2003); G: White-tailed Eagle (Nordlof et al., 2012b); H: Northern Goshawk (Wiesmuller et al., 2002), Peregrine Falcon (Malisch and Baum, 2007), Eurasian Sparrowhawk, Eurasian Hobby (Wiesmuller et al., 2002); J: Northern Fulmar (Knudsen et al., 2007); K: Common Pheasant, Rock Dove, Common Kestrel (Senthilkumar et al., 2002), Short-tailed Albatross (Kunisue et al., 2006), Black Kite (Kubota et al., 2006), Large-billed Crow, Eastern Cattle Egret (Senthilkumar et al., 2002), Great Cormorant (Kubota et al., 2004), Ural Owl, Northern Goshawk, Grey Heron (Senthilkumar et al., 2002); L: Laysan Albatross, Black-footed Albatross (Tanabe et al., 2004); M: Grey-headed Albatross, Light-mantled Albatross, Black-browed Albatross (Tanabe et al., 2004); N: Western Osprey (Elliott et al., 2001); O: Black-crowned Night Heron, Little Egret, Chinese Pond Heron (Wang et al., 2012).

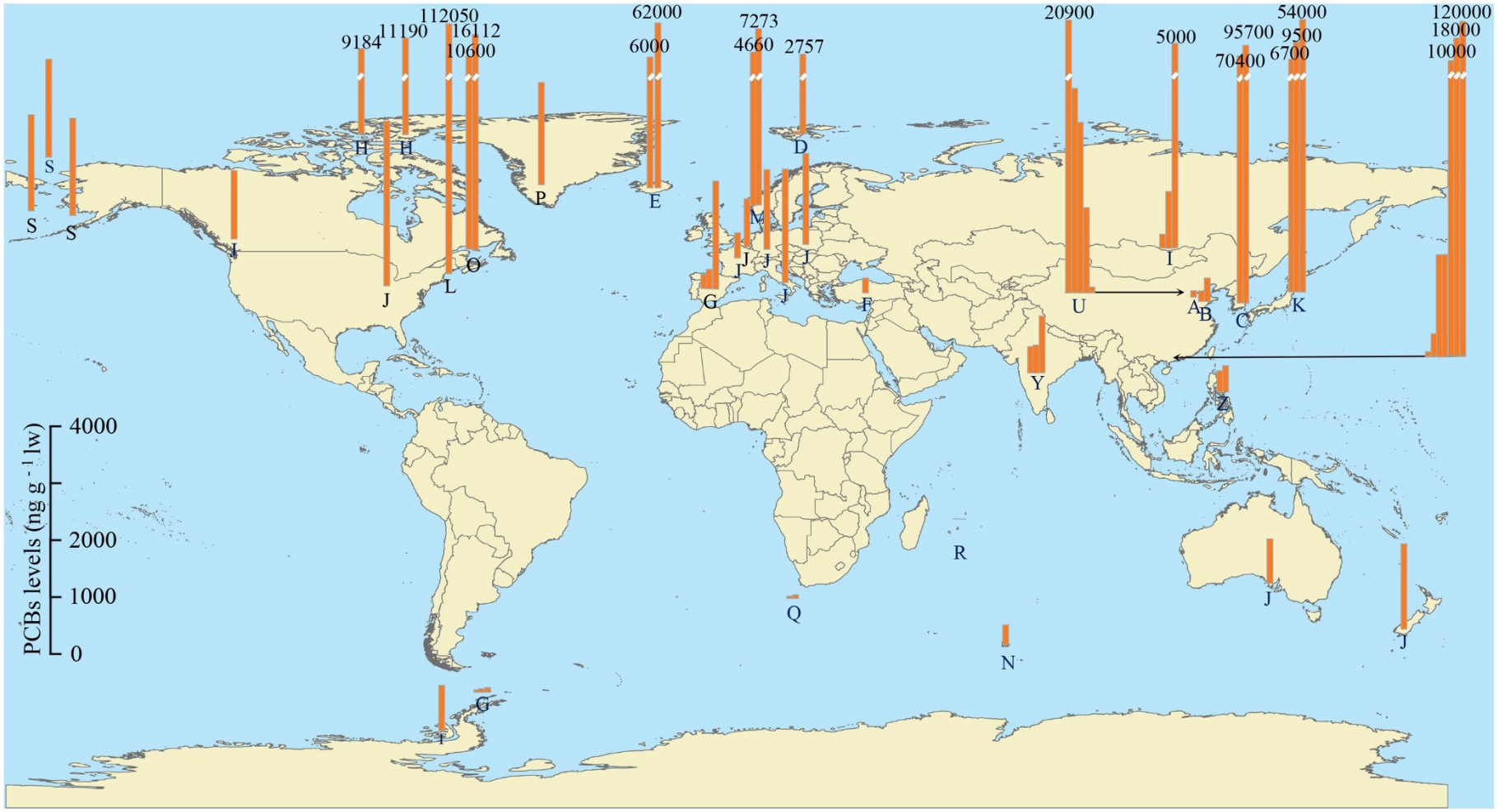

Fig. S4 Spatial distribution of the reported PCBs concentrations in birds around the world. The concentrations were obtained from A: Kentish

Plover (Zheng et al., 2018); B: Kentish Plover, Black-tailed Gull (Gao et al., 2009); C: Black-tailed Gull, Pacific Loon (Hong et al., 2014); D: Black-legged Kittiwake (Tartu et al., 2015); E: Lesser Black-backed Gull, South Polar Skua (Jorundsdottir et al., 2010); F: Yellow-legged Gull (Kocagoz et al., 2014); G: Common Starling (Eens et al., 2013), Common Kestrel (Luzardo et al., 2014), Eurasian Eagle-Owl(Guerra et al., 2012); H: Northern Fulmar (Braune et al., 2014); I: Grey Heron, House Sparrow, Carrion Crow (Kunisue et al., 2003); J: Common Starling (Eens et al., 2013); K: Kelp Gull, Laysan Albatross, Black-footed Albatross (Kunisue et al., 2008); L: Western Osprey (Chen et al., 2010); M: Glaucous Gull (Bustnes et al., 2010), Northern Fulmar (Knudsen et al., 2007); N: Antarctic Prion (Fromant et al., 2016); O: Black-legged Kittiwake, Herring Gull (Lavoie et al., 2010); P: White-tailed Eagle (Jaspers et al., 2013); Q: African Penguin (Bouwman et al., 2015); R: Brown Noddy, Sooty Tern (Bouwman et al., 2012); S: Glaucous Gull (Vander Pol et al., 2009); T: Wandering Albatross (Tartu et al., 2015); U: Gentoo Penguin, Adelie Penguin, Chinstrap Penguin (Mello et al., 2016); V: Peregrine Falcon (Park et al., 2009); W: Eurasian Tree Sparrow (Yu et al., 2014), Great Tit (Peng et al., 2015), Common Kingfisher (Mo et al., 2013), Ruddy-breasted Crake, Slaty-breasted Rail, White-breasted Waterhen, Chinese Pond Heron (Luo et al., 2009); X: Besra, Japanese Sparrowhawk, Little Owl, Long-eared Owl (Chen et al., 2009); Y: Black Drongo, Common Myna, Kentish Plover (Kunisue et al., 2003); Z: Yellow Bittern, Von Schrenck's Bittern (Kunisue et al., 2003).

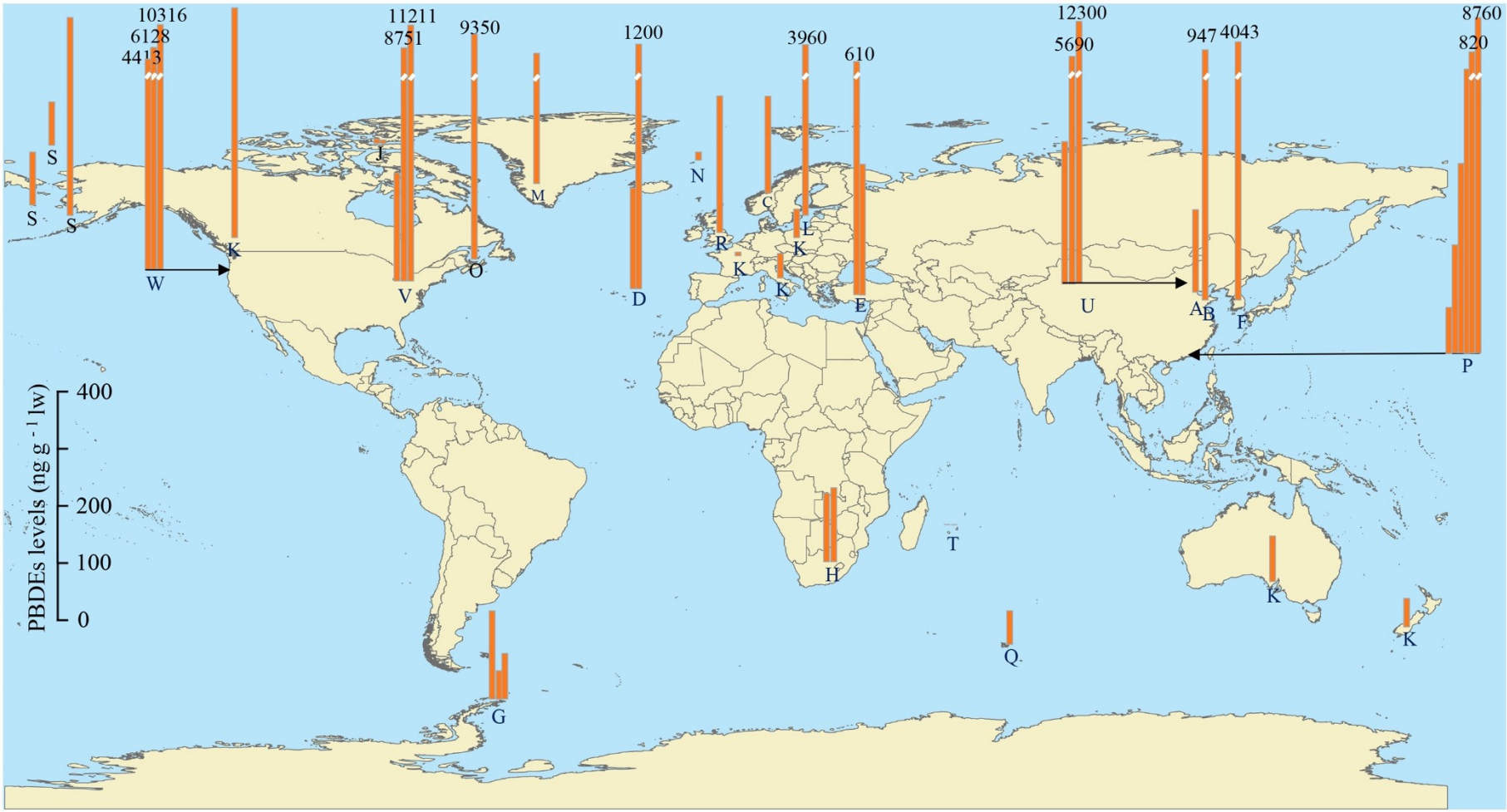

Fig. S5 Spatial distribution of the reported PBDEs concentrations in birds around the world. The concentrations were obtained from A: Kentish

Plover(Zheng et al., 2018); B: Kentish Plover (Gao et al., 2009); C: Black-legged Kittiwake (Sagerup et al., 2014); D: Gull-billed Tern (Baron et al., 2014), Lesser Black-backed Gull (Jorundsdottir et al., 2013); E: Yellow-legged Gull, Eurasian Coot (Kocagoz et al., 2014); F: Black-tailed Gull (Hong et al., 2014); G: South Polar Skua, Chinstrap Penguin, Gentoo Penguin (Yogui and Sericano, 2009); H: Crowned Lapwing, White-fronted Plover (Polder et al., 2008); J: Thick-billed Murre (Braune et al., 2014), Northern Fulmar (Jorundsdottir et al., 2013); K: Common Starling (Eens et al., 2013); L: White-tailed Eagle (Nordlof et al., 2010); M: White-tailed Eagle (Jaspers et al., 2013); N: Northern Fulmar (Karlsson et al., 2006); O: Western Osprey (Chen et al., 2010); P: Oriental Magpie-Robin (Peng et al., 2015), Eurasian Tree Sparrow (Yu et al., 2014), Light-vented Bulbul (Sun et al., 2012), White-breasted Waterhen, Slaty-breasted Rail (Zhang et al., 2011), Common Kingfisher (Mo et al., 2012); Q: Antarctic Prion (Fromant et al., 2016); R: Eurasian Sparrowhawk (Crosse et al., 2013); S: Glaucous Gull(Vander Pol et al., 2009); T: Brown Noddy, Sooty Tern (Bouwman et al., 2012); U: Eurasian Tree Sparrow (Yu et al., 2014), Eurasian Sparrowhawk, Common Kestrel (Chen et al., 2007); V: Common Starling (Eens et al., 2013), Herring Gull (Gauthier et al., 2008); W: Western Osprey (Henny et al., 2009)

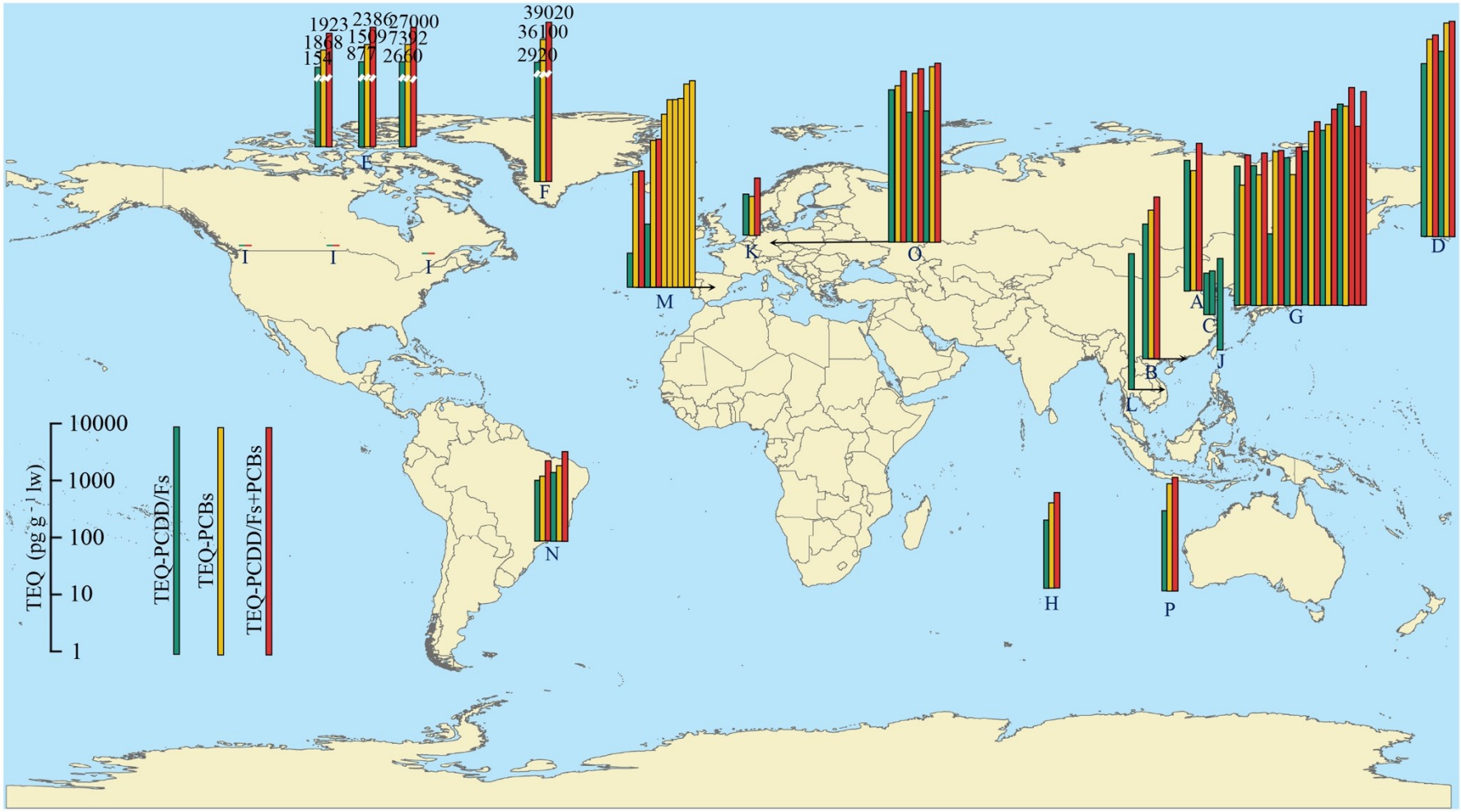

Fig. S6 Spatial distribution of the reported TEQ values of PCDD/Fs, dioxin-like PCBs and ∑ (PCDD/Fs + dioxin-like PCBs) in birds around the

world (pg TEQ g^{-1} lw). The values were obtained from A: Kentish Plover(Zheng et al., 2018); B: Chinese Pond Heron, Black-crowned Night Heron, Little Egret (Wang et al., 2012); C: Tundra Bean Goose, Mallard (Fang et al., 2007); D: Laysan Albatross, Black-footed Albatross (Tanabe et al., 2004); E: Thick-billed Murre, Black-legged Kittiwake, Northern Fulmar (Braune and Simon, 2003); F: White-tailed Eagle(Nordlof et al., 2012b); G: Black Kite (Kubota et al., 2006), Common Pheasant, Short-tailed Shearwater, Whimbrel (Senthilkumar et al., 2002), Black-footed Albatross(Kunisue et al., 2006), Great Cormorant (Kubota et al., 2004), Great Egret, Northern Goshawk (Senthilkumar et al., 2002); H: Black-browed Albatross (Tanabe et al., 2004); I : chicken (Rawn et al., 2012); J: duck (Wu et al., 2014); K: chicken (Van Overmeire et al., 2009); L: duck (Hoang et al., 2014); M: Yellow-legged Gull, Audouin's Gull (Morales et al., 2016), Long-eared Owl, Eastern Buzzard, Common Kestrel, Western Barn Owl, Barbary Falcon, Eurasian Sparrowhawk (Luzardo et al., 2014); N: Manx Shearwater, Great Egret (Ferreira, 2012; Ferreira, 2013); O: Eurasian Sparrowhawk, Northern Goshawk (Wiesmüller et al., 2002), Peregrine Falcon (Malisch and Baum, 2007; Wiesmüller et al., 2002); P: Light-mantled Albatross (Tanabe et al., 2004).

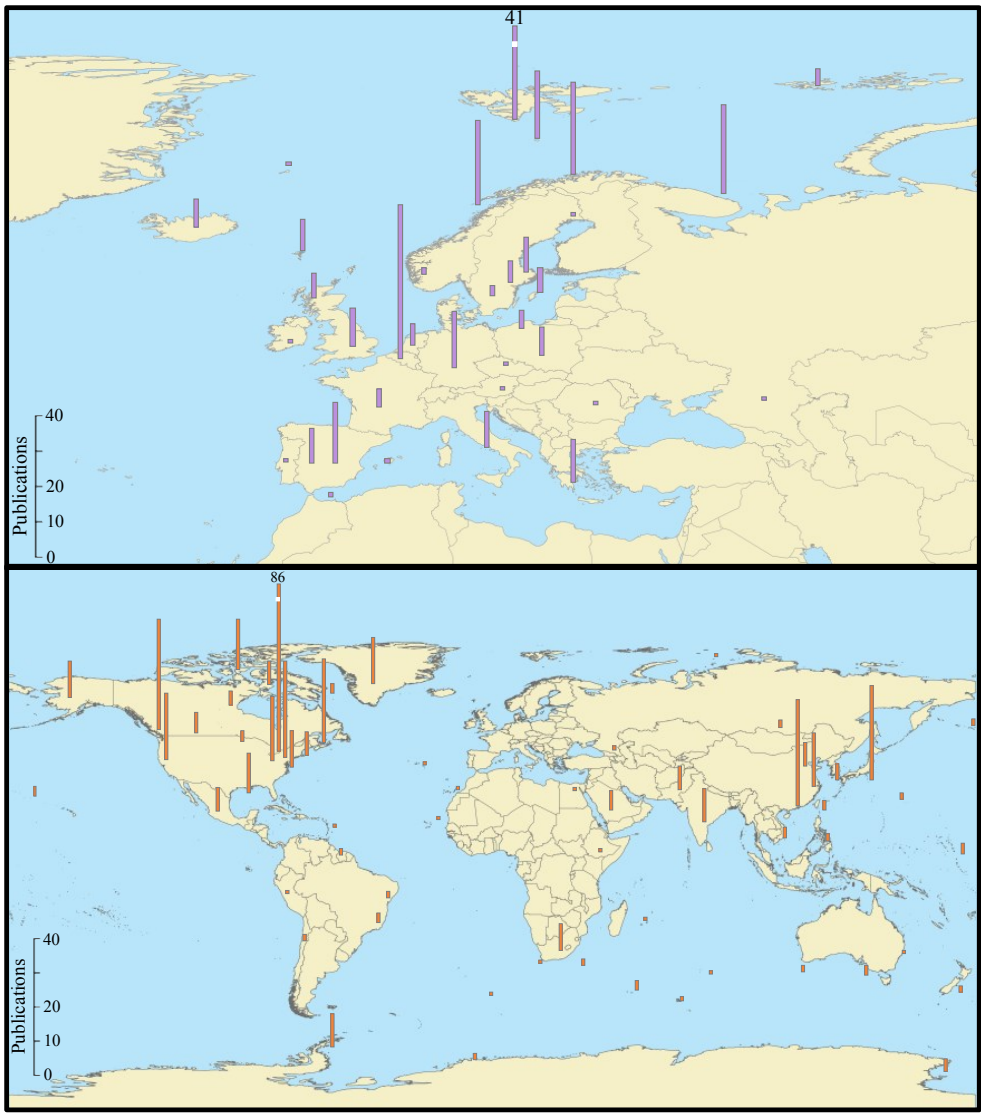

Fig. S7 Global distribution of the publications on POPs related to avian species.

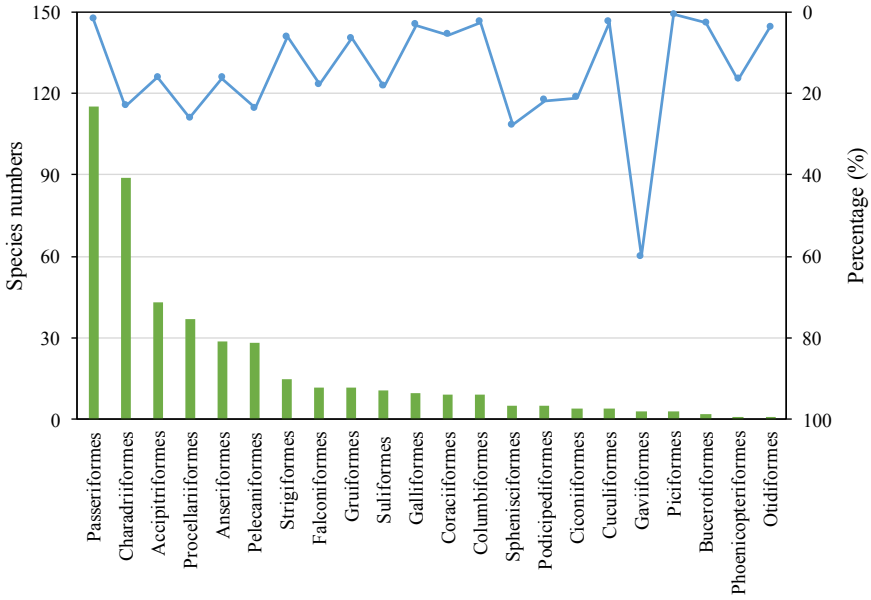

Fig. S8 Publications on investigated orders of avian species and the percentages of investigated species numbers in each order.

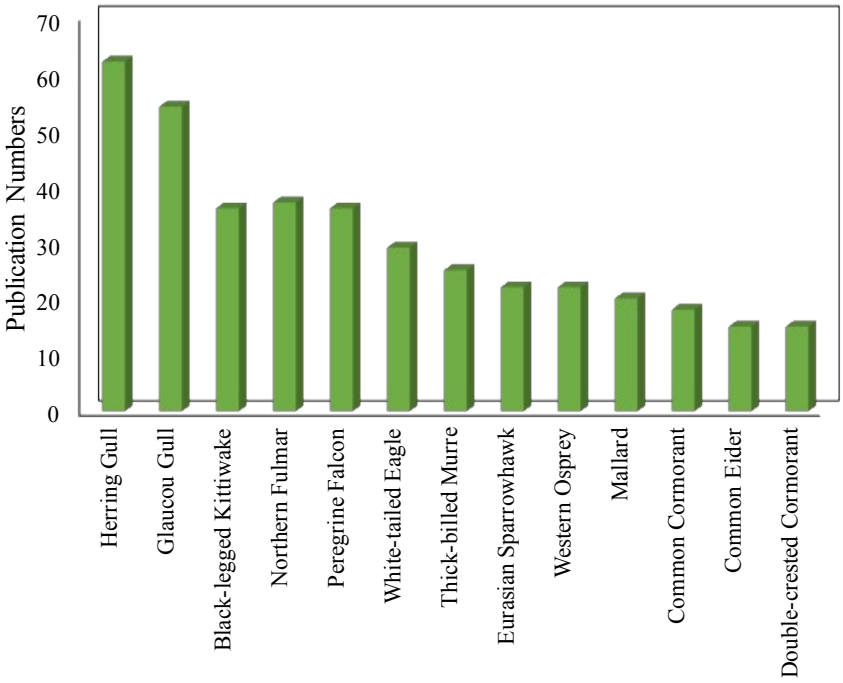

Fig. S9 Publications on investigated bird species.

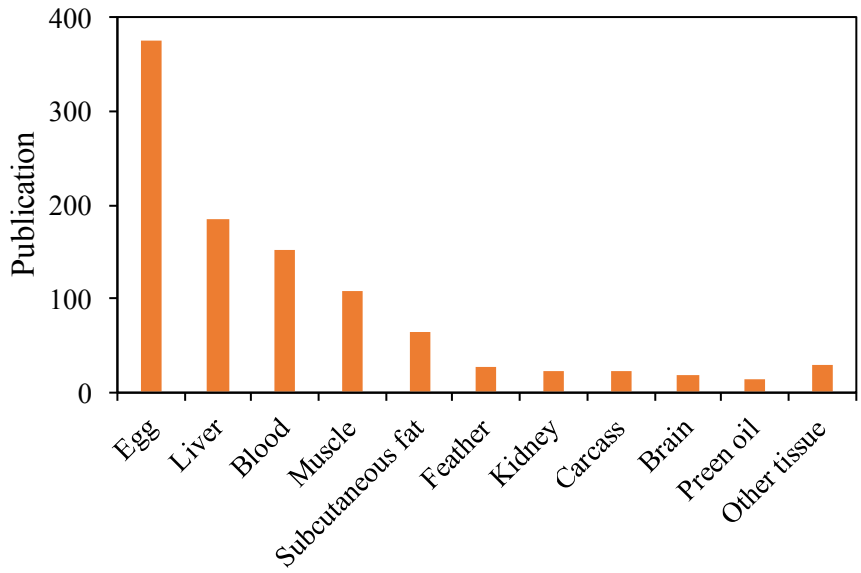

Fig. S10 Publications on the different employed matrices.

Table S1 Associations between POP exposure and thyroid hormones.

Avian	compounds	index	correlation	References
adult Glaucous Gull	OCs	T_4	Negative correlation	Verreault et al., 2004
Northern Fulmar	OCs	T_4	Positive correlation	Verreault et al., 2013
Ring-billed Gull	PCBs, PBDEs and chlordanes	T_4	Positive correlation	Techer et al., 2016
Bald Eagle	PCBs	T_4	Positive correlation	Cesh et al., 2010
Glaucous Gull	OCs	T_4/T_3	Negative correlation	Verreault et al., 2004
Northern Fulmar	OCs	T_4/T_3	Positive correlation	Techer et al., 2016
Northern Fulmar	OCs	T_3	Negative correlation	Techer et al., 2016
Ring-billed Gull	PBDEs	T_3	independent	Cesh et al., 2010

T_4: thyroxin

T_3: triiodothyronine

References

Baron E, Manez M, Andreu AC, Sergio F, Hiraldo F, Eljarrat E, et al. Bioaccumulation and biomagnification of emerging and classical flame retardants in bird eggs of 14 species from Donana Natural Space and surrounding areas (South-western Spain). Environ. Int. 2014; 68: 118-26.

Borga K, Hop H, Skaare JU, Wolkers H, Gabrielsen GW. Selective bioaccumulation of chlorinated pesticides and metabolites in Arctic seabirds. Environ. Pollut. 2007; 145: 545-53.

Bouwman H, Govender D, Underhill L, Polder A. Chlorinated, brominated and fluorinated organic pollutants in African Penguin eggs: 30 years since the previous assessment. Chemosphere 2015; 126: 1-10.

Bouwman H, Kylin H, Yive NS, Tatayah V, Loken K, Skaare JU, et al. First report of chlorinated and brominated hydrocarbon pollutants in marine bird eggs from an oceanic Indian Ocean island. Environ. Res. 2012; 118: 53-64.

Bouwman H, Viljoen IM, Quinn LP, Polder A. Halogenated pollutants in terrestrial and aquatic bird eggs: converging patterns of pollutant profiles, and impacts and risks from high levels. Environ. Res. 2013; 126: 240-53.

Braune BM, Gaston AJ, Letcher RJ, Grant Gilchrist H, Mallory ML, Provencher JF. A geographical comparison of chlorinated, brominated and fluorinated compounds in seabirds breeding in the eastern Canadian Arctic. Environ. Res. 2014; 134: 46-56.

Braune BM, Mallory ML, Grant Gilchrist H, Letcher RJ, Drouillard KG. Levels and trends of organochlorines and brominated flame retardants in ivory gull eggs from the Canadian Arctic, 1976 to 2004. Sci. Total Environ. 2007; 378: 403-17.

Braune BM, Simon M. Dioxins, furans, and non-ortho PCBs in Canadian Arctic seabirds. Environ. Sci. Technol. 2003; 37: 3071-7.

Bustnes JO, Bangjord G, Yoccoz NG. Variation in concentrations of organochlorines and brominated flame retardants among eggs in abandoned clutches of a terrestrial raptor. Chemosphere 2015; 118: 357-60.

Bustnes JO, Gabrielsen GW, Verreault J. Climate variability and temporal trends of persistent organic pollutants in the arctic: a study of glaucous gulls. Environ. Sci. Technol. 2010; 44: 3155-61.

Cesh LS, Elliott KH, Quade S, McKinney MA, Maisoneuve F, Garcelon DK, Sandau

CD, Letcher RJ, Williams TD, Elliott JE. Polyhalogenated aromatic hydrocarbons and metabolites: Relation to circulating thyroid hormone and retinol in nestling bald eagles (Haliaeetus leucocephalus). Environ. Toxicol. Chem., 2010; 29: 2388-2388.

Chen D, Hale RC, Watts BD, La Guardia MJ, Harvey E, Mojica EK. Species-specific accumulation of polybrominated diphenyl ether flame retardants in birds of prey from the Chesapeake Bay region, USA. Environ. Pollut. 2010; 158: 1883-9.

Chen D, Mai B, Song J, Sun Q, Luo Y, Luo X, et al. Polybrominated diphenyl ethers in birds of prey from Northern China. Environ. Sci. Technol. 2007; 41: 1828-33.

Chen D, Zhang X, Mai B, Sun Q, Song J, Luo X, et al. Polychlorinated biphenyls and organochlorine pesticides in various bird species from northern China. Environ. Pollut. 2009; 157: 2023-9.

Choi JW, Matsuda M, Kawano M, Min BY, Wakimoto T. Accumulation profiles of persistent organochlorines in waterbirds from an estuary in Korea. Arch. Environ. Contam. Toxicol. 2001; 41: 353-63.

Covaci A, Gheorghe A, Hulea O, Schepens P. Levels and distribution of organochlorine pesticides, polychlorinated biphenyls and polybrominated diphenyl ethers in sediments and biota from the Danube Delta, Romania. Environ. Pollut. 2006; 140: 136-49.

Crosse JD, Shore RF, Jones KC, Pereira MG. Key factors affecting liver PBDE concentrations in sparrowhawks (Accipiter nisus). Environ. Pollut. 2013; 177: 171-6.

Dauwe T, Van den Steen E, Jaspers VL, Maes K, Covaci A, Eens M. Interspecific differences in concentrations and congener profiles of chlorinated and brominated organic pollutants in three insectivorous bird species. Environ. Int. 2009; 35: 369-75.

Eens M, Jaspers VL, Van den Steen E, Bateson M, Carere C, Clergeau P, et al. Can starling eggs be useful as a biomonitoring tool to study organohalogenated contaminants on a worldwide scale? Environ. Int. 2013; 51: 141-9.

Elliott JE, Wilson LK, Henny CJ, Trudeau SF, Leighton FA, Kennedy SW, et al. Assessment of biological effects of chlorinated hydrocarbons in osprey chicks. Environ. Toxicol. Chem. 2001; 20: 866-79.

Fang L, Zheng M, Zhang B, Gao L, Liu W, Zhao X. Polychlorinated dibenzo-p-dioxins and dibenzofurans in eggs of eight avian species from Dongting Lake,

China. Chemosphere 2007; 69: 411-21.

Fangstrom B, Athanasiadou M, Athanassiadis I, Bignert A, Grandjean P, Weihe P, et al. Polybrominated diphenyl ethers and traditional organochlorine pollutants in fulmars (Fulmarus glacialis) from the Faroe Islands. Chemosphere 2005; 60: 836-43.

Ferreira AP. Measurement of chlorinated dioxins, furans and PCBs in Ardea alba Great Egret, and Puffinus puffinus Manx Shearwater: Ilha Grande Bay, Rio de Janeiro, Brazil. Revista de Gestão Costeira Integrada 2012; 12: 7-15.

Ferreira AP. Polychlorinated biphenyl (PCB) congener concentrations in aquatic birds. Case study: Ilha Grande Bay, Rio de Janeiro, Brazil. An Acad Bras Cienc 2013; 85: 1379-88.

Fromant A, Carravieri A, Bustamante P, Labadie P, Budzinski H, Peluhet L, et al. Wide range of metallic and organic contaminants in various tissues of the Antarctic prion, a planktonophagous seabird from the Southern Ocean. Sci. Total Environ. 2016; 544: 754-64.

Gao F, Luo XJ, Yang ZF, Wang XM, Mai BX. Brominated flame retardants, polychlorinated biphenyls, and organochlorine pesticides in bird eggs from the Yellow River Delta, North China. Environ. Sci. Technol. 2009; 43: 6956-62.

Gao L, Zheng M, Zhang B, Liu W, Xiao K, Su G, et al. Poly chlorinated dibenzo-p-dioxins and dibenzofurans in different tissues of the cormorants (Phalacrocorax carbo) from Dongting Lake, China. J. Environ. Sci. 2011; 23: 1709-1713.

Gauthier LT, Hebert CE, Weseloh DV, Letcher RJ. Dramatic changes in the temporal trends of polybrominated diphenyl ethers (PBDEs) in herring gull eggs from the Laurentian Great Lakes: 1982-2006. Environ. Sci. Technol. 2008; 42: 1524-30.

Gomara B, Gonzalez MJ, Baos R, Hiraldo F, Abad E, Rivera J, et al. Unexpected high PCB and total DDT levels in the breeding population of red kite (Milvus milvus) from Donana National Park, south-western Spain. Environ. Int. 2008; 34: 73-8.

Gomez-Ramirez P, Martinez-Lopez E, Garcia-Fernandez AJ, Zweers AJ, van den Brink NW. Organohalogen exposure in a Eurasian Eagle owl (Bubo bubo) population from Southeastern Spain: temporal-spatial trends and risk assessment. Chemosphere 2012; 88: 903-11.

Guerra P, Alaee M, Jimenez B, Pacepavicius G, Marvin C, MacInnis G, et al. Emerging and historical brominated flame retardants in peregrine falcon (Falco peregrinus) eggs from Canada and Spain. Environ. Int. 2012; 40: 179-86.

Helander B, Bignert A, Asplund L. Using raptors as environmental sentinels: Monitoring the white-tailed sea eagle Haliaeetus albicilla in Sweden. Ambio 2008; 37: 425-431.

Henny CJ, Kaiser JL, Grove RA, Johnson BL, Letcher RJ. Polybrominated diphenyl ether flame retardants in eggs may reduce reproductive success of ospreys in Oregon and Washington, USA. Ecotoxicology 2009; 18: 802-13.

Hoang TT, Traag WA, Murk AJ, Hoogenboom RL. Levels of polychlorinated dibenzo-p-dioxins, dibenzofurans (PCDD/Fs) and dioxin-like PCBs in free range eggs from Vietnam, including potential health risks. Chemosphere 2014; 114: 268-74.

Hong SH, Shim WJ, Han GM, Ha SY, Jang M, Rani M, et al. Levels and profiles of persistent organic pollutants in resident and migratory birds from an urbanized coastal region of South Korea. Sci. Total Environ. 2014; 470-471: 1463-70.

Ito A, Yamashita R, Takada H, Yamamoto T, Shiomi K, Zavalaga C, et al. Contaminants in tracked seabirds showing regional patterns of marine pollution. Environ. Sci. Technol. 2013; 47: 7862-7.

Jaspers V, Covaci A, Maervoet J, Dauwe T, Voorspoels S, Schepens P, et al. Brominated flame retardants and organochlorine pollutants in eggs of little owls (Athene noctua) from Belgium. Environ. Pollut. 2005; 136: 81-8.

Jaspers VL, Covaci A, Voorspoels S, Dauwe T, Eens M, Schepens P. Brominated flame retardants and organochlorine pollutants in aquatic and terrestrial predatory birds of Belgium: levels, patterns, tissue distribution and condition factors. Environ. Pollut. 2006; 139: 340-52.

Jaspers VL, Sonne C, Soler-Rodriguez F, Boertmann D, Dietz R, Eens M, et al. Persistent organic pollutants and methoxylated polybrominated diphenyl ethers in different tissues of white-tailed eagles (Haliaeetus albicilla) from West Greenland. Environ. Pollut. 2013; 175: 137-46.

Jorundsdottir H, Bignert A, Svavarsson J, Nygard T, Weihe P, Bergman A. Assessment of emerging and traditional halogenated contaminants in Guillemot (Uria aalge) egg from North-Western Europe and the Baltic Sea. Sci. Total Environ. 2009; 407: 4174-83.

Jorundsdottir H, Lofstrand K, Svavarsson J, Bignert A, Bergman A. Organochlorine compounds and their metabolites in seven Icelandic seabird species - a comparative study. Environ. Sci. Technol. 2010; 44: 3252-9.

Jorundsdottir H, Lofstrand K, Svavarsson J, Bignert A, Bergman A. Polybrominated diphenyl ethers (PBDEs) and hexabromocyclododecane (HBCD) in seven different marine bird species from Iceland. Chemosphere 2013; 93: 1526-32.

Karlsson M, Ericson I, van Bavel B, Jensen JK, Dam M. Levels of brominated flame retardants in Northern Fulmar (Fulmarus glacialis) eggs from the Faroe Islands. Sci. Total Environ. 2006; 367: 840-6.

Kelly BC, Ikonomou MG, Blair JD, Gobas FA. Hydroxylated and methoxylated polybrominated diphenyl ethers in a Canadian Arctic marine food web. Environ. Sci. Technol. 2008; 42: 7069-77.

Knudsen LB, Borga K, Jorgensen EH, van Bavel B, Schlabach M, Verreault J, et al. Halogenated organic contaminants and mercury in northern fulmars (Fulmarus glacialis): levels, relationships to dietary descriptors and blood to liver comparison. Environ. Pollut. 2007; 146: 25-33.

Kocagoz R, Onmus O, Onat I, Cagdas B, Siki M, Orhan H. Environmental and biological monitoring of persistent organic pollutants in waterbirds by non-invasive versus invasive sampling. Toxicol. Lett. 2014; 230: 208-17.

Kubota A, Iwata H, Tanabe S, Yoneda K, Tobata S. Levels and toxicokinetic behaviors of PCDD, PCDF, and coplanar PCB congeners in common cormorants from Lake Biwa, Japan. Environ. Sci. Technol. 2004; 38: 3853-9.

Kubota A, Iwata H, Tanabe S, Yoneda K, Tobata S. Congener-specific toxicokinetics of polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls in black-eared kites (Milvus migrans): cytochrome P4501A-dependent hepatic sequestration. Environ. Toxicol. Chem. 2006; 25: 1007-16.

Kunisue T, Higaki Y, Isobe T, Takahashi S, Subramanian A, Tanabe S. Spatial trends of polybrominated diphenyl ethers in avian species: utilization of stored samples in the Environmental Specimen Bank of Ehime University (es-Bank). Environ. Pollut. 2008; 154: 272-82.

Kunisue T, Minh TB, Fukuda K, Watanabe M, Tanabe S, Titenko AM. Seasonal variation of persistent organochlorine accumulation in birds from Lake Baikal, Russia, and the role of the South Asian region as a source of pollution for wintering migrants. Environ. Sci. Technol. 2002; 36: 1396-1404.

Kunisue T, Nakanishi S, Oka N, Sato F, Tsurumi M, Tanabe S. Dioxins and related compounds in albatrosses from the Torishima Island, Japan: accumulation

features by growth stage and toxicological implications. Environ. Sci. Technol. 2006; 40: 6919-27.

Kunisue T, Watanabe M, Subramanian A, Sethuraman A, Titenko AM, Qui V, et al. Accumulation features of persistent organochlorines in resident and migratory birds from Asia. Environ. Pollut. 2003; 125: 157-72.

Lavoie RA, Champoux L, Rail JF, Lean DR. Organochlorines, brominated flame retardants and mercury levels in six seabird species from the Gulf of St. Lawrence (Canada): relationships with feeding ecology, migration and molt. Environ. Pollut. 2010; 158: 2189-99.

Luo XJ, Zhang XL, Liu J, Wu JP, Luo Y, Chen SJ, et al. Persistent halogenated compounds in waterbirds from an e-waste recycling region in South China. Environ. Sci. Technol. 2009; 43: 306-11.

Luzardo OP, Ruiz-Suarez N, Henriquez-Hernandez LA, Valeron PF, Camacho M, Zumbado M, et al. Assessment of the exposure to organochlorine pesticides, PCBs and PAHs in six species of predatory birds of the Canary Islands, Spain. Sci. Total Environ. 2014; 472: 146-53.

Malisch R, Baum F. PCDD/Fs, dioxin-like PCBs and marker PCBs in eggs of peregrine falcons from Germany. Chemosphere 2007; 67: S1-15.

Mello FV, Roscales JL, Guida YS, Menezes JF, Vicente A, Costa ES, et al. Relationship between legacy and emerging organic pollutants in Antarctic seabirds and their foraging ecology as shown by delta13C and delta15N. Sci. Total Environ. 2016; 573: 1380-1389.

Miljeteig C, Strom H, Gavrilo MV, Volkov A, Jenssen BM, Gabrielsen GW. High levels of contaminants in ivory gull Pagophila eburnea eggs from the Russian and Norwegian Arctic. Environ. Sci. Technol. 2009; 43: 5521-8.

Mo L, Wu JP, Luo XJ, Li KL, Peng Y, Feng AH, et al. Using the kingfisher (Alcedo atthis) as a bioindicator of PCBs and PBDEs in the dinghushan biosphere reserve, China. Environ. Toxicol. Chem. 2013; 32: 1655-62.

Mo L, Wu JP, Luo XJ, Zou FS, Mai BX. Bioaccumulation of polybrominated diphenyl ethers, decabromodiphenyl ethane, and 1,2-bis(2,4,6-tribromophenoxy) ethane flame retardants in kingfishers (Alcedo atthis) from an electronic waste-recycling site in South China. Environ. Toxicol. Chem. 2012; 31: 2153-8.

Morales L, Gene'rosa Martrat M, Parera J, Bertolero A, Abalos M, Santos FJ, et al. Dioxins and dl-PCBs in gull eggs from Spanish Natural Parks (2010-2013). Sci.

Total Environ. 2016; 550: 114-22.

Murvoll KM, Skaare JU, Anderssen E, Jenssen BM. Exposure and effects of persistent organic pollutants in European shag (Phalacrocorax aristotelis) hatchlings from the coast of Norway. Environ. Toxicol. Chem. 2006a; 25: 190-8.

Murvoll KM, Skaare JU, Moe B, Anderssen E, Jenssen BM. Spatial trends and associated biological responses of organochlorines and brominated flame retardants in hatchlings of north Atlantic kittiwakes (Rissa tridactyla). Environ. Toxicol. Chem. 2006b; 25: 1648-56.

Nordlof U, Helander B, Bignert A, Asplund L. Levels of brominated flame retardants and methoxylated polybrominated diphenyl ethers in eggs of white-tailed sea eagles breeding in different regions of Sweden. Sci. Total Environ. 2010; 409: 238-46.

Nordlof U, Helander B, Eriksson U, Zebuhr Y, Asplund L. Comparison of organohalogen compounds in a white-tailed sea eagle egg laid in 1941 with five eggs from 1996 to 2001. Chemosphere 2012a; 88: 286-91.

Nordlof U, Helander B, Zebuhr Y, Bignert A, Asplund L. Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans and non-ortho-PCBs in eggs of white-tailed sea eagles collected along the Swedish coast in the Baltic Sea. Sci. Total Environ. 2012b; 438: 166-73.

Park JS, Holden A, Chu V, Kim M, Rhee A, Patel P, et al. Time-trends and congener profiles of PBDEs and PCBs in California peregrine falcons (Falco peregrinus). Environ. Sci. Technol. 2009; 43: 8744-51.

Peng Y, Wu JP, Tao L, Mo L, Tang B, Zhang Q, et al. Contaminants of legacy and emerging concern in terrestrial passerines from a nature reserve in South China: Residue levels and inter-species differences in the accumulation. Environ. Pollut. 2015; 203: 7-14.

Polder A, Venter B, Skaare JU, Bouwman H. Polybrominated diphenyl ethers and HBCD in bird eggs of South Africa. Chemosphere 2008; 73: 148-54.

Rawn DF, Sadler AR, Quade SC, Sun WF, Kosarac I, Hayward S, et al. The impact of production type and region on polychlorinated biphenyl (PCB), polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/F) concentrations in Canadian chicken egg yolks. Chemosphere 2012; 89: 929-35.

Sagerup K, Asbakk K, Polder A, Skaare JU, Gabrielsen GW, Barrett RT. Relationships between persistent organic pollutants and circulating

immunoglobulin-Y in black-legged kittiwakes and Atlantic puffins. J. Toxicol. Environ. Health A 2014; 77: 481-94.

Senthilkumar K, Iseki N, Hayama S, Nakanishi J, Masunaga S. Polychlorinated dibenzo-p-dioxins, dibenzofurans, and dioxin-like polychlorinated biphenyls in livers of birds from Japan. Arch. Environ. Contam. Toxicol. 2002; 42: 244-55.

Sun YX, Luo XJ, Mo L, Zhang Q, Wu JP, Chen SJ, et al. Brominated flame retardants in three terrestrial passerine birds from South China: geographical pattern and implication for potential sources. Environ. Pollut. 2012; 162: 381-8.

Tanabe S, Watanabe M, Minh TB, Kunisue T, Nakanishi S, Ono H, et al. PCDDs, PCDFs, and coplanar PCBs in albatross from the North Pacific and Southern Oceans: levels, patterns, and toxicological implications. Environ. Sci. Technol. 2004; 38: 403-13.

Techer R, Houde M, Verreault J. Associations between organohalogen concentrations and transcription of thyroid-related genes in a highly contaminated gull population, Sci. Total Environ. 2016; 545: 289-298.

Tartu S, Angelier F, Bustnes JO, Moe B, Hanssen SA, Herzke D, et al. Polychlorinated biphenyl exposure and corticosterone levels in seven polar seabird species. Environ. Pollut. 2015; 197: 173-80.

Van Overmeire I, Waegeneers N, Sioen I, Bilau M, De Henauw S, Goeyens L, et al. PCDD/Fs and dioxin-like PCBs in home-produced eggs from Belgium: levels, contamination sources and health risks. Sci. Total Environ. 2009; 407: 4419-29.

Vander Pol SS, Becker PR, Ellisor MB, Moors AJ, Pugh RS, Roseneau DG. Monitoring organic contaminants in eggs of glaucous and glaucous-winged gulls (Larus hyperboreus and Larus glaucescens) from Alaska. Environ. Pollut. 2009; 157: 755-62.

Vander Pol SS, Becker PR, Kucklick JR, Pugh RS, Roseneau DG, Simac KS. Persistent organic pollutants in Alaskan murre (Uria spp.) eggs: geographical, species, and temporal comparisons. Environ. Sci. Technol. 2004; 38: 1305-12.

Verreault J, Helgason LB, Gabrielsen GW, Dam M, Braune BM. Contrasting retinoid and thyroid hormone status in differentially-contaminated northern fulmar colonies from the Canadian Arctic, Svalbard and the Faroe Islands. Environ. Int. 2013; 52: 29-40.

Verreault J, Letcher RJ, Muir DC, Chu S, Gebbink WA, Gabrielsen GW. New organochlorine contaminants and metabolites in plasma and eggs of glaucous

gulls (Larus hyperboreus) from the Norwegian Arctic. Environ. Toxicol. Chem. 2005; 24: 2486-99.

Verreault J, Skaare J U, Jenssen BM, Gabrielsen GW. Effects of organochlorine contaminants on thyroid hormone levels in arctic breeding glaucous gulls, Larus hyperboreus. Environ. Health Perspect. 2004; 112: 532-537.

Wang Y, Lam JC, So MK, Yeung LW, Cai Z, Hung CL, et al. Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), dioxin-like polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) in waterbird eggs of Hong Kong, China. Chemosphere 2012; 86: 242-7.

Wiesmuller T, Sommer P, Volland M, Schlatterer B. PCDDs/PCDFs, PCBs, and organochlorine pesticides in eggs of Eurasian sparrowhawks (Accipiter nisus), hobbies (Falco subbuteo), and northern goshawks (Accipiter gentilis) collected in the area of Berlin-Brandenburg, Germany. Arch. Environ. Contam. Toxicol. 2002; 42: 486-96.

Wiesmüller T, Sömmer P, Volland M, Schlatterer B. PCDDs/PCDFs, PCBs, and organochlorine pesticides in eggs of Eurasian sparrowhawks (Accipiter nisus), hobbies (Falco subbuteo), and northern goshawks (Accipiter gentilis) collected in the area of Berlin-Brandenburg, Germany. Arch. Environ. Contam. Toxicol. 2002; 42: 486-496.

Wu TW, Lee JW, Liu HY, Lin WH, Chu CY, Lin SL, et al. Accumulation and elimination of polychlorinated dibenzo-p-dioxins and dibenzofurans in mule ducks. Sci. Total Environ. 2014; 497-498: 260-6.

Yogui GT, Sericano JL. Levels and pattern of polybrominated diphenyl ethers in eggs of Antarctic seabirds: Endemic versus migratory species. Environ. Pollut. 2009; 157: 975-80.

Yu LH, Luo XJ, Liu HY, Zeng YH, Zheng XB, Wu JP, et al. Organohalogen contamination in passerine birds from three metropolises in China: geographical variation and its implication for anthropogenic effects on urban environments. Environ. Pollut. 2014; 188: 118-23.

Zhang XL, Luo XJ, Liu HY, Yu LH, Chen SJ, Mai BX. Bioaccumulation of several brominated flame retardants and dechlorane plus in waterbirds from an e-waste recycling region in South China: associated with trophic level and diet sources. Environ. Sci. Technol. 2011; 45: 400-5.

Zheng S, Wang P, Sun H, Matsiko J, Hao Y, Meng D, et al. Tissue distribution and

maternal transfer of persistent organic pollutants in Kentish Plovers (Charadrius alexandrines) from Cangzhou Wetland, Bohai Bay, China. Sci. Total Environ. 2018; 612: 1105-1113.

Zhou Y, Asplund L, Yin G, Athanassiadis I, Wideqvist U, Bignert A, et al. Extensive organohalogen contamination in wildlife from a site in the Yangtze River Delta. Sci. Total Environ. 2016a; 554-555: 320-8.

Zhou Y, Yin G, Asplund L, Qiu Y, Bignert A, Zhu Z, et al. A novel pollution pattern: Highly chlorinated biphenyls retained in Black-crowned night heron (Nycticorax nycticorax) and Whiskered tern (Chlidonias hybrida) from the Yangtze River Delta. Chemosphere 2016b; 150: 491-498.