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Mercury Threat to Declining Migratory Shorebirds Along the East Asian-Australasian Flyway

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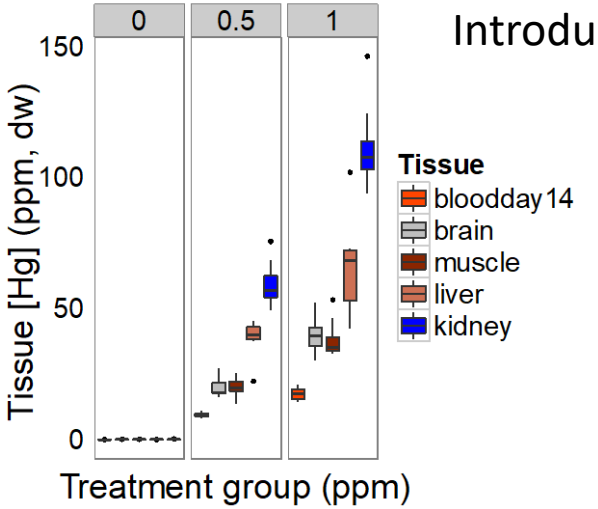
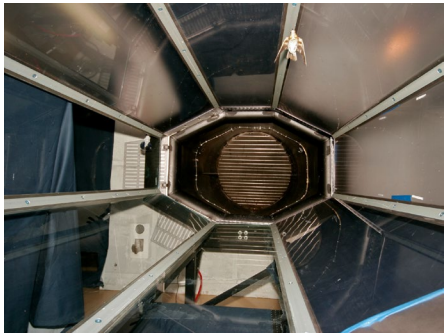
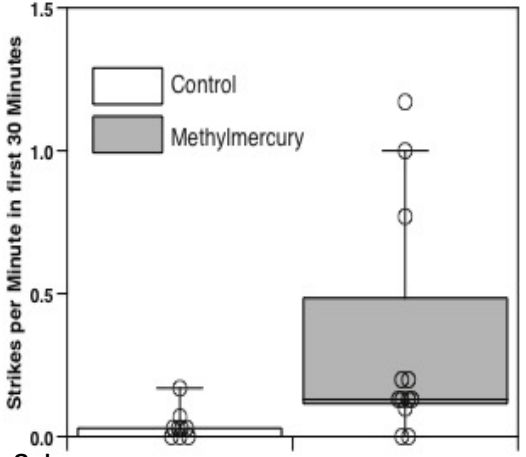
Photo credit: Qingquan Bai

Mercury（Hg）has negative impacts on birds, particularly migratory species;



rapidly accumulate high level in organs, extended molt period, impaired takeoff, alter stopover decisions, reduce endurance performance, and decrease survival.

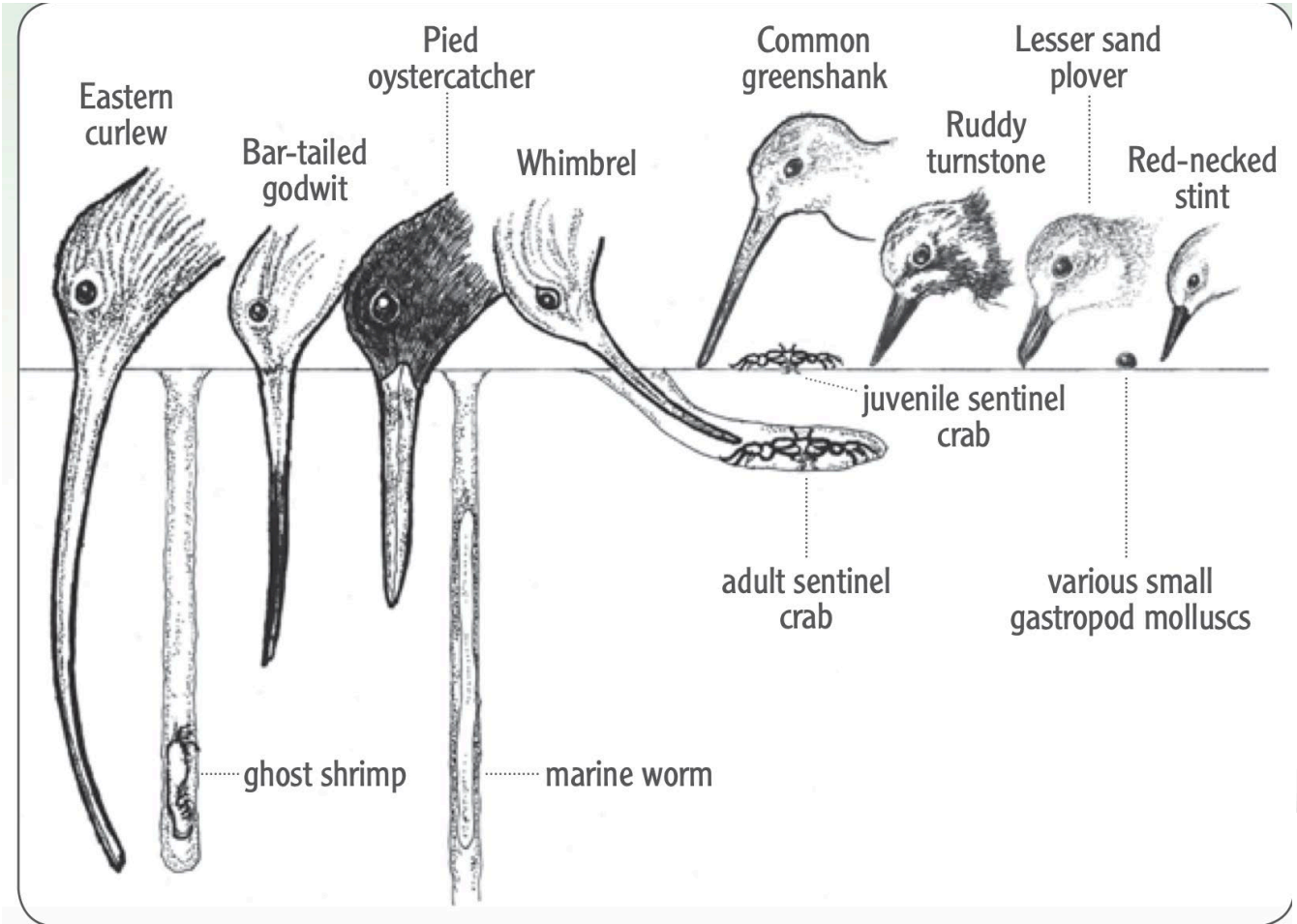




Bottini et al., 2024; Carlson et al., 2014; Seewagen et al., 2019; Ma et al., 2018 a & b.

Bird: sentinel species for ecosystem health, bioindicators for evaluating the effectiveness of the Minamata Convention on Mercury

Shorebirds (order Charadriiformes) heavily rely on costal wetlands.



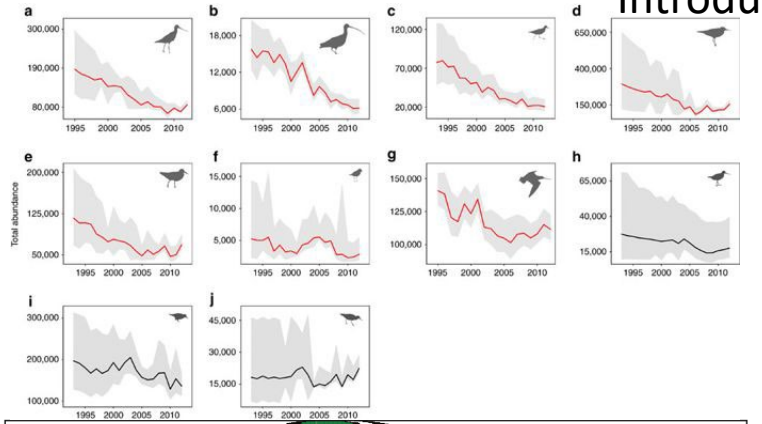
birds are in our nature

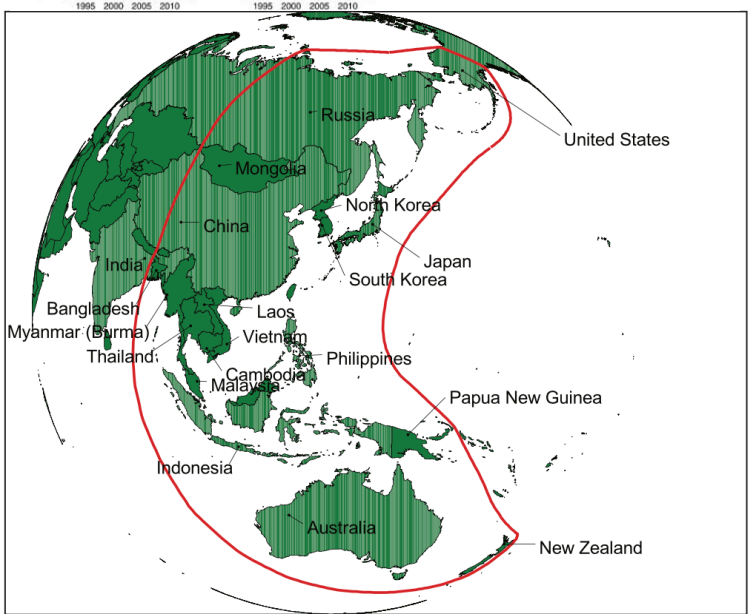
birdlife AUSTRALIA

The East Asian-Australasian Flyway (EAAF): one of the world's most important migratory flyways, stretching from the Russian Arctic and Alaska to southern Australia and New Zealand.

It supports ~ 8 million migratory shorebirds (order Charadriiformes) moving annually at a continental scale.

Except for climate change and habitat loss, steep decline of shorebird populations may be at risk from pollution, particularly Hg contamination.





Studds et al., 2017; UN Environment, 2019

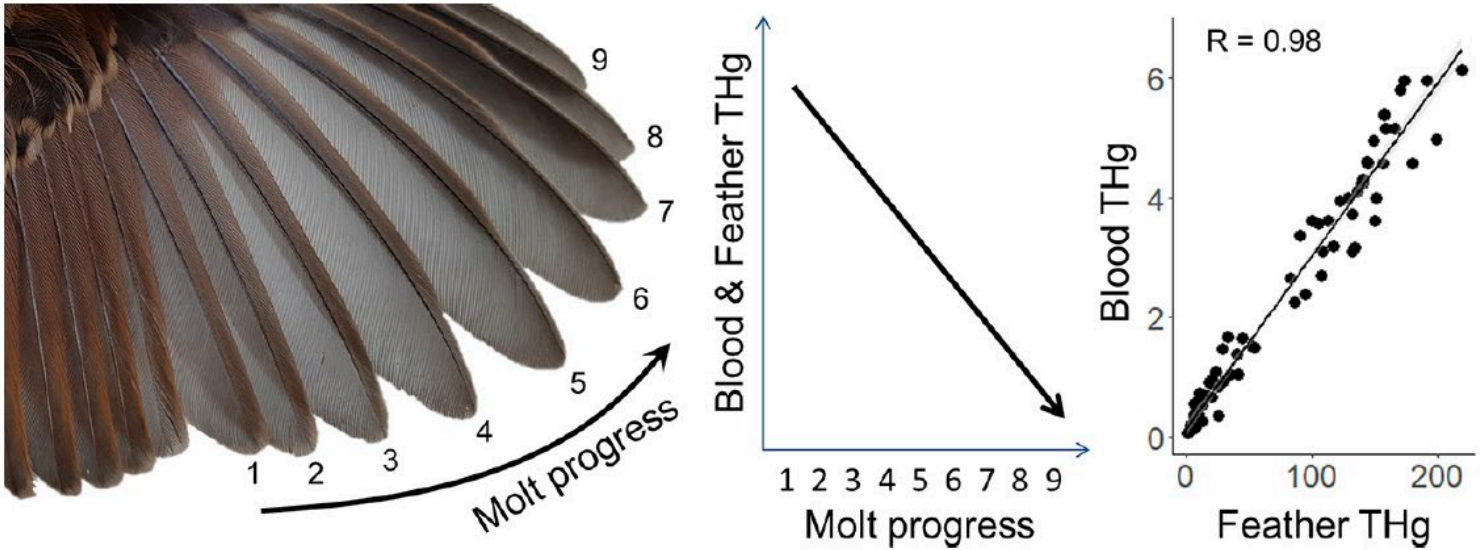
- Asia contributes ~half of the global Hg emissions.
- Hg can migrate over long distances and reach major breeding grounds of migratory birds (e.g. Arctic).
- Wetlands are significant areas for Hg methylation, which leads to its bioaccumulation and transfer within food webs.

UN Environment, 2019

Distinguishing environmental Hg exposure and potential risks to migratory shorebirds spending their lives on a vast spatial scale is crucial for their conservation

Research question: What is the exposure level of Hg in shorebirds along EAAF? Which factor(s) affecting Hg in shorebirds?

Feathers, as a useful biomonitoring tool, accurately reflect blood Hg at time of feather growth



Molt ecology may hamper interpretation

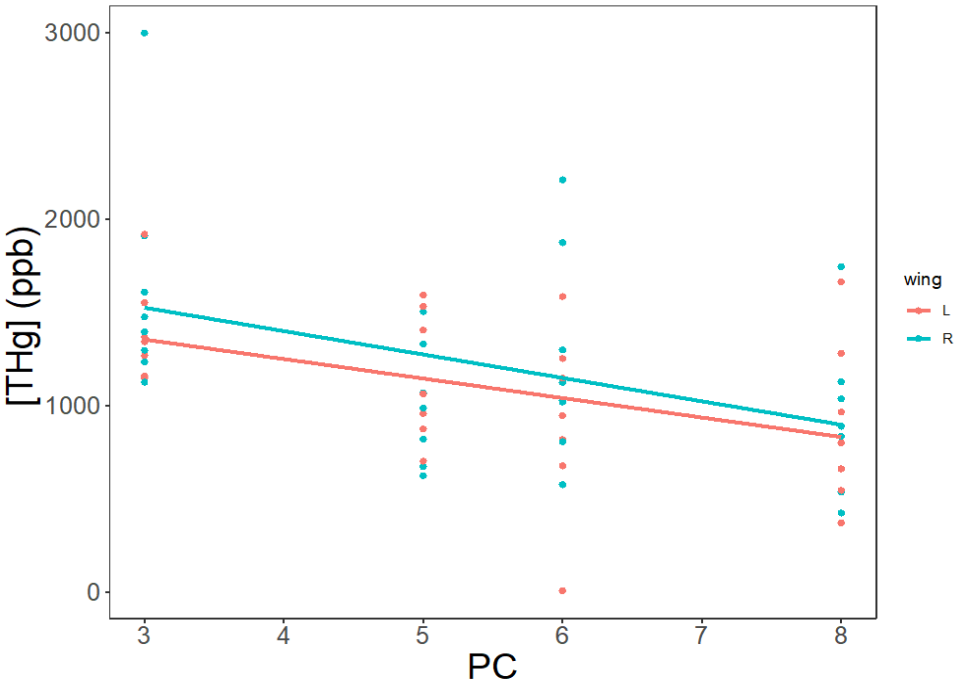
Bottini et al., 2021

Feather Hg indicates the Hg body burden at molting sites

- Standardized sampling is recommended
  - Feather Hg indicates the Hg body burden at molting sites

    Juvenile: Breeding ground

    Adult: stopping/wintering site

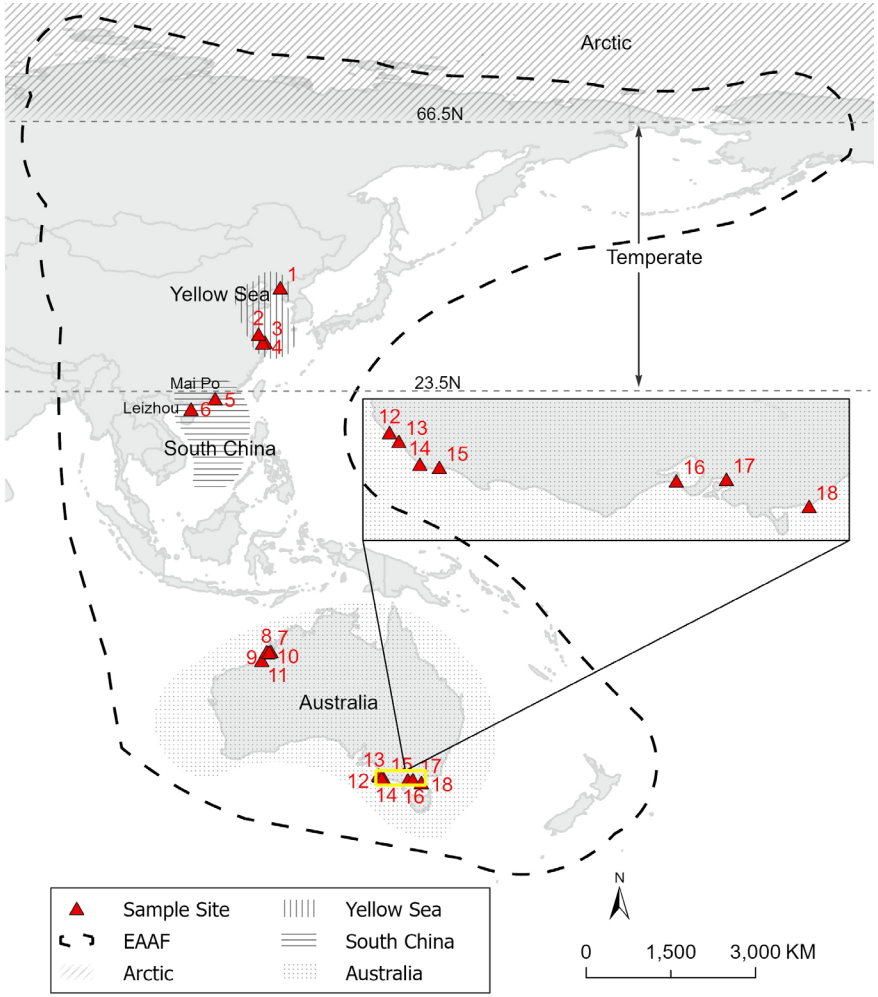


Ma et al., in prep.

Methods

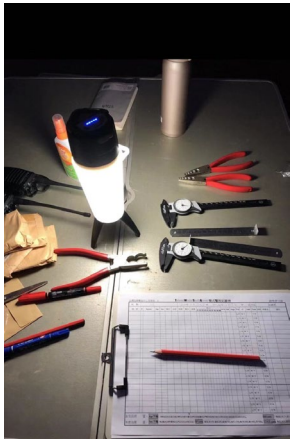
- 18 sampling sites
- China coast: mist nets or clap nets, between 2019 and 2022, n = 622;
- Australia: cannon nets or mist nets, between 2004 and 2016, n = 362

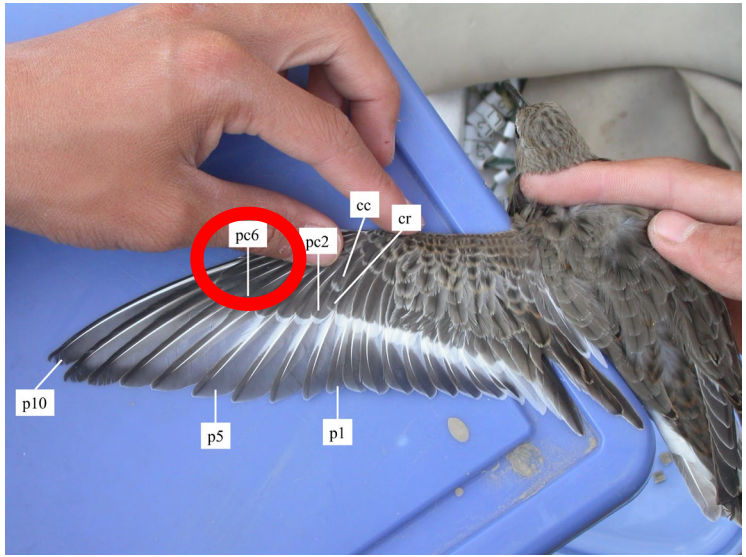
Age	Indicated contamination	Sampling season	Sampling sites
Juveniles	Breeding grounds Breeding grounds	Southward migration/Late winter period/ accidentally killed individuals	Stopovers Wintering grounds
Adults	Non-breeding grounds		



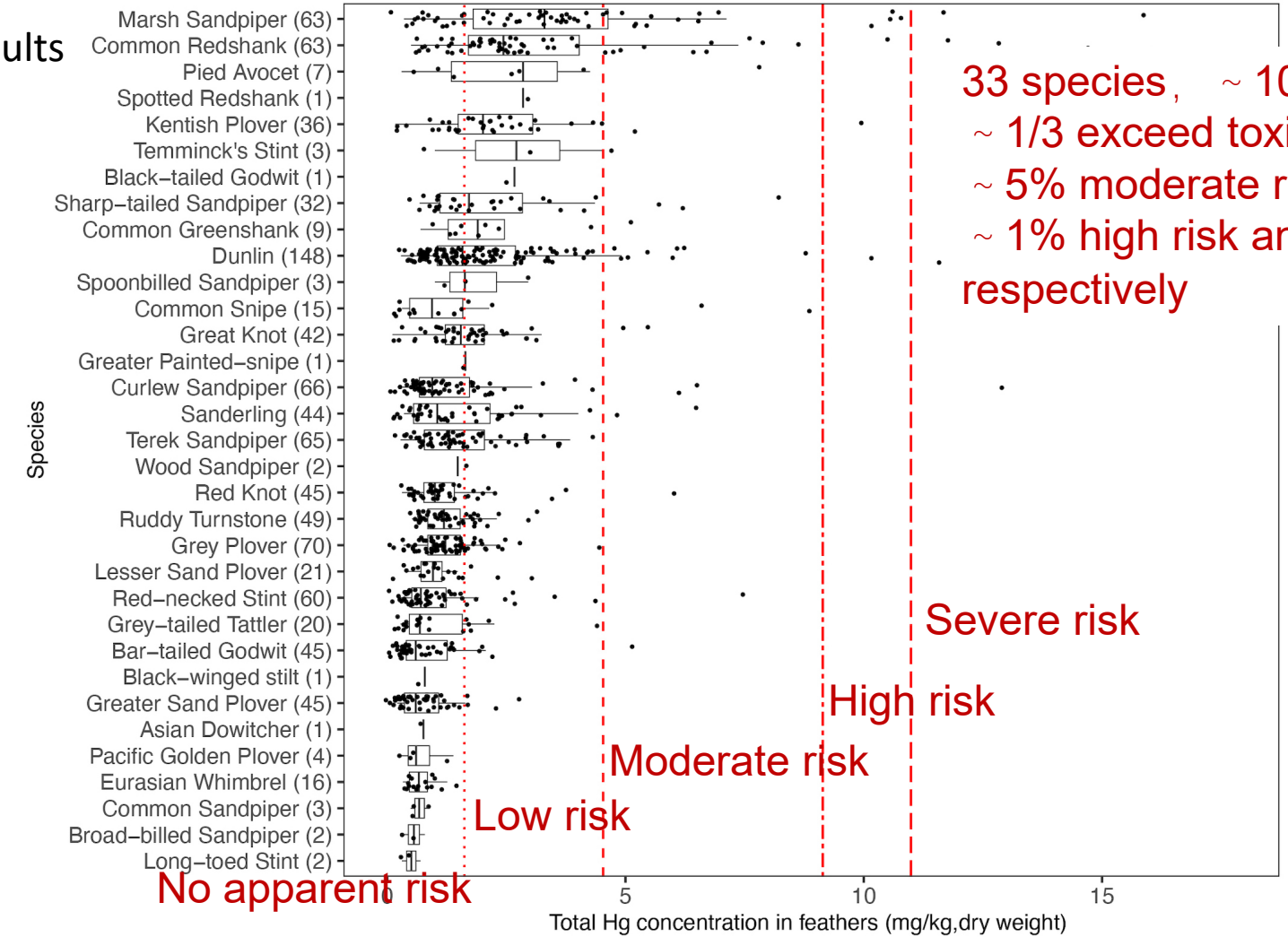
Methods

- Bird capture and sampling: A lot of fun! ☺
- Risk assessment: Chastel, et al., 2022; Ackerman et al., 2016





Results



33 species, ~ 1000 individuals

~ 1/3 exceed toxicity benchmarks

~ 5% moderate risk

~ 1% high risk and severe risk, respectively

Results

Table 1 | Mercury-contamination associated risk levels for migratory shorebirds along the East Asian-Australasian Flyway

Species	Scientific name	Sample size	Risk category (%)				
			N	L	M	H	S
Marsh Sandpiper	***Tringa stagnatilis***	**63**	**22.22**	**50.79**	**15.87**	**6.35**	**4.76**
Common Redshank	***Tringa totanus***	**63**	**22.22**	**55.56**	**14.29**	**1.59**	**6.35**
Kentish Plover	***Charadrius alexandrinus***	**36**	**33.33**	**58.33**	**2.78**	**2.78**	**2.78**
Sharp-tailed Sandpiper	***Calidris acuminata***	**32**	**50.00**	**40.63**	**9.38**	**0.00**	**0.00**
Dunlin	***Calidris alpina***	**148**	**50.68**	**42.57**	**5.41**	**0.68**	**0.68**
Great Knot			52				
Sanderling			61				
Terek Sandpipe			67				
Curlew Sandpip			72				
Grey-tailed Tatt			75				
Ruddy Turnstor			75				
Grey Plover			78				
Red Knot			80				
Red-necked Sti			86				
Bar-							
Grea			93				
All S			**62**				

Specie
appare
N no a derate risk, *H* high risk, *S* severe risk.

- Species belonging to the *Tringa* genus with a preference for inland wetlands and agricultural habitats
- 2 of 7 individuals at severe risk, from the temperate zone, while 5 were from South China

Linear mixed-effects model selection for predicting feather total Hg

- moulting region explain most
- habitat preference, diet and foraging stratum also contributed, but less pronounced

Table 2 | Linear mixed-effects model selection for predicting feather total mercury (logHg: log_{10} transformed THg) for migratory shorebirds along the EAAF

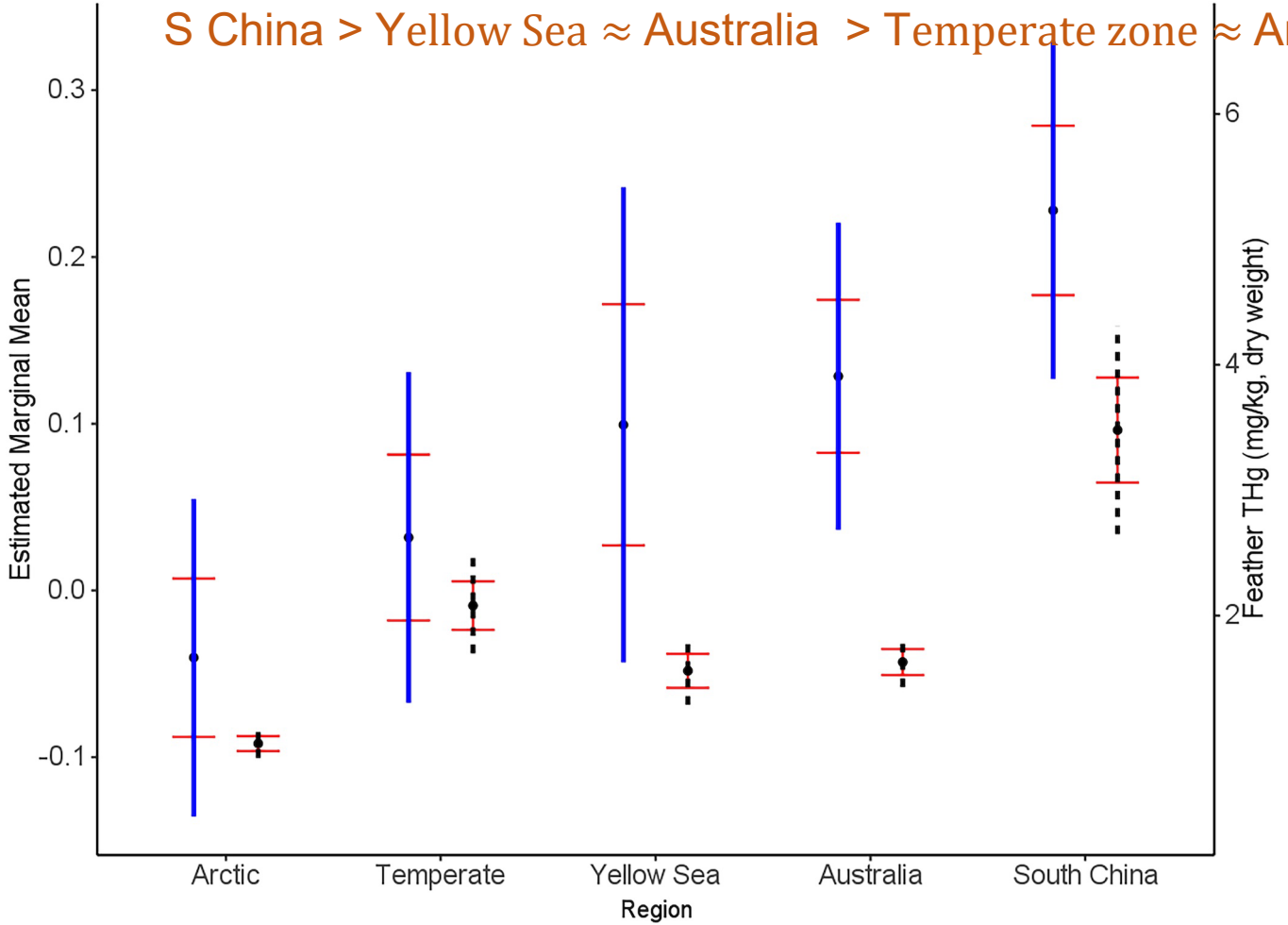
Model	Intercept	df	logLik	AICc	ΔAICc	Weight
logHg ~ Region + (1|Species) + (1|Year)	**−0.02**	**8**	**−161.19**	**338.58**	**0.00**	**0.26**
logHg ~ Region + Habitat Preference + (1|Species) + (1|Year)	**−0.08**	**9**	**−160.28**	**338.80**	**0.22**	**0.23**
logHg ~ Region + Diet + (1|Species) + (1|Year)	**−0.06**	**9**	**−160.90**	**340.04**	**1.46**	**0.13**
logHg ~ Region + Foraging Stratum + (1|Species)+ (1|Year)	**0.00**	**9**	**−161.06**	**340.36**	**1.78**	**0.11**
logHg ~ Region + Foraging Stratum + Habitat Preference + (1|Species) + (1|Year)	−0.06	10	−160.17	340.65	2.07	0.09
logHg ~ Region + Diet + Habitat Preference + (1|Species) + (1|Year)	−0.09	10	−160.20	340.70	2.12	0.09
logHg ~ Region + Diet + Foraging Stratum + (1|Species) + (1|Year)	−0.04	10	−160.73	341.77	3.19	0.05
logHg ~ Region + Foraging Stratum + Habitat Preference + Diet + (1|Species) + (1|Year)	−0.07	11	−160.08	342.52	3.94	0.04
logHg ~ Habitat Preference + (1|Species) + (1|Year)	0.01	5	−185.23	380.54	41.96	0.00
logHg ~ 1 + (1| Species) + (1|Year)	**0.09**	**4**	**−186.42**	**380.89**	**42.31**	**0.00**
logHg ~ Diet + (1|Species) + (1|Year)	0.03	5	−185.93	381.95	43.37	0.00
logHg ~ Foraging Stratum + Habitat Preference + (1|Species) + (1|Year)	0.05	6	−184.92	381.95	43.37	0.00
logHg ~ Foraging Stratum + (1|Species) + (1|Year)	0.13	5	−186.05	382.18	43.60	0.00
logHg ~ Diet + Habitat Preference + (1|Species) + (1|Year)	−0.01	6	−185.07	382.25	43.67	0.00
logHg ~ Diet + Foraging Stratum + (1|Species) + (1|Year)	0.07	6	−185.50	383.12	44.54	0.00
logHg ~ Foraging Stratum + Habitat Preference + Diet + (1|Species) + (1|Year)	0.03	7	−184.72	383.58	45.00	0.00

Species and sampling years were included as a random effect. The number of observations used in all models was 742. Individuals without clear region information were omitted. The selected models (ΔAICc ≤ 2) and the intercept-only model are depicted in bold.

Results

Non-breeding grounds > breeding grounds (Hgnonbreeding=1.5 *Hgbreeding)

S China > Yellow Sea ≈ Australia > Temperate zone ≈ Arctic region



Summary

- Molt ecology is critical to interpret feather Hg in shorebirds;
- Feather, particularly primary coverts can be potential biomonitoring tool for shorebirds;
- Shorebirds seem especially vulnerable to environmental Hg in non-breeding regions;
- Southern China has the highest Hg along EAAF indicated by Feather Hg.

Research priorities

- Southeast Asia and Yellow Sea lack or has limited data;
- Aquatic-related species (*Tringa* genus, e.g., Common Redshanks and Marsh Sandpipers) need to be paid more attention;
- More pollutants in more shorebirds should be studied;
- Standardized biomonitoring protocols using feathers would make long-term monitoring and regional comparison possible.

Acknowledgements

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