

Raptors and Contaminants

A tragedy of circumstance in five acts

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Contents

- Part 1: Prelude – in which we introduce the characters and setting
- Part 2: The Tragedy – in which the Lords of the sky are brought low
- Part 3: Epilogue – in which we try to make some sense of it all



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List of Characters

Acciptriformes - the ancient royal order (57 Ma):

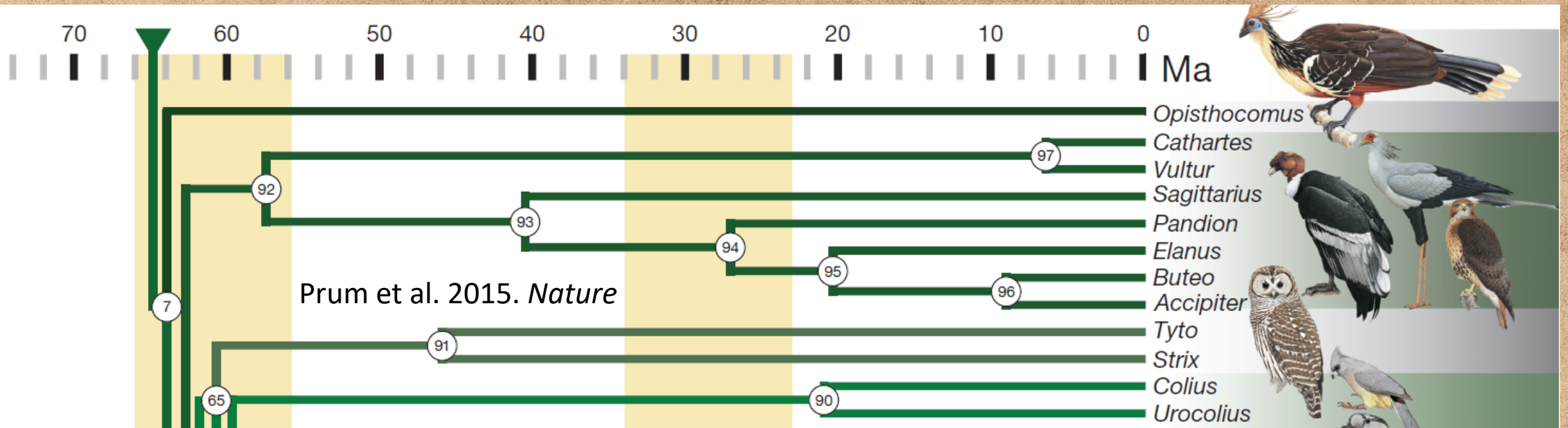
- OSPREY [**PANDION**]
- SOARING HAWKS [**BUTEO**]
- SEA EAGLES [**HALIAEETUS**]
- FOREST HAWKS [**ACCIPITER**]
- OLD WORLD VULTURES [**GYPS**]
- NEW WORLD VULTURES [**CATHARTES**]

Falconiformes - the upstart nephew (18 Ma)

- FALCONS [**FALCO**]

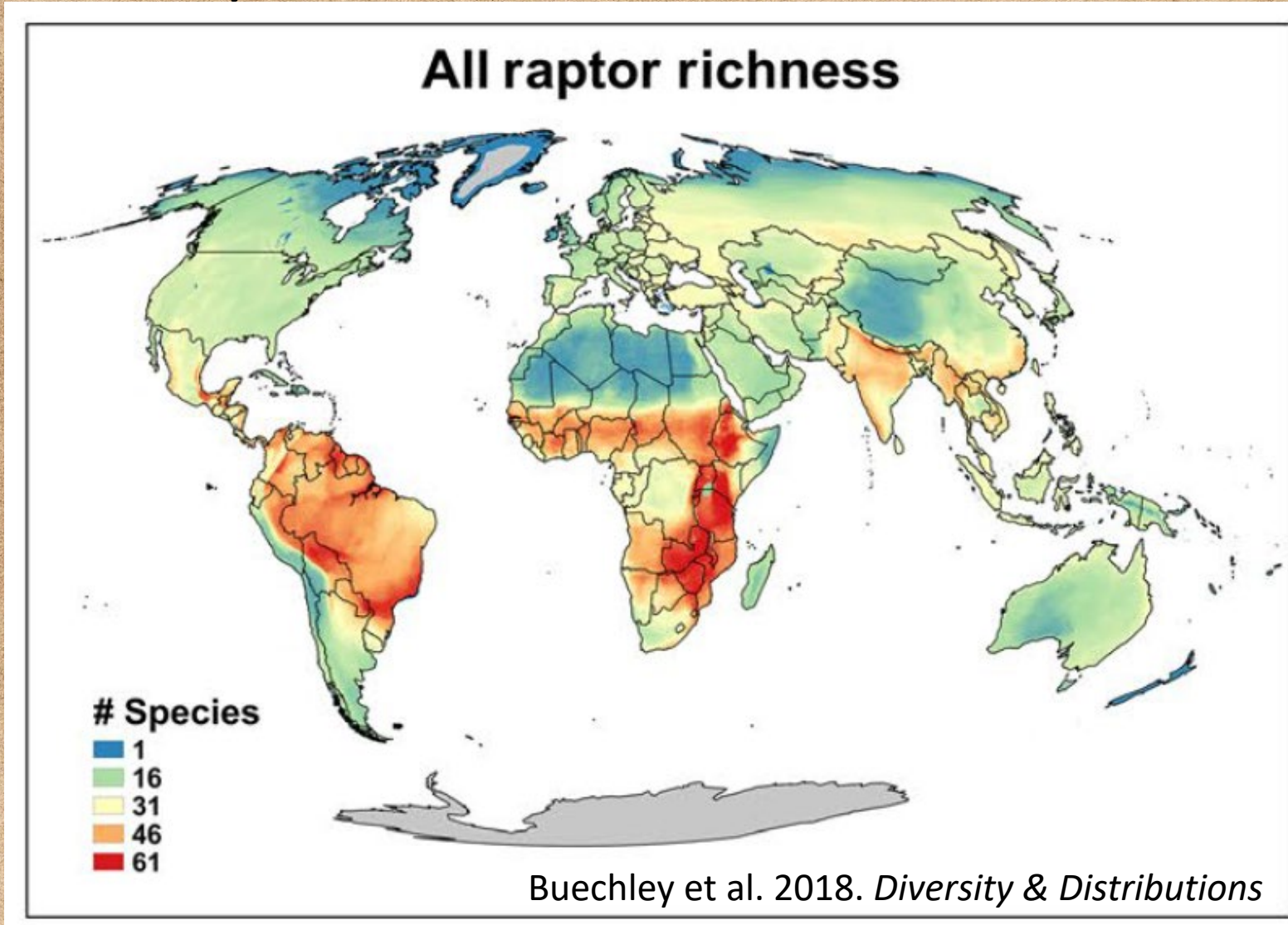
Strigiformes - the night stalkers (62 Ma)

Disclaimer – there are many more genera in these orders than can be covered here!



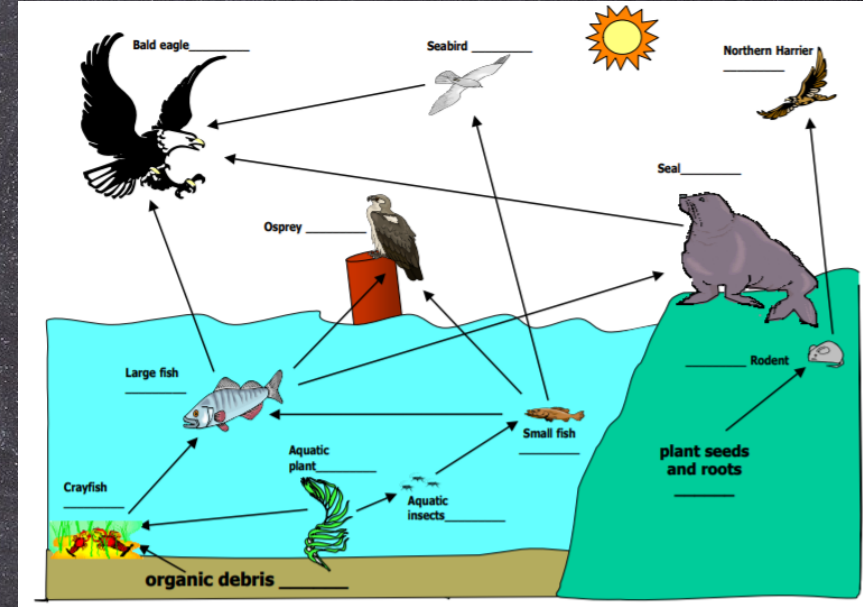
Global Raptor Diversity

- 557 Extant species
 - Acciptriformes (257)
 - Strigiformes (236)
 - Falconiformes (64)
- Tropical Bias
- 8 Species extinct since 1500 (island endemics)



Ecotox Princíple(s)

- Bioaccumulation – intake > elimination

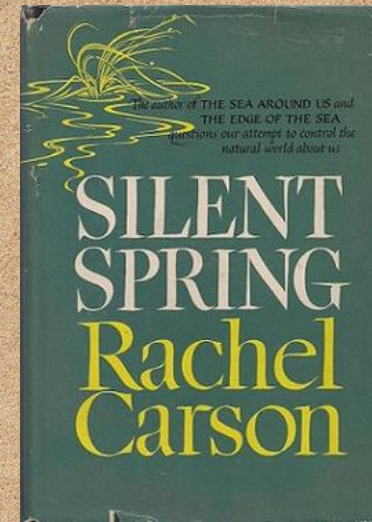
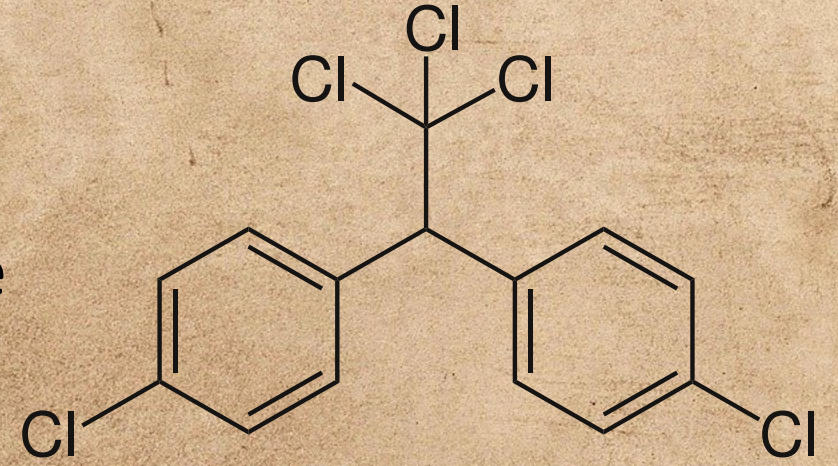


- Bioconcentration – organism > environment/substrate

- Biomagnification – increased concentration with increased trophic level

Act 1. Organochlorines

- DDT (DDE, DDD): Dichlorodiphenyltrichloroethane
- Insect neurotoxin (sodium channel activation)
- Very persistent (soil half-life: 2-15 yr)
- Bioaccumulative
- Introduced to US 1945
- Banned in US 1972



Regulatory Authority:

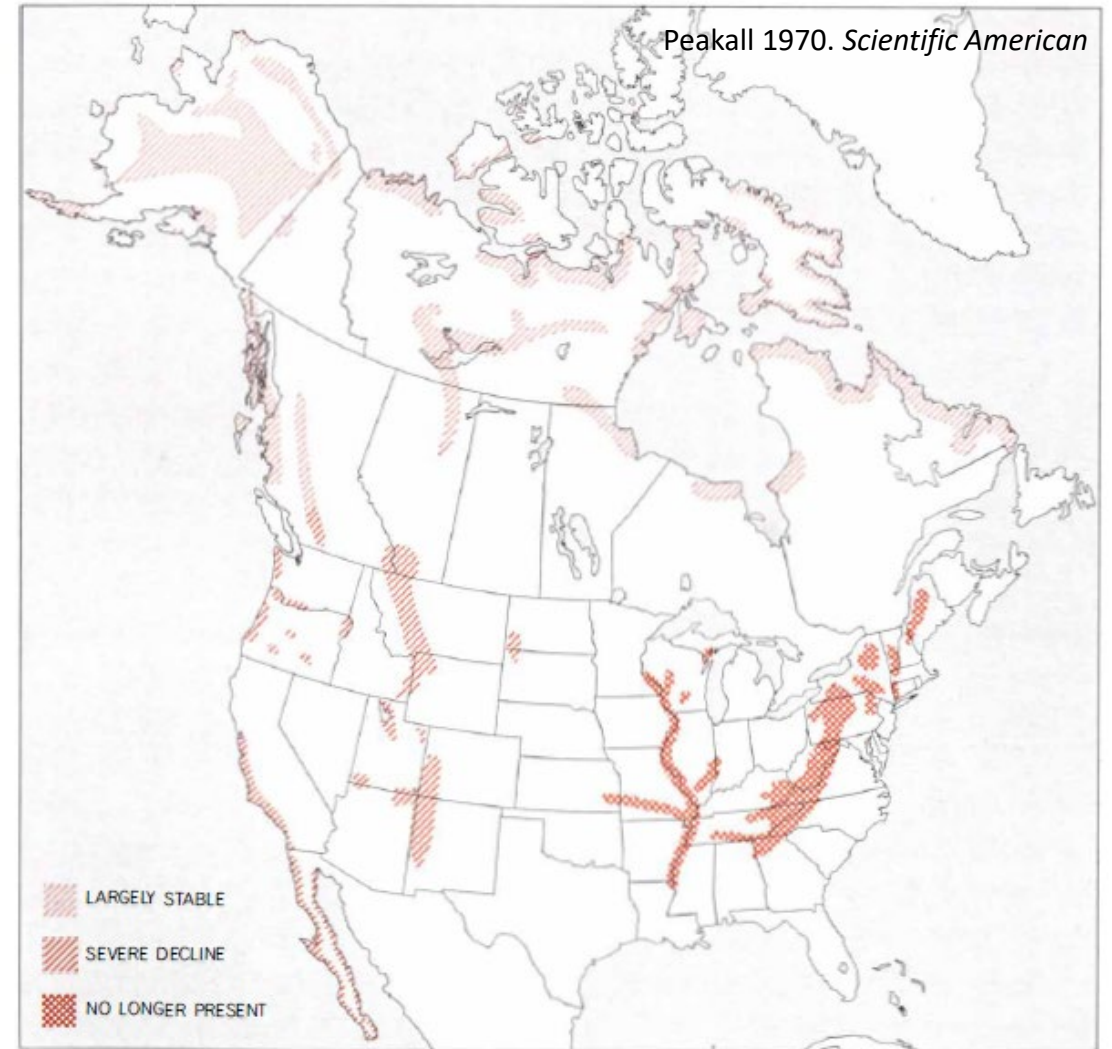
US EPA under the Federal Insecticide, Fungicide and Rodenticide Act (1972)

1950s & 1960s sharp declines in raptor populations



Raptors *most* affected (North America):

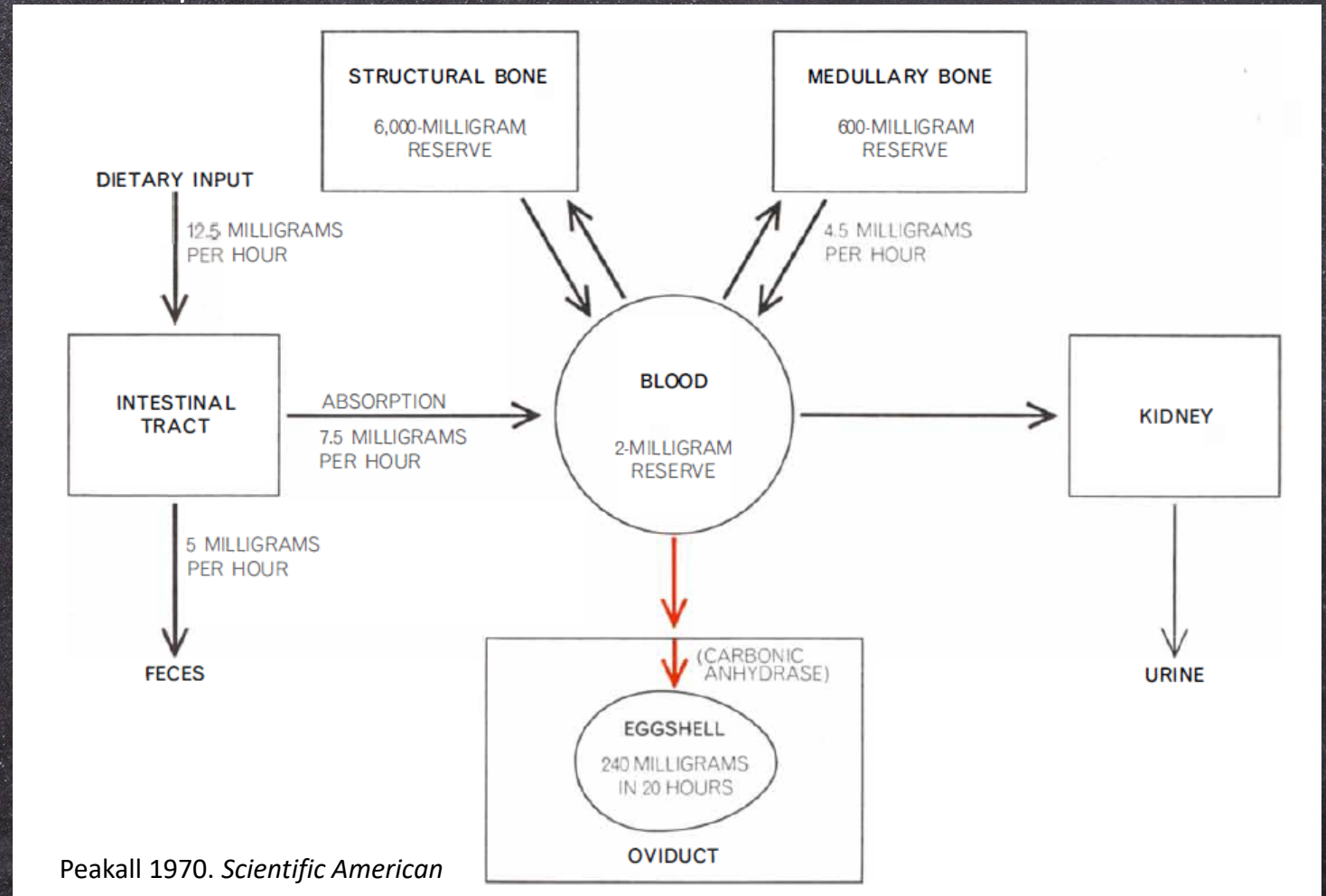
- Osprey (*Pandion*)
- Bald Eagle (*Haliaeetus*)
- Cooper's Hawk (*Accipiter*)
- Peregrine Falcon (*Falco*)



Peregrine Falcon Population Status 1970

Ecotox Principle(s)

- Mechanism of Action (MOA) – the specific interaction between chemical and organism that produces the (adverse) effect – inhibition of calcium ATPase



Recovery

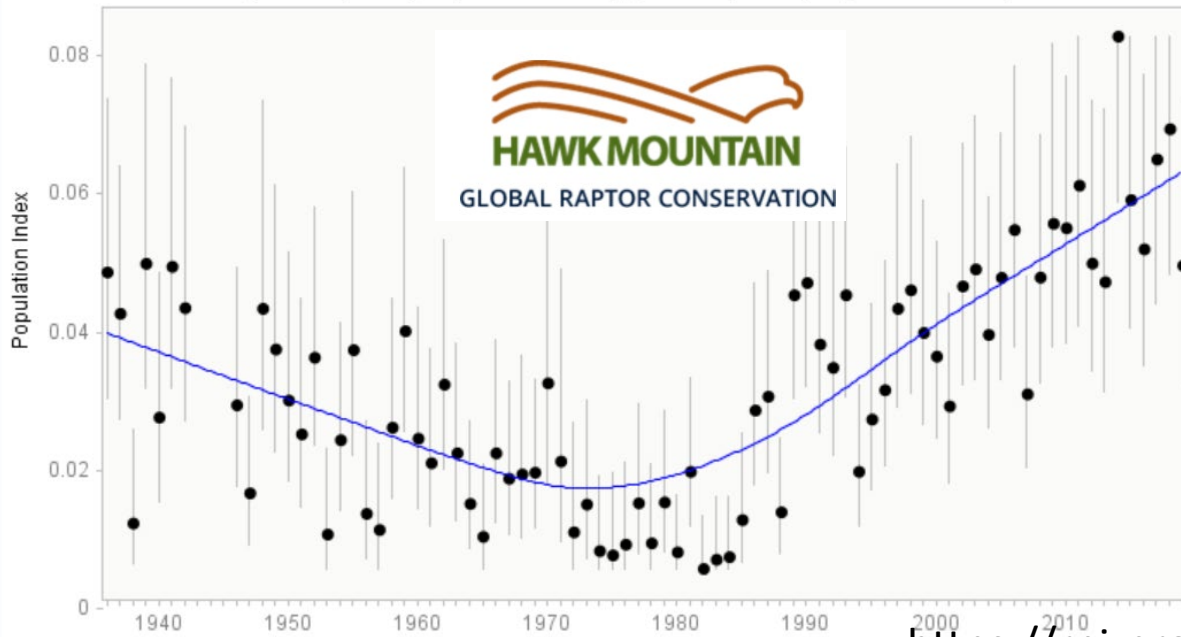


Photo: H. Toutonghi

Peregrine Falcon

Hawk Mountain Sanctuary - fall

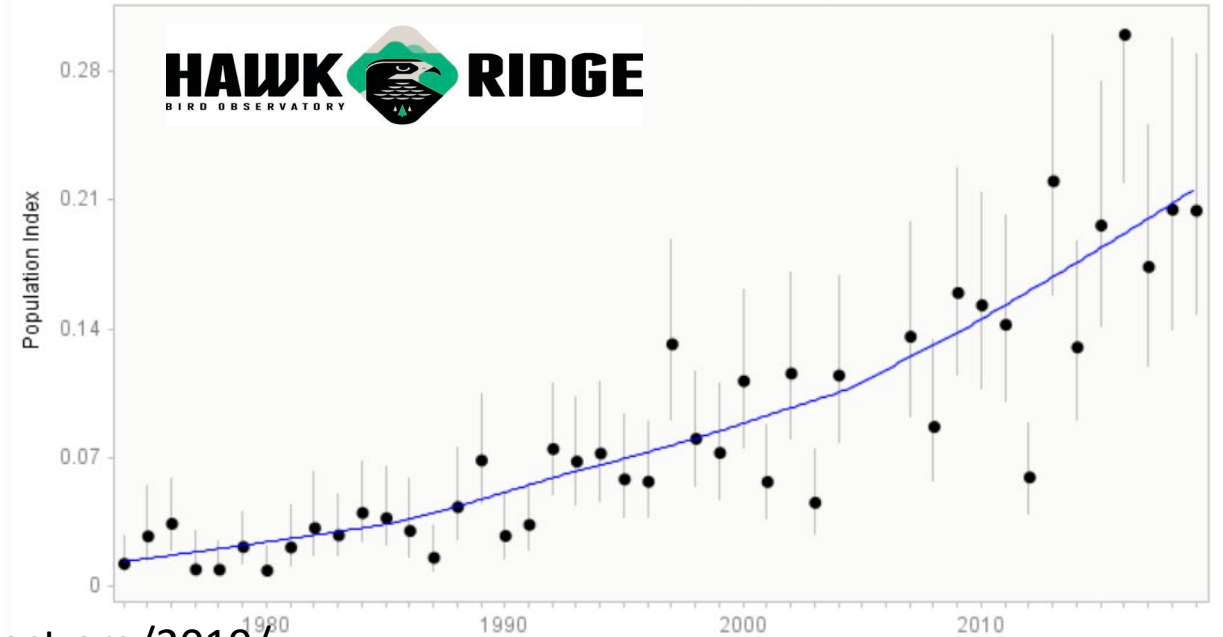
Trend (1936-2019): 0.5%/year (CI: -1.39% / 2.22%); (2009-2019): -0.5%/year (CI: -2.96% / 2.02%)



Peregrine Falcon

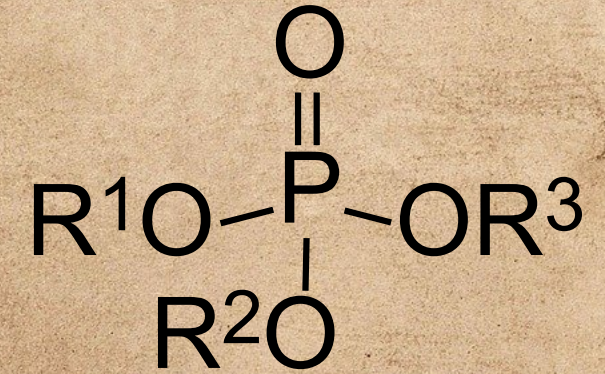
Hawk Ridge - fall

Trend (1974-2019): 5.97%/year (CI: 5.13% / 6.82%)*; (2009-2019): 4.71%/year (CI: -1.19% / 10.63%)

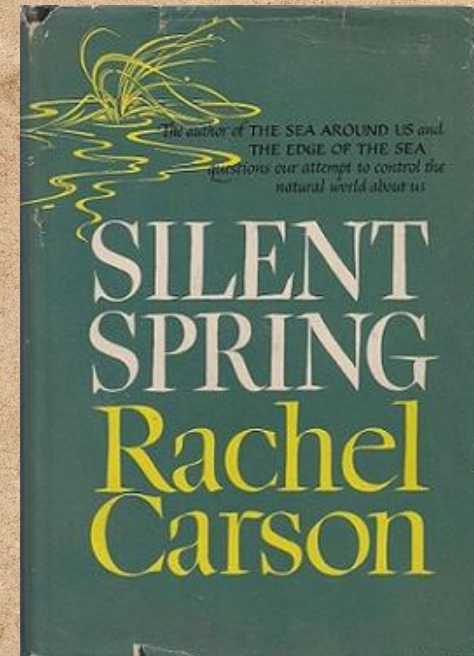


Act 2. Organophosphates

- Pesticides
- MOA – acetylcholinesterase inhibition (neurotoxin)
- Do not bioaccumulate
- Do not impair reproduction



Pesticide	Class	Persistence (soil half-life)	Potency (LD50)
Monocrotophos	Organophosphate	1-5 days	2.51 mg/kg
DDT	Organochlorine	2-15 years	1,334 mg/kg

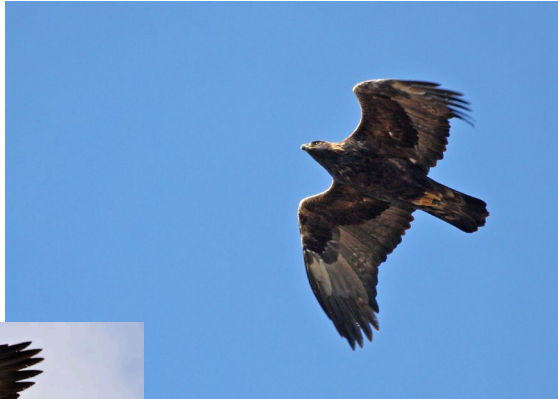


Regulatory Authority:

US EPA under the Federal Insecticide, Fungicide and Rodenticide Act (1972)

Birds of prey reported killed in US 1985-1995 due to organophosphate poisoning

From: Mineau et al. 1999



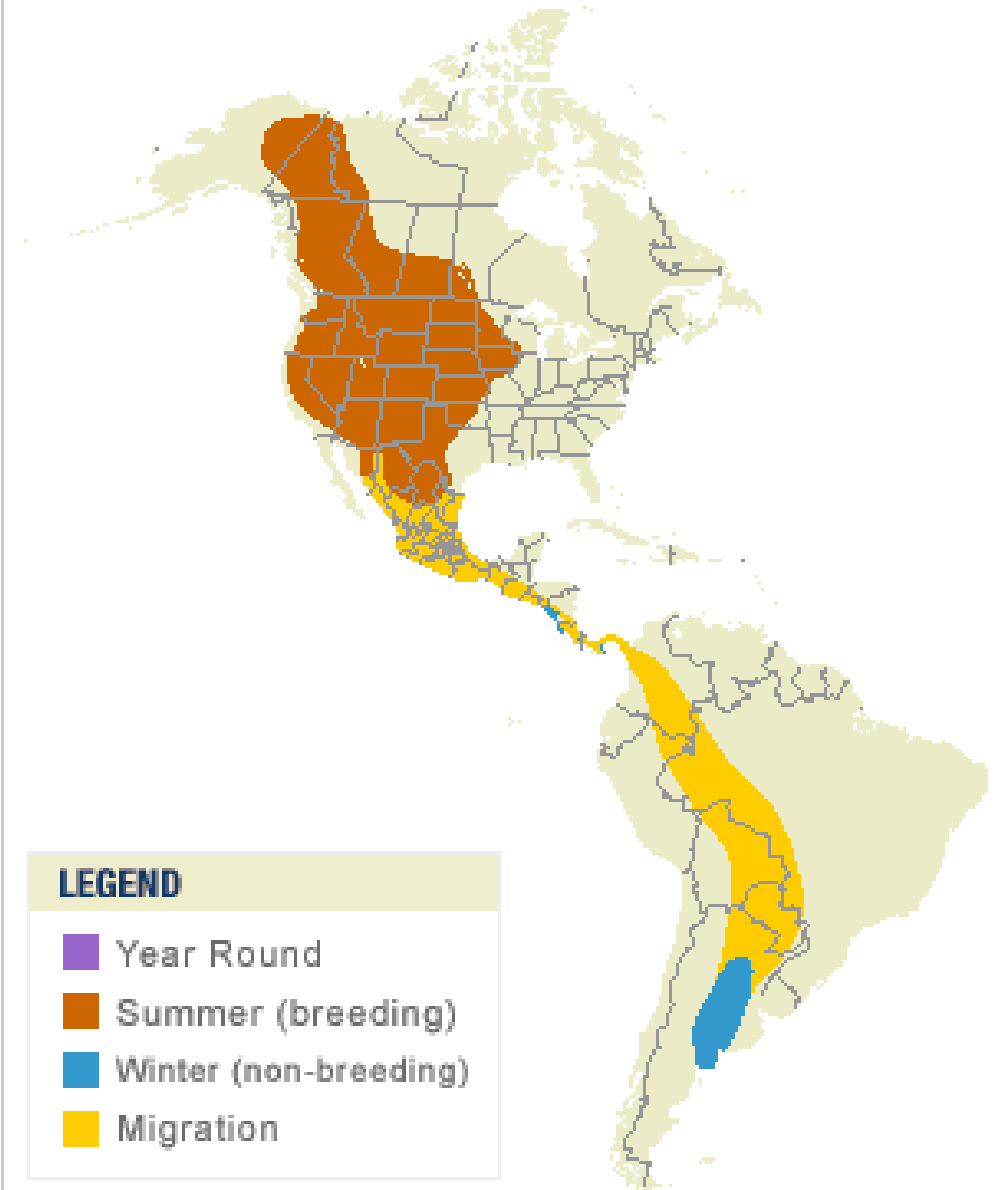
SPECIES	NUMBER OF INDIVIDUALS				
	LABELED USES	ABUSES	USE UNKNOWN	SPILLS	TOTAL
Turkey Vulture	—	8	2	1	11
Black Vulture	—	61	—	—	61
Osprey	—	—	2	—	2
White-tailed Kite	1	—	—	—	1
Mississippi Kite	17	—	—	—	17
Bald Eagle	31	87	125	—	243
Hen (Northern) Harrier	7	6	1	—	14
Sharp-shinned Hawk	2	—	—	—	2
Cooper's Hawk	9	—	3	—	12
Red-shouldered Hawk	—	—	2	—	2
Swainson's Hawk	20	—	—	—	20
Ferruginous Hawk	—	3	—	—	3
Rough-legged Hawk	1	—	—	—	1
Red-tailed Hawk	57	47	29	—	133
Golden Eagle	—	125	19	—	144
Unidentified hawk	0	8	—	1	9
American Kestrel	3	—	1	—	4
Prairie Falcon	—	1	—	—	1
Peregrine Falcon	5	—	1	—	6
Barn Owl	—	—	1	1	2
Short-eared Owl	1	—	—	—	1
Great Horned Owl	8	5	5	—	18
Barred Owl	4	—	1	—	5
Snowy Owl	2	—	1	—	3
Eastern Screech Owl	3	—	1	—	4
Unidentified owl	10	5	—	—	15
Totals	181	356	194	3	736

Swainson's Hawk

- *Buteo Swainsoni*
- Gregarious, forages in flocks
- Often feeds on ground
- Diet
 - Breeding: rodents > reptiles > insects
 - Non-breeding: Primarily insects (grasshoppers)



Swainson's Hawk
Buteo swainsoni



Map by Cornell Lab of Ornithology
Range data by NatureServe

Swainson's Hawk mortality events

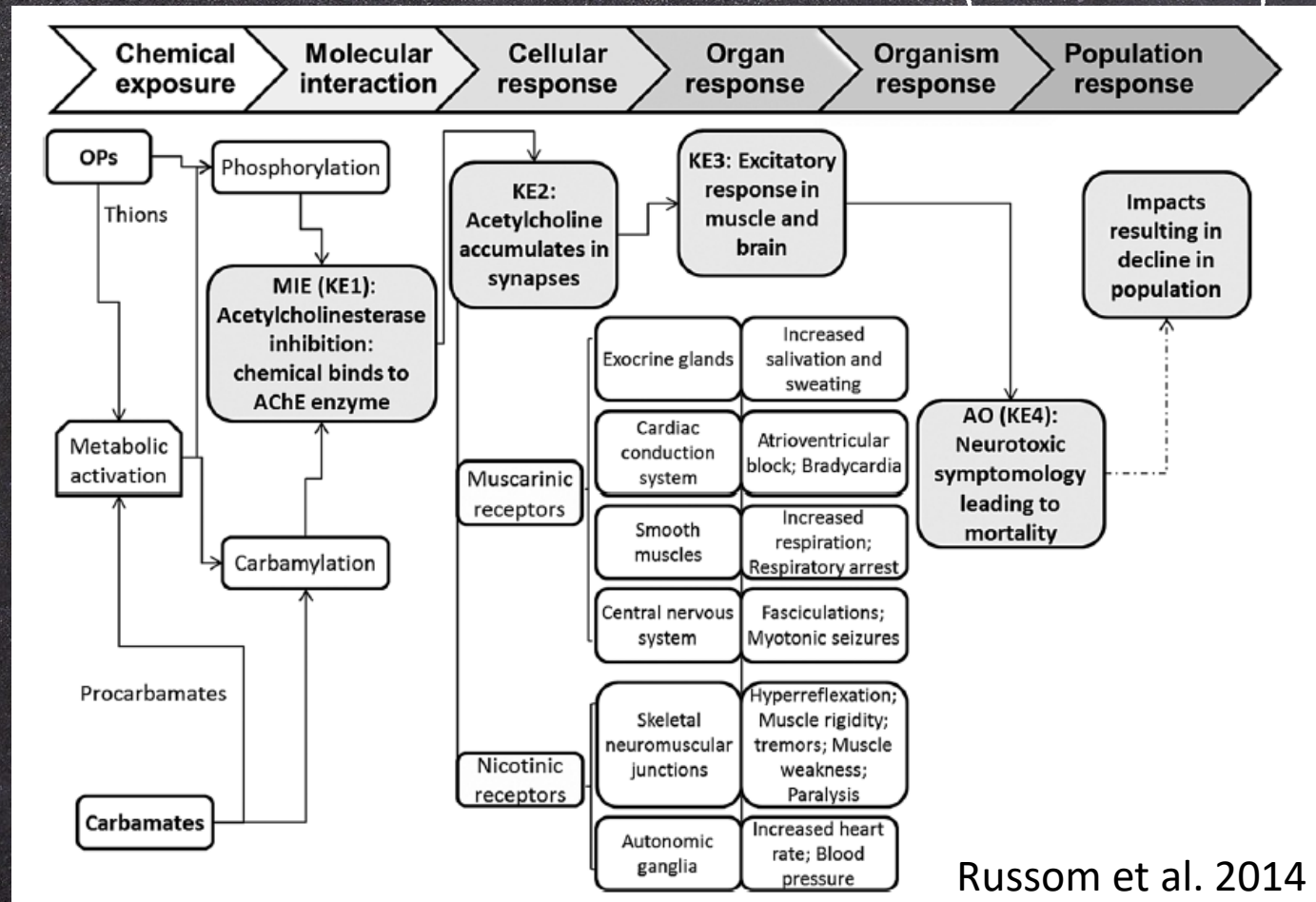
Table 2. Swainson's hawk mortality incidents from January through March 1996 in the pampas of central Argentina and forensic results from sites where tissues were sampled

Incident Site ID	Locality	Type of measurement	No. dead	Farmer testimony	Analytical results	Mean \pm SE MCP ($\mu\text{g/g}$)
<i>Trip 1 (3 January–17 January 1996)</i>						
T1	Roost	Count	1	MCP	MCP	0.09 ($n = 1$)
<i>Trip 2 (27 January–8 February 1996)</i>						
I	Corn	Count	387	MCP	MCP	0.10 \pm 0.03 (range 0.05–0.19, $n = 6$)
II	Alfalfa	Count	103	Dimethoate	NA ^b	—
III	Alfalfa	Extrapolation ^a	3024	Unid ^b	MCP	0.13 \pm 0.03 (range 0.06–0.25, $n = 6$)
IV	Alfalfa	Count	592	MCP	MCP	0.07 \pm 0.01 (range 0.05–0.12, $n = 8$)
<i>INTA Surveys^c (15 February–31 March 1996)</i>						
V	Alfalfa	Count	14	MCP	NA	—
VI	Alfalfa	Estimate ^d	81	MCP	NA	—
VII	Unid	Estimate	300	MCP	NA	—
VIII	Alfalfa	Estimate	50	MCP	NA	—
IX	Wheat	Count	9	Chlorpyrifos	MCP	0.47 \pm 0.12 (range 0.05–1.08, $n = 8$)
X	Alfalfa	Count	28	MCP	NA	—
XI	Alfalfa	Estimate	120	MCP	NA	—
XII	Roost	Count	3	MCP	NA	—
XIII	Roost	Count	4	Unid	MCP	0.09 (range 0.06–0.12, $n = 2$)
XIV	Alfalfa	Estimate	200	MCP	NA	—
XV	Alfalfa	Estimate	Unid	MCP	NA	—
XVI	Alfalfa	Estimate	40	MCP	NA	—
XVII	Alfalfa	Estimate	30	MCP	NA	—
XVIII	Sorghum	Count	109	Chlorpyrifos	NA	—
Total			5095		Mean \pm SE	0.20 \pm 0.05 (range 0.05–1.08, $n = 31$)



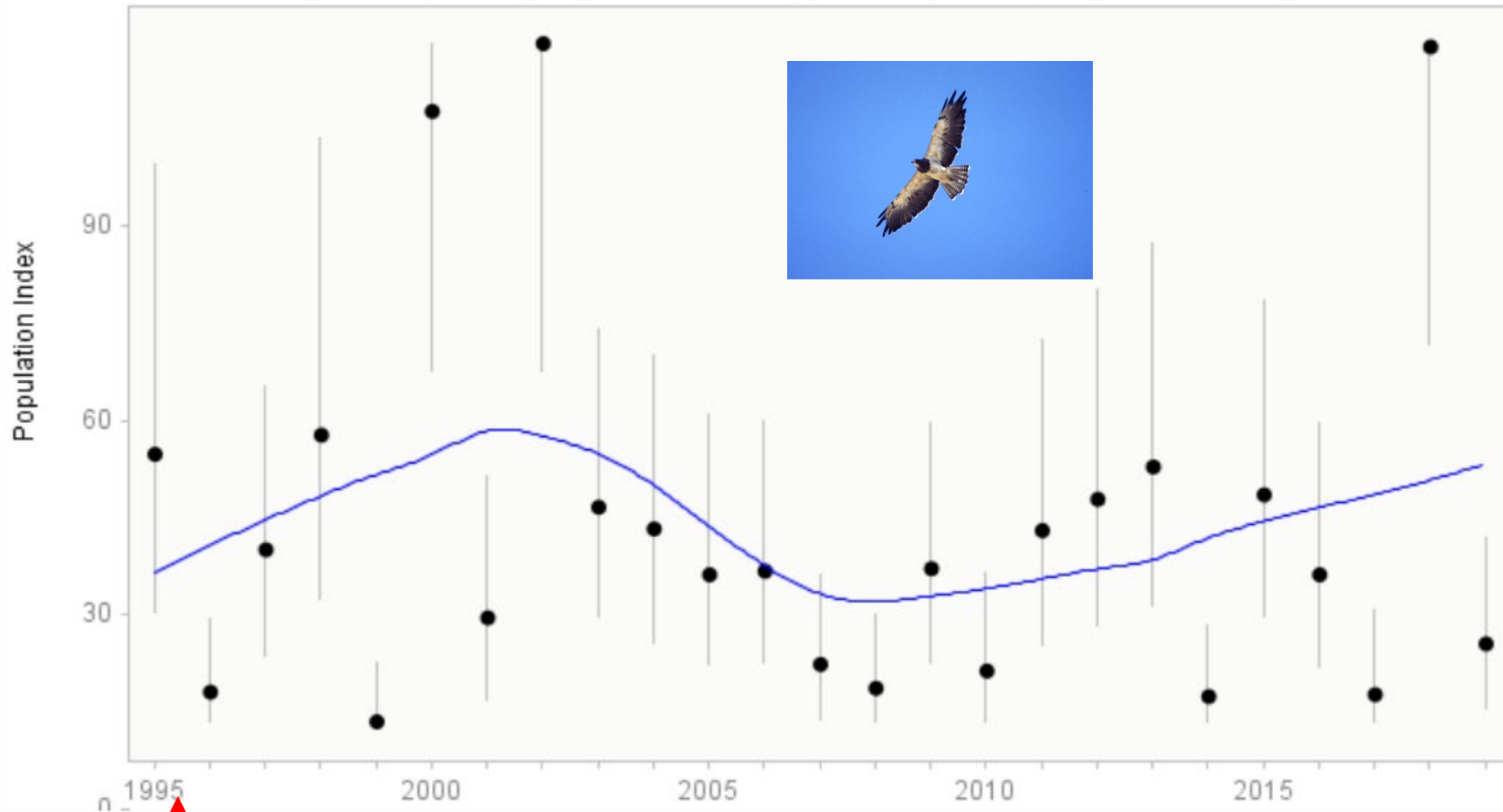
Ecotox Principle(s)

- Adverse Outcome Pathway – the series of events from an initial molecular initiating event (MIE) through a series of key events (KE) that result in an adverse outcome (AO) to fitness or population health

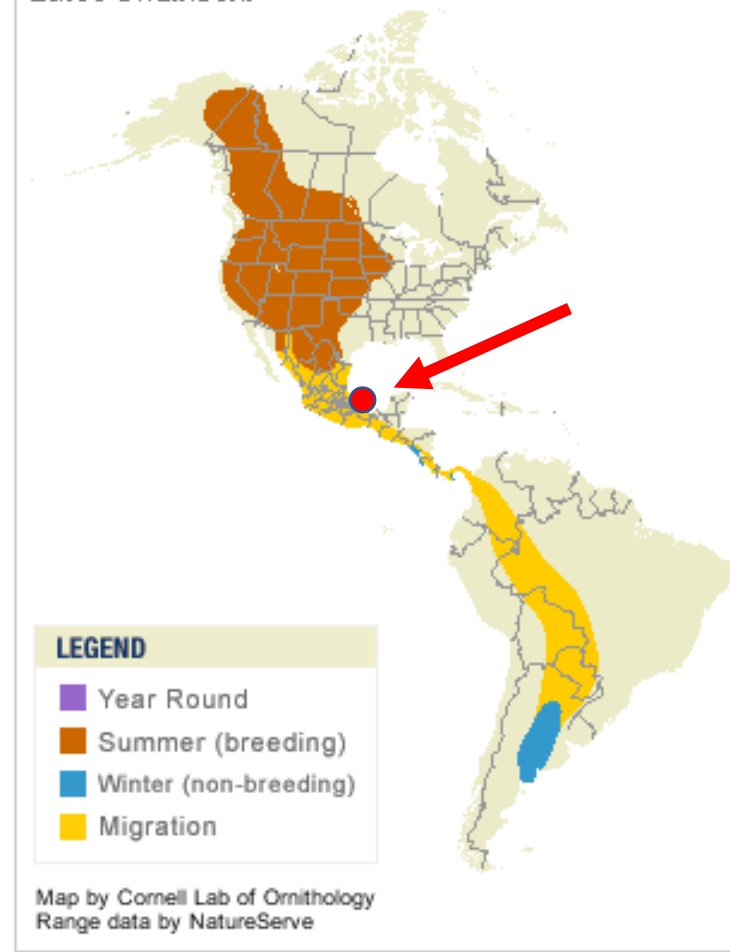


A population effect?

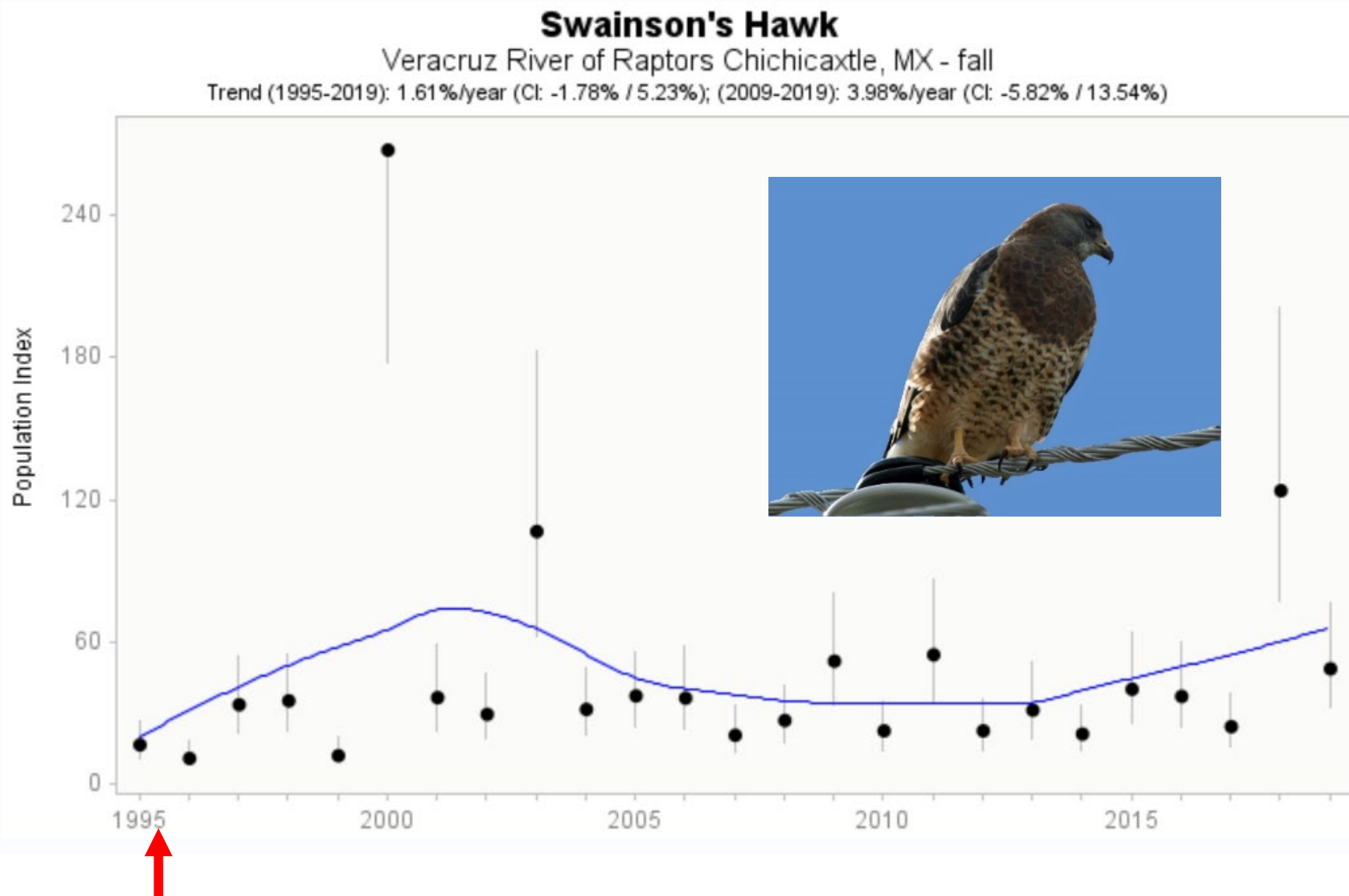
Swainson's Hawk
Veracruz River of Raptors Cardel, MX - fall
Trend (1995-2019): -0.5%/year (CI: -2.86% / 1.82%); (2009-2019): -1.78%/year (CI: -7.69% / 4.6%)



Swainson's Hawk
Buteo swainsoni



A population effect?



Act 3. Diclofenac

- Non-steroidal anti-inflammatory drug
- MOA – inhibits prostaglandin synthesis
- Widespread veterinary use in South Asia
- Very acutely toxic to old world vultures
 - Visceral gout & kidney failure due to uric acid build-up
 - LD50 = 0.225 mg/kg
 - (monocrotophos LD50 = 2.51 mg/kg)



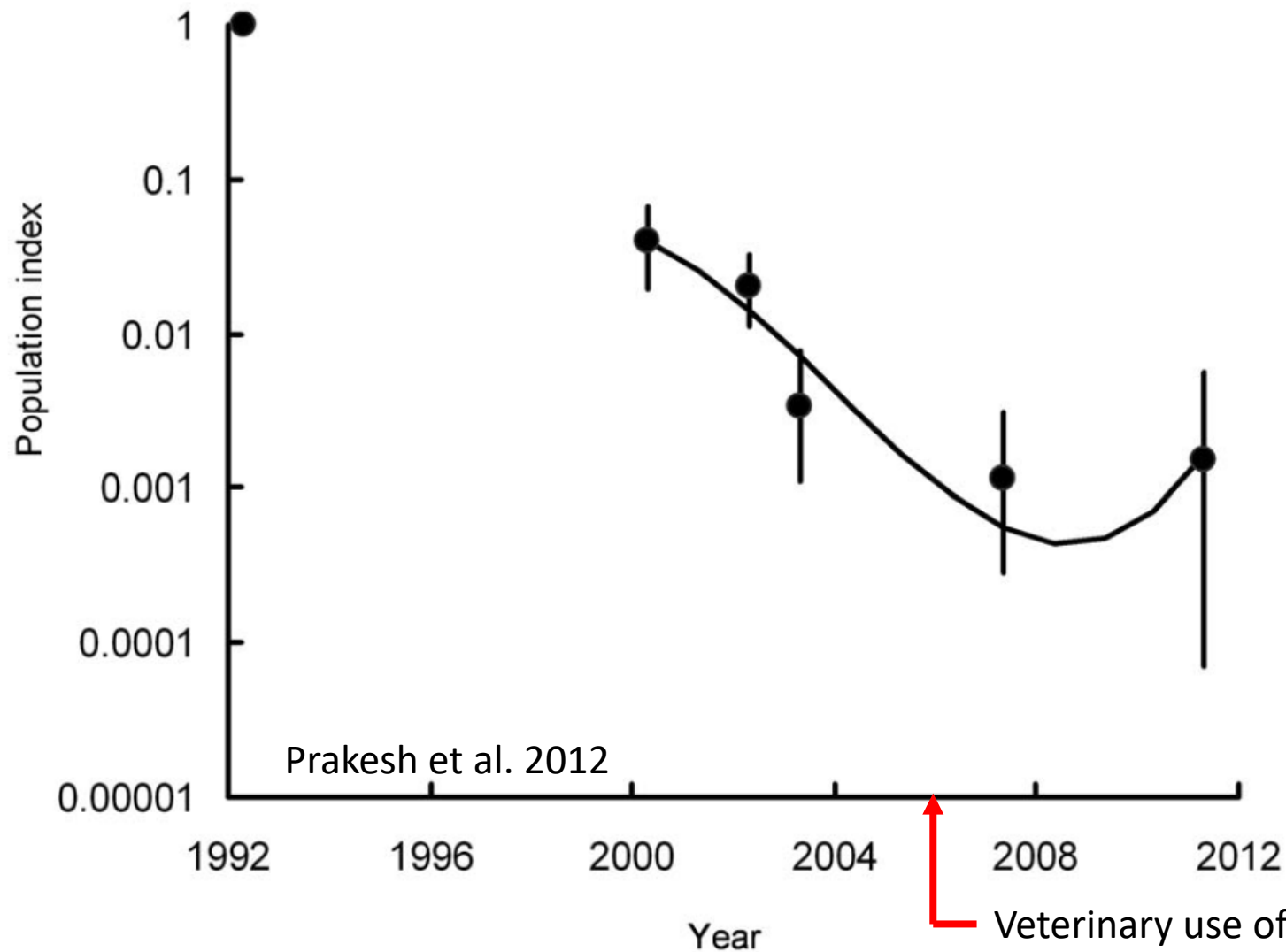
Photo: Goran Ekstrom



Regulatory Authority:

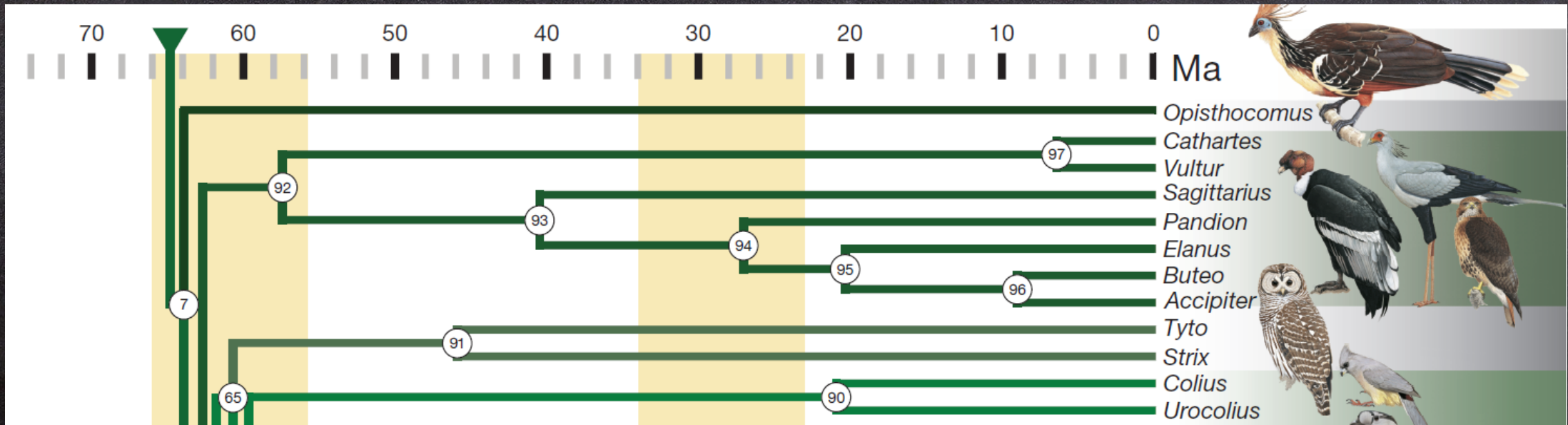
US FDA under the Federal Food Drug and Cosmetic Act (1938)

The Asian Vulture Crisis



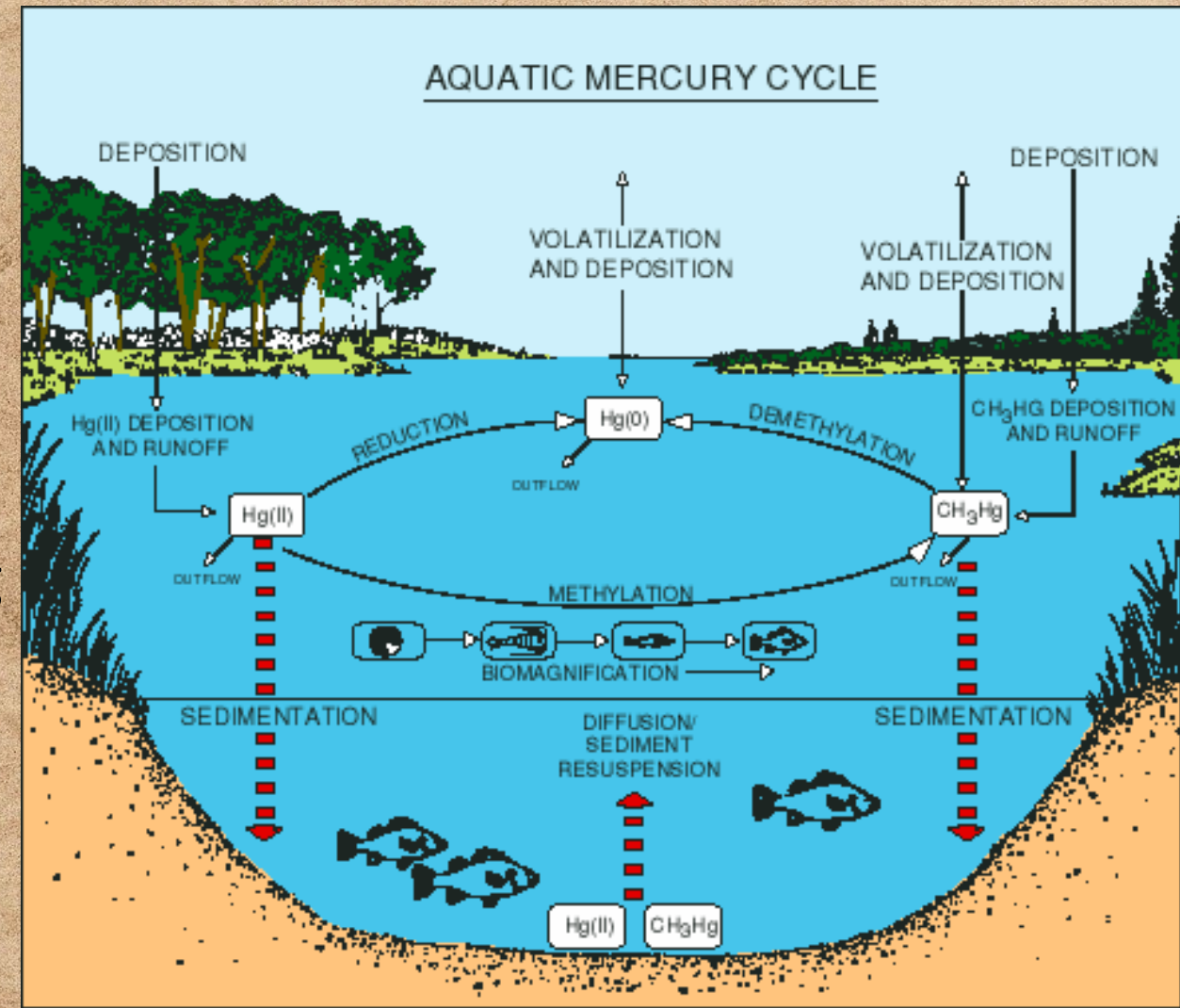
Ecotox Principle(s)

- Species Sensitivity – Species differ, sometimes markedly, in their sensitivity to a toxicant
- For Turkey Vultures (*Cathartes aura*) “Diclofenac failed to evoke overt signs of toxicity, visceral gout, renal necrosis, or elevate plasma uric acid at concentrations greater than 100 times the estimated median lethal dose reported for *Gyps* vultures.” Rattner et al. 2008



Act 4. Methylmercury

- Source: manufacturing and fossil fuel burning (Hg^{2+})
- Methylated to CH_3Hg , usually in shallow and/or acidic wetlands by sulfur-reducing bacteria
- Bioaccumulative
- Neurotoxin (among other things)

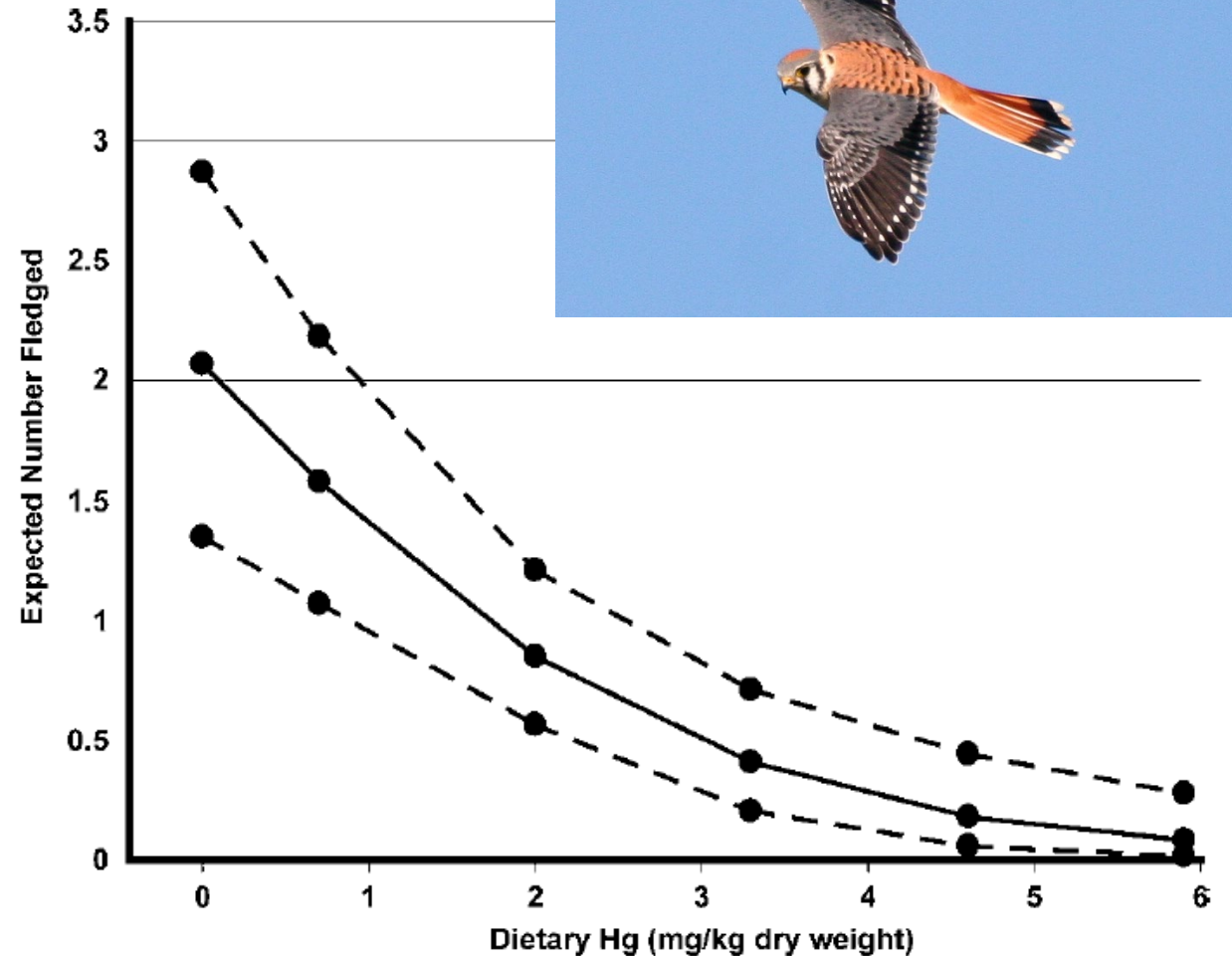
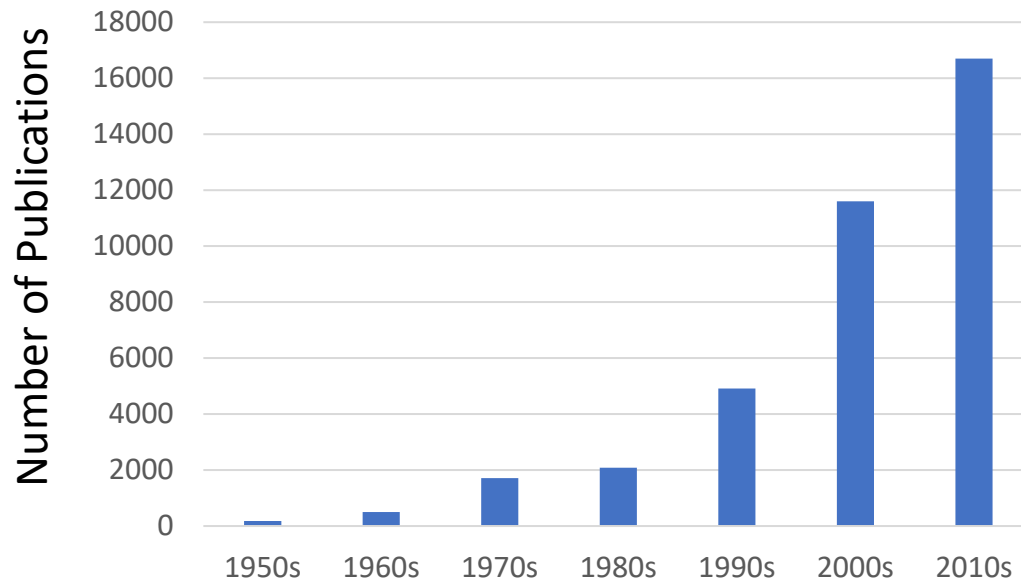


Regulatory Authority:
US EPA under the Clean Water Act and Clean Air Act

Increasing Hg concern for birds

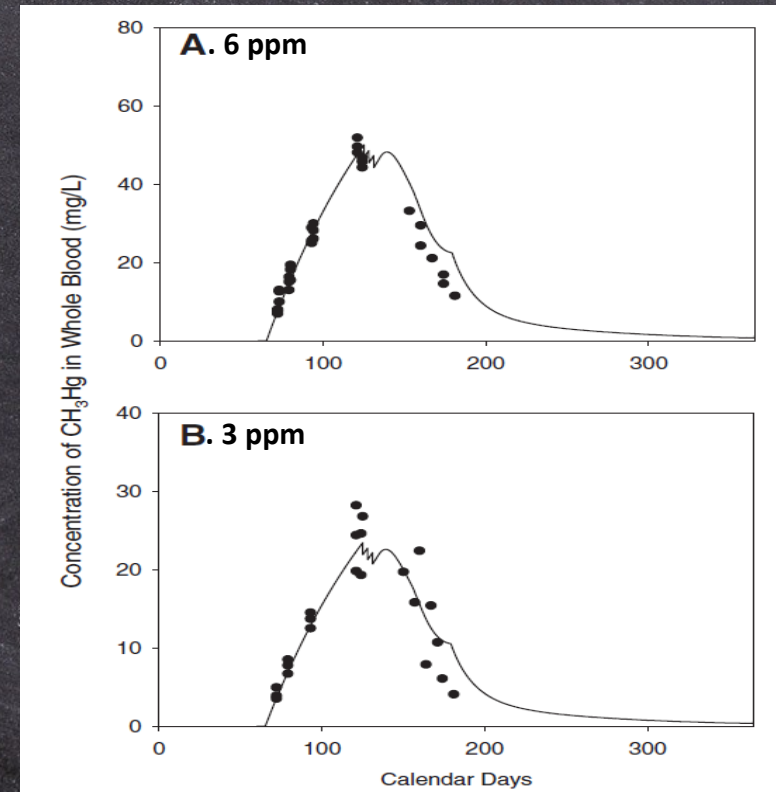
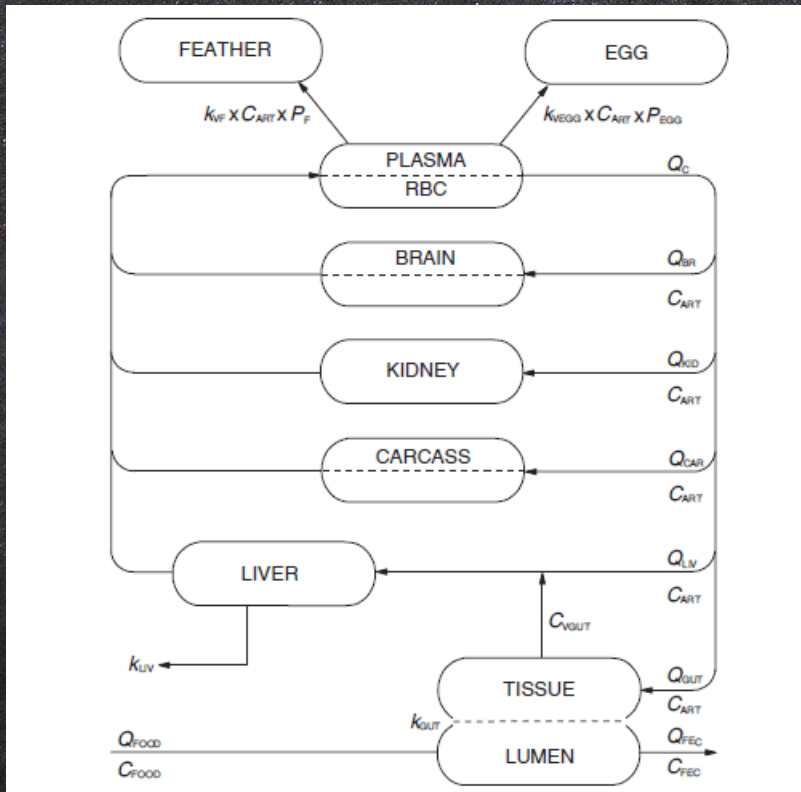
Google Scholar search by decade for
“mercury toxicity birds”

Scholar Citations

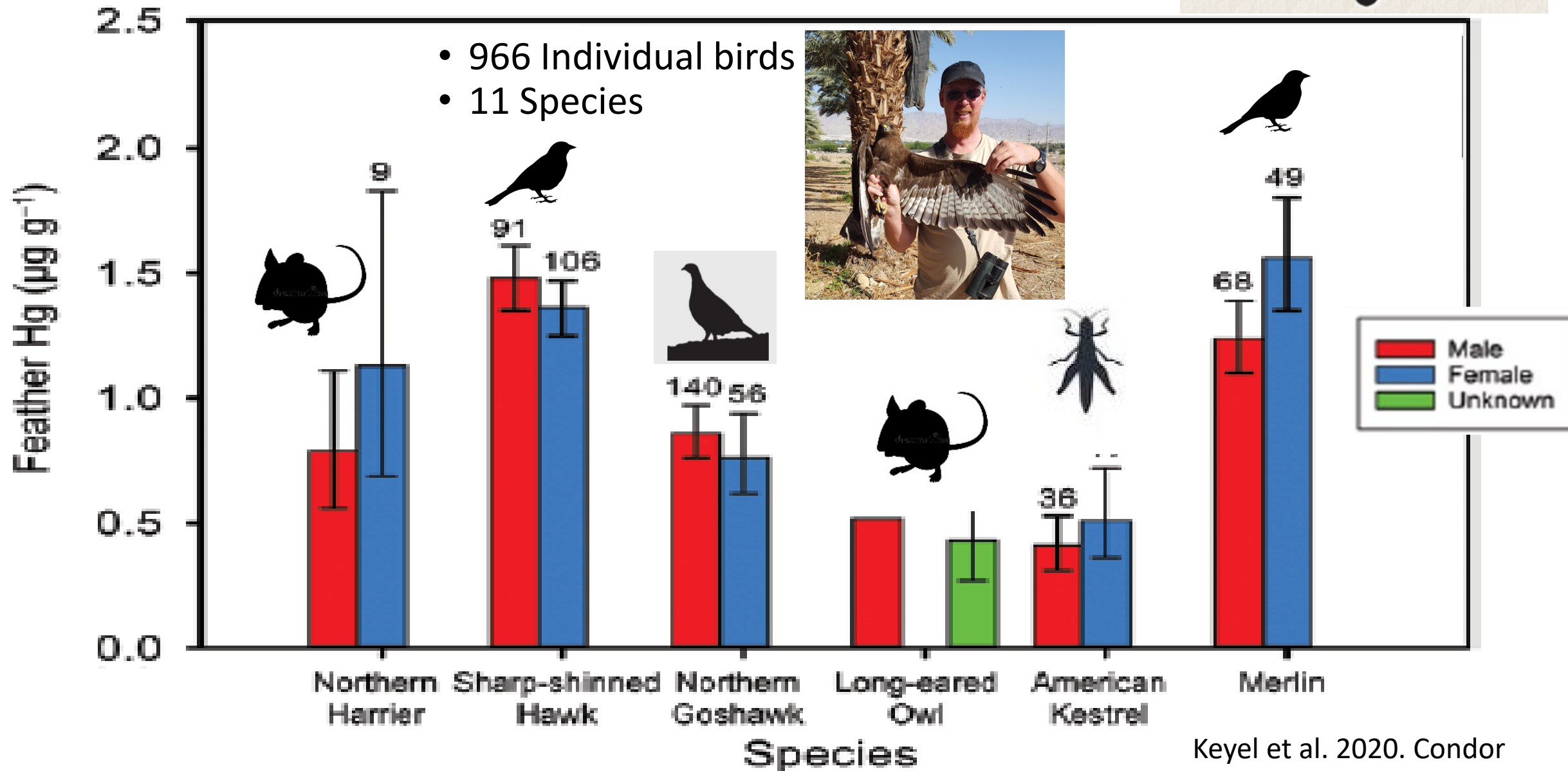


Ecotox Principle(s)

- Toxicokinetics – the time course of uptake and distribution of a toxicant within an organism
- Toxicodynamics – the time course of damage accruing from internal exposure to a toxicant, often at a target site of activity



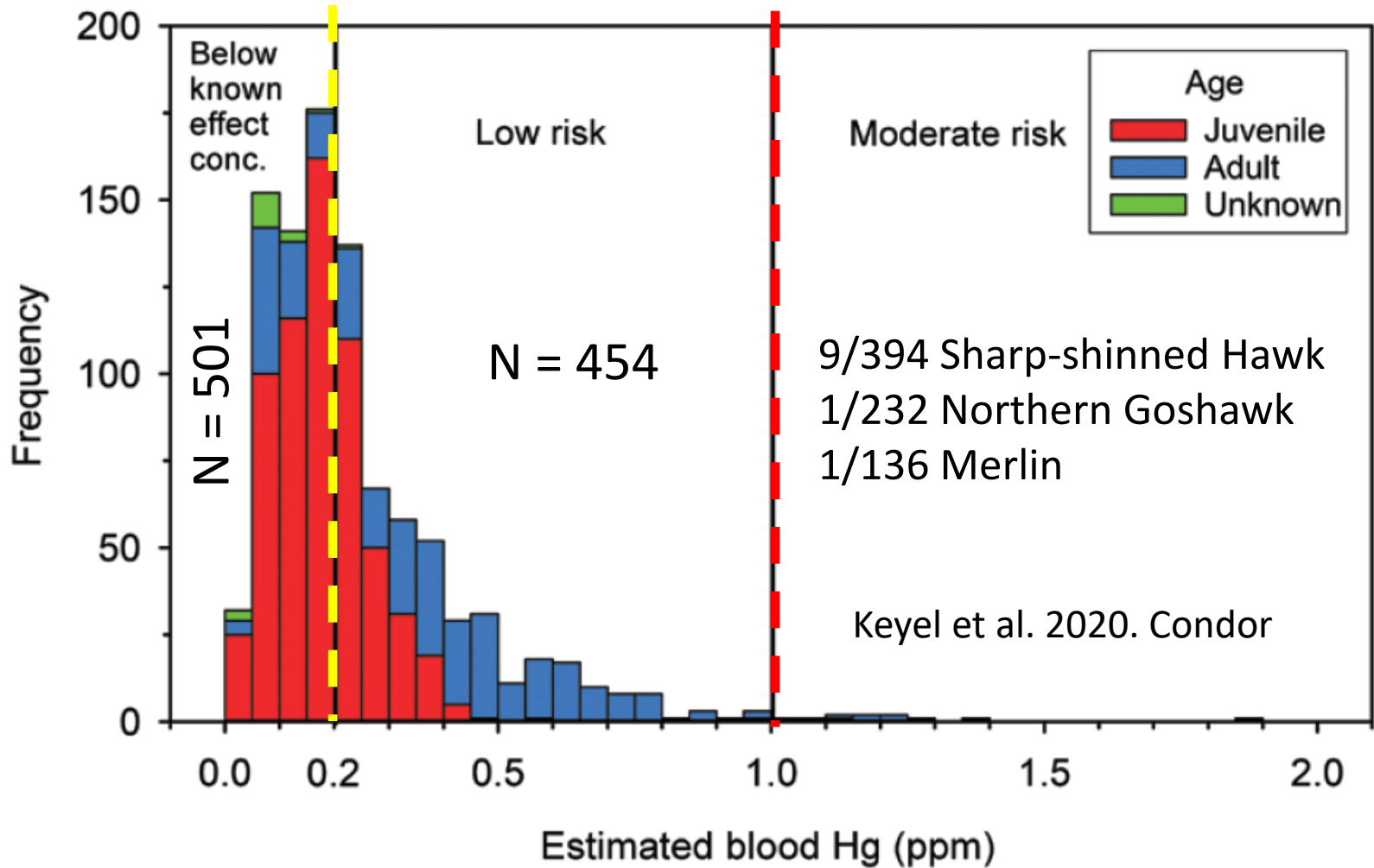
Hawk Ridge Mercury Study





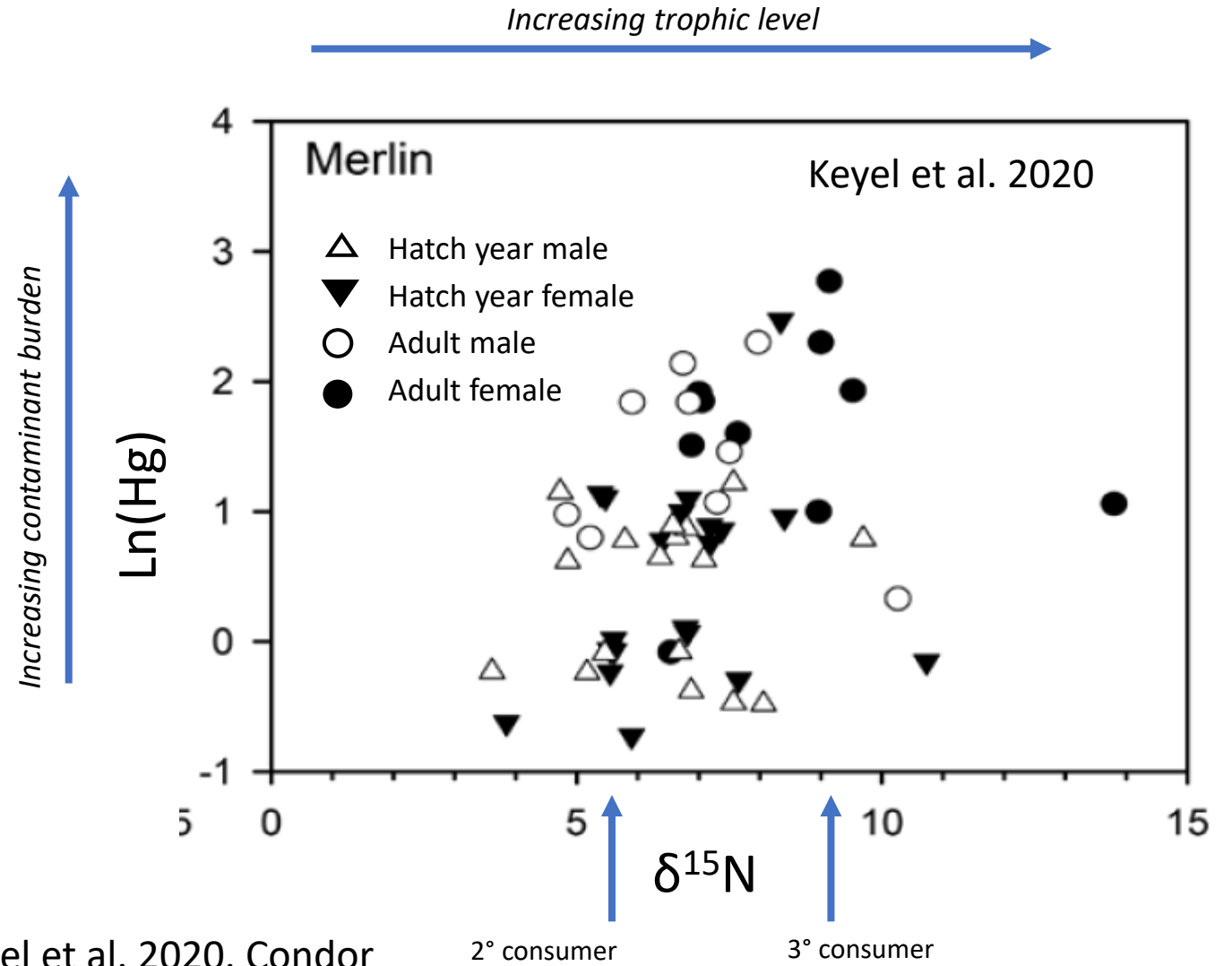
Risk	Blood Hg PPM
Negligible	< 0.2
Low	0.2 – 1.0
Moderate	1.0 – < 3.0
High	3.0 – 4.0
Severe	> 4.0

Risk categories from
Ackerman et al. 2016. SOTN





Mercury increases with trophic level



Keyel et al. 2020. Condor

Act 5. Polyfluoralkyl Substances (PFAS)

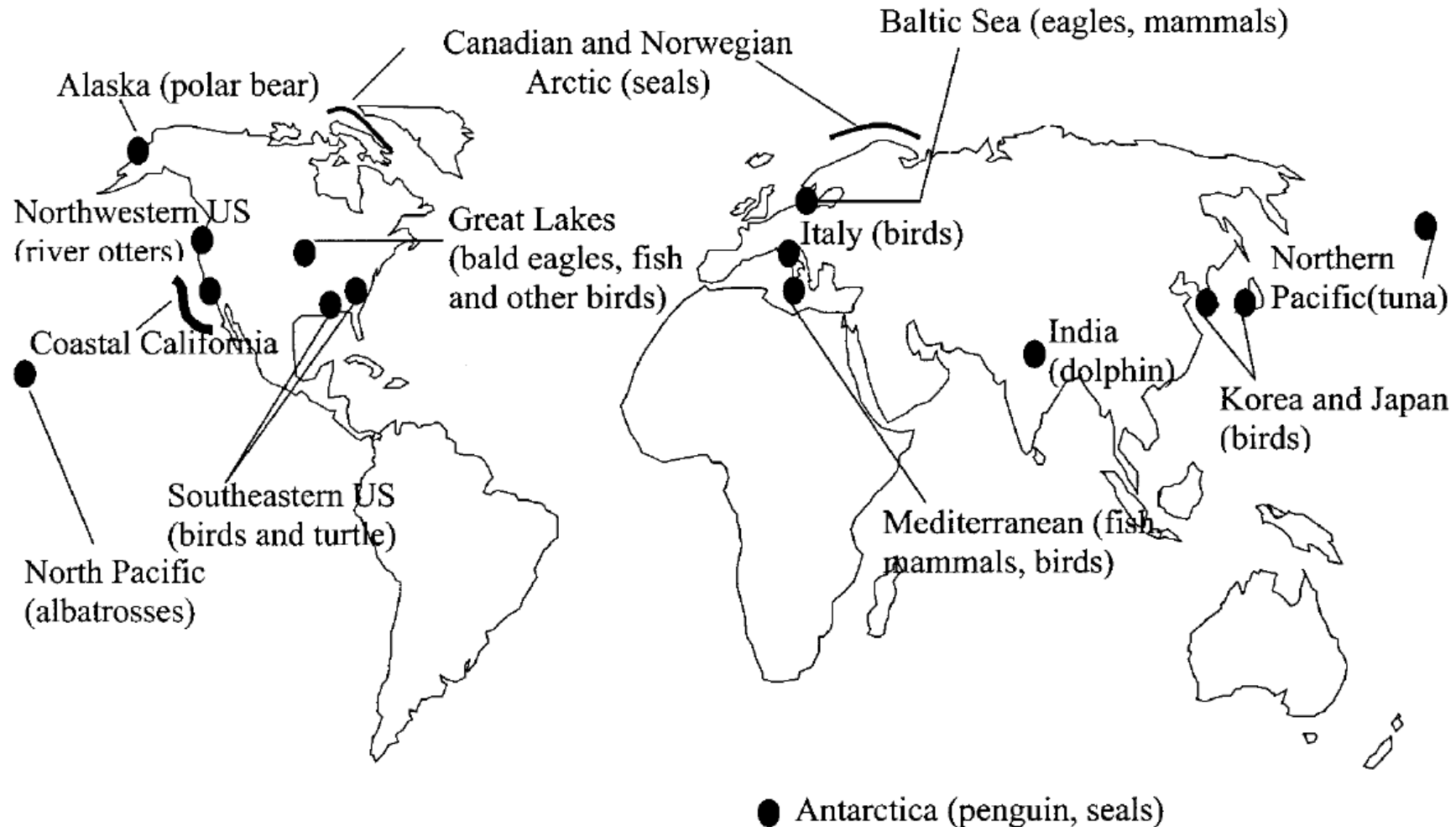
- Used in manufacturing (teflon, scotch guard, food packaging)
- Used in fire suppression (aqueous film forming foams, AFFF)
- First synthesized on industrial scales in the 1940s
- Class of over 4,000 compounds
 - Some are bioaccumulative
 - Some are toxic
 - Some are both
 - Most are poorly understood from a toxicological perspective

Aerial view – Lake Superior College
Emergency Response Training Center,
Duluth, MN



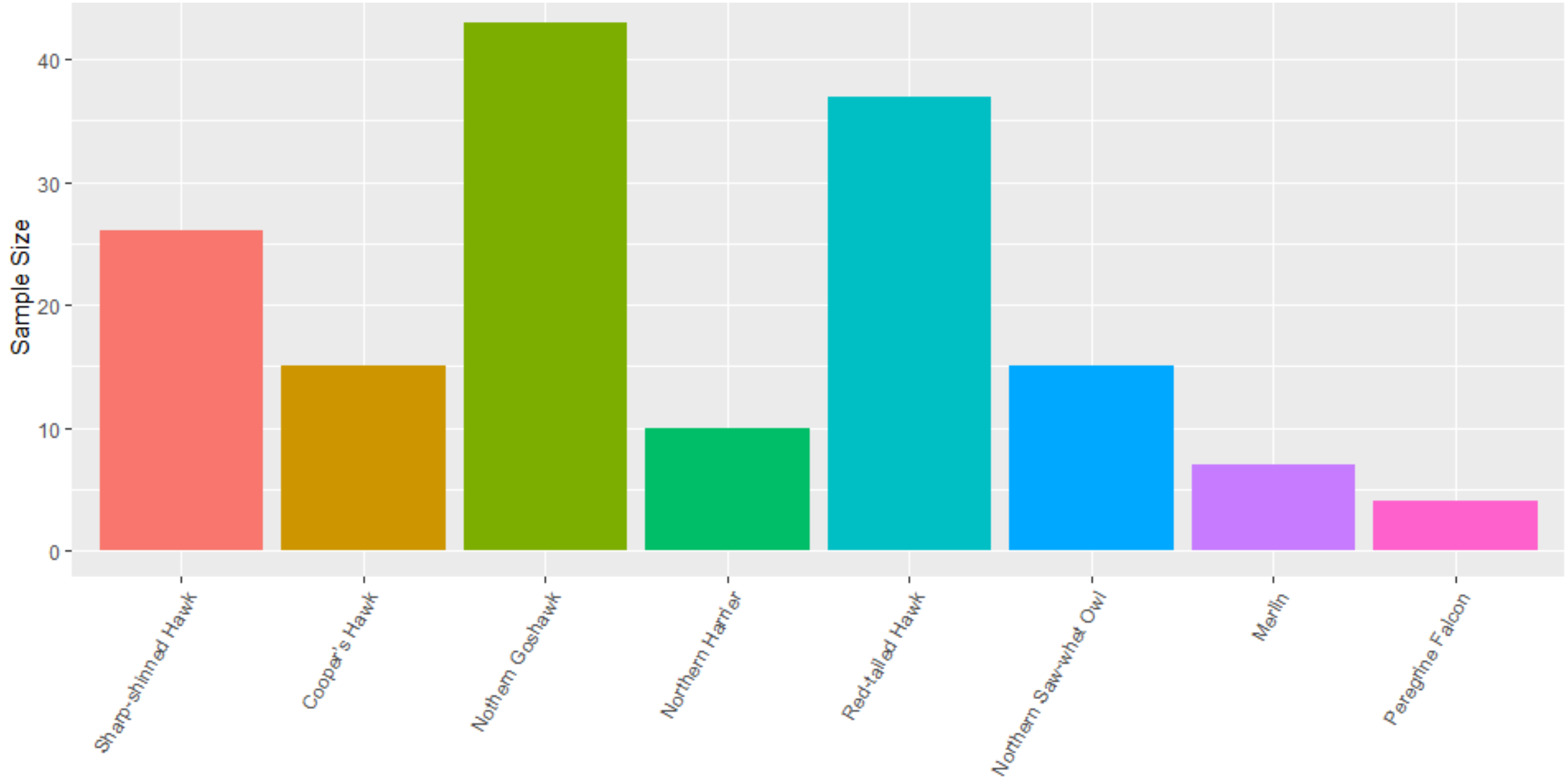
Regulatory Authority:
US EPA under the Toxic Substances Control Act

Emerging PFOS awareness and concern

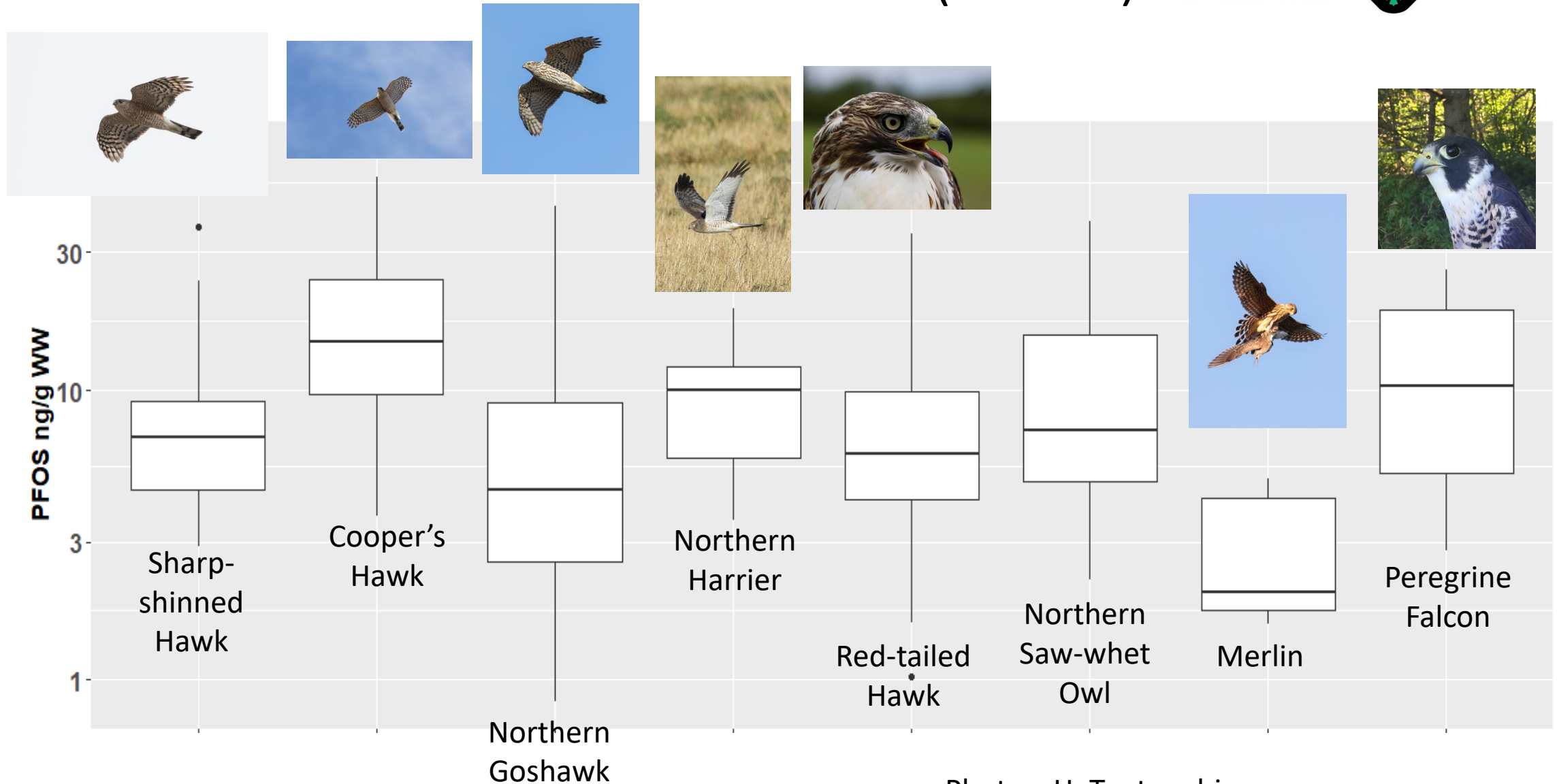


From: Giesy & Kannan 2001. Env. Sci. & Tech.

PFAS sampling at Hawk Ridge



Perfluorooctane Sulfonate (PFOS)

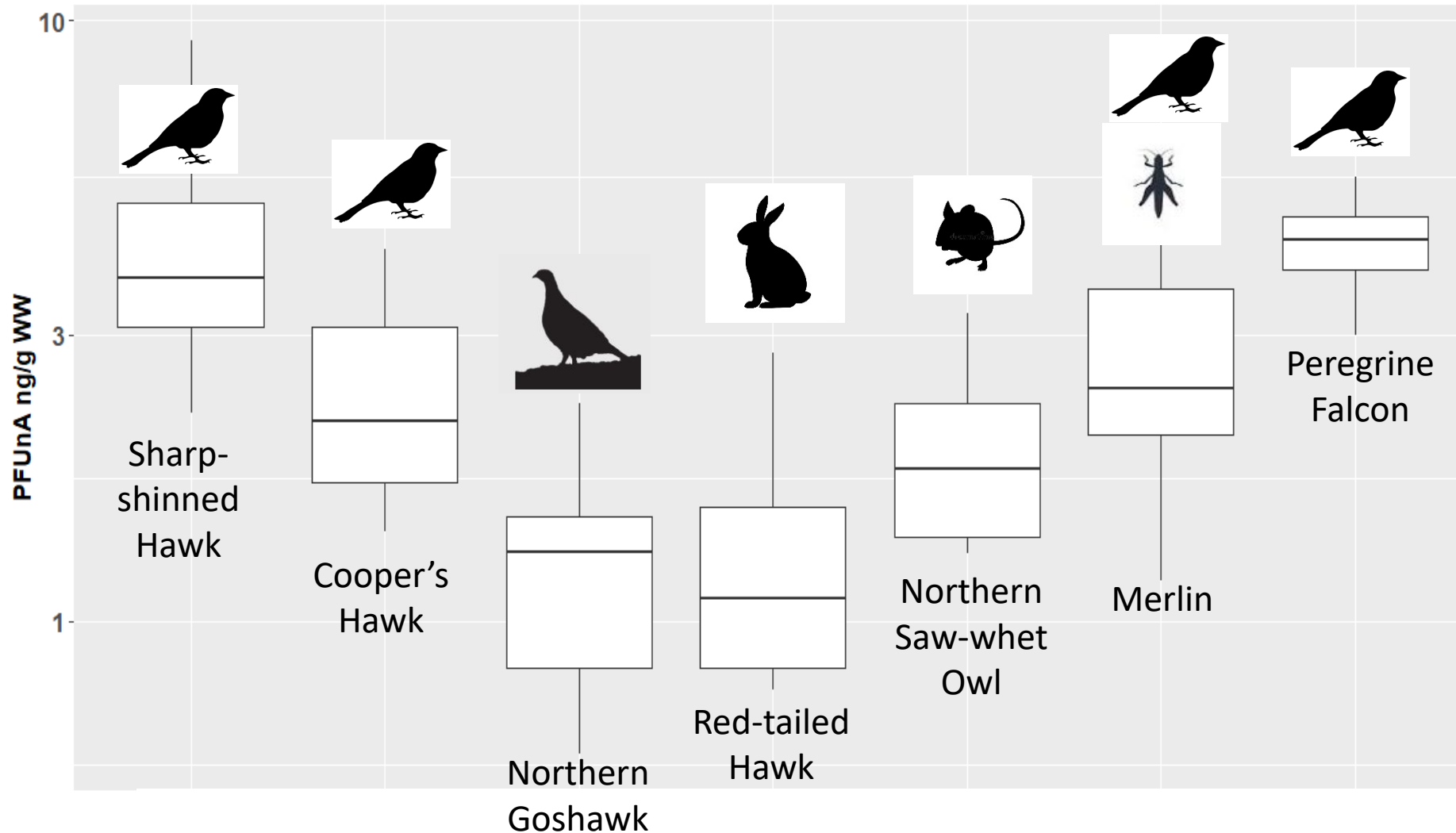


Photos: H. Toutonghi

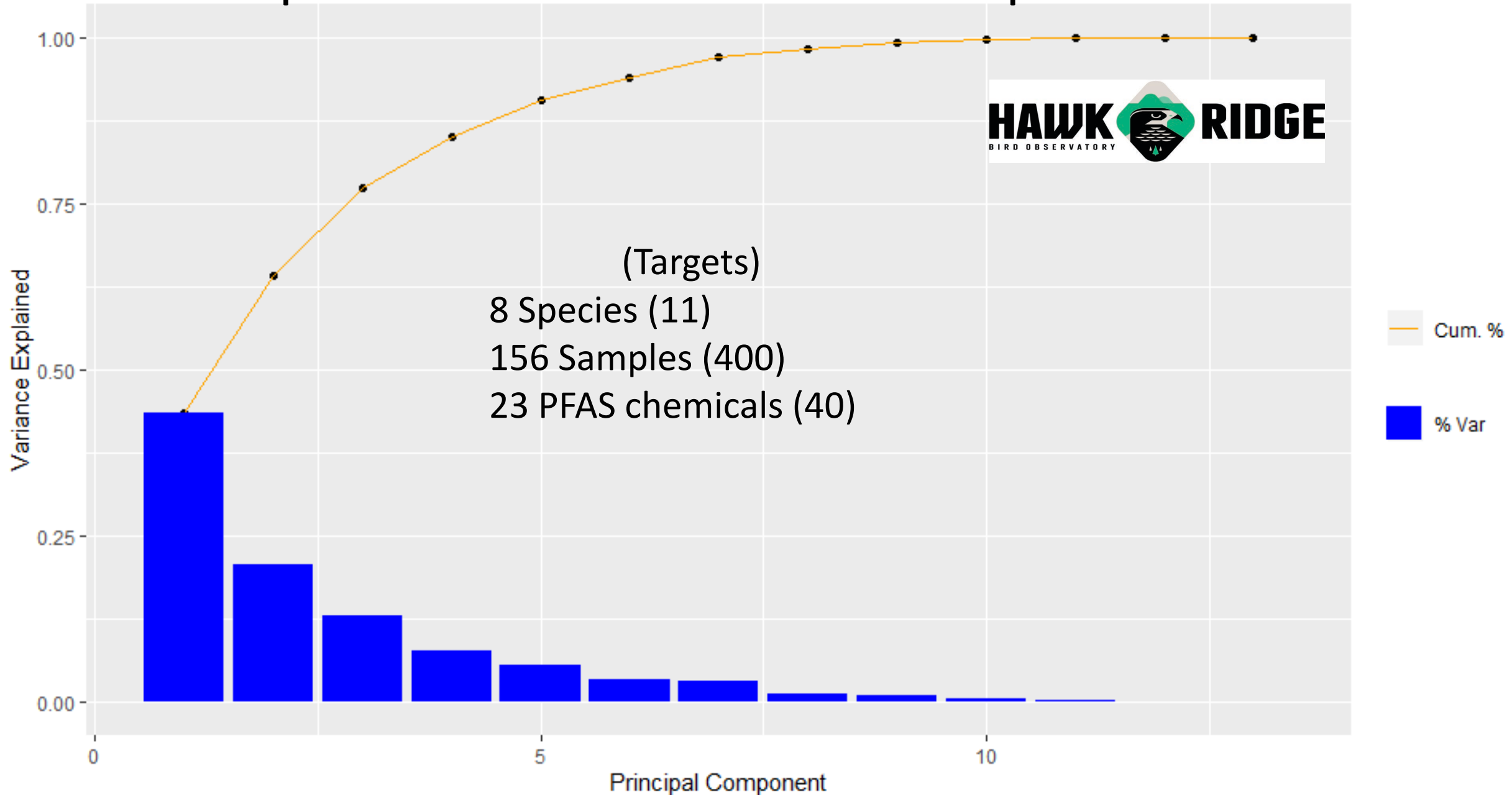
Perfluoroundecanoic Acid



PFUnA from serum samples collected at Hawk Ridge, Duluth, MN, Fall 2019



Are exposures to different PFAS independent?



How dangerous are these exposures?

We don't know

Stay tuned...

Some stories untold...

- PCBs/dioxins
- Lead
- Neonicotinoids
- Brominated chemicals
- Cadmium
- Anticoagulant Rodenticides

Epilogue

Why does this keep happening?

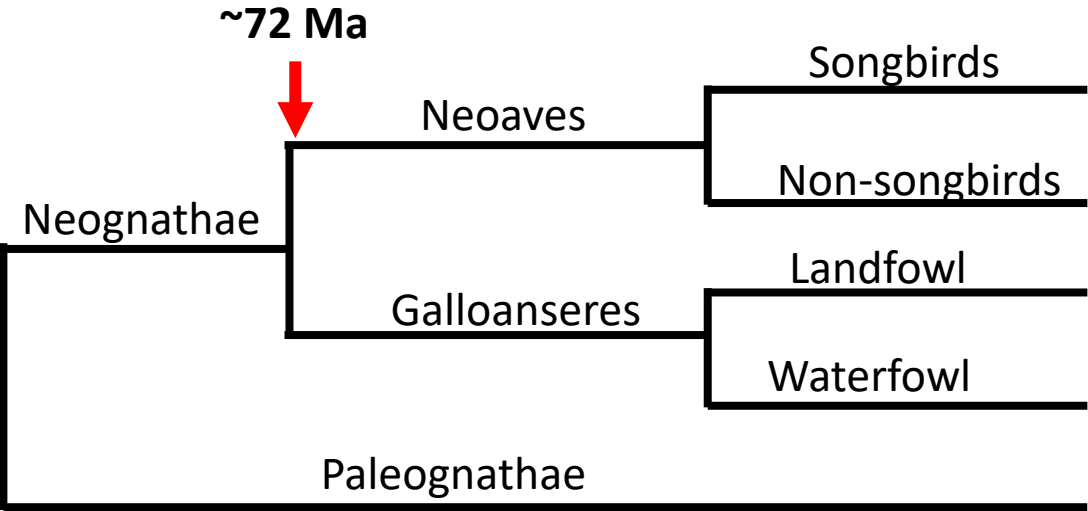
What can Hawk Ridge Bird Observatory do?

Why does this keep happening?

- Bad luck?
- Different regulatory frameworks?
- Variation in avian risk?
 - Life-history differences
 - Differential sensitivity
 - Variation in exposure
- Limited toxicity information?
- Scientific stove-piping?

Limited toxicity information

Avian phylogeny from: <https://www.worldbirdnames.org/>
Toxicity test results from: <https://cfpub.epa.gov/ecotox/>

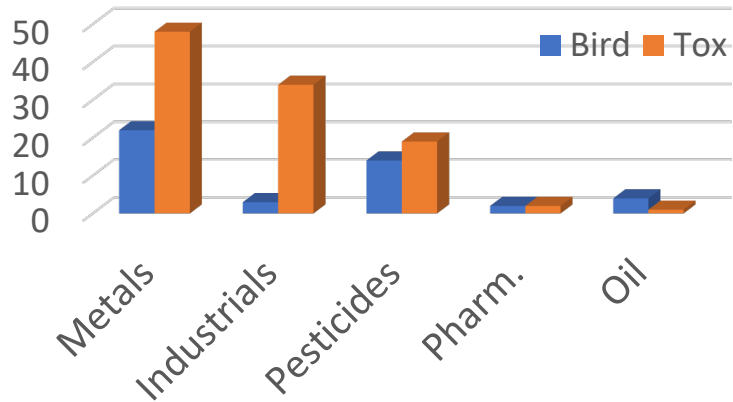


Avian Orders	Species	Ecotox Results
2% (1)	59% (6,456)	4% (1,695)
78% (32)	36% (3,952)	2% (627)
2% (1)	3% (300)	74% (26,980)
2% (1)	2% (177)	20% (7,222)
12% (5)	<1% (60)	0% (0)



Scientific stove-piping?

Number of Studies



8/14 (57%) pesticide studies published in 4 avian journals are of pesticides already banned in US

	Avian Journals Publishing Toxicology Papers				Toxicology Journals Publishing Avian Papers	
Class/Journal	Auk	Condor	Waterbirds	JRR	ET&C	Ecotoxicology
Metals	2	6	7	7	19	29
Pesticides	1	2	4	7	13	6
Oil	0	0	3	1	1	0
Industrials	0	0	3	0	26	8
Pharm	0	0	0	2	2	0
Total Papers	3	8	16	14	47	42
Journal Issues	41	41	46	41	40	43
Papers/issue	0.07	0.20	0.35	0.34	1.18	0.98
Interval	13.7	5.1	2.9	2.9	0.85	1.02

What can Hawk Ridge Bird Observatory do?



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Hawk Ridge – 2 data streams



Migration Counts



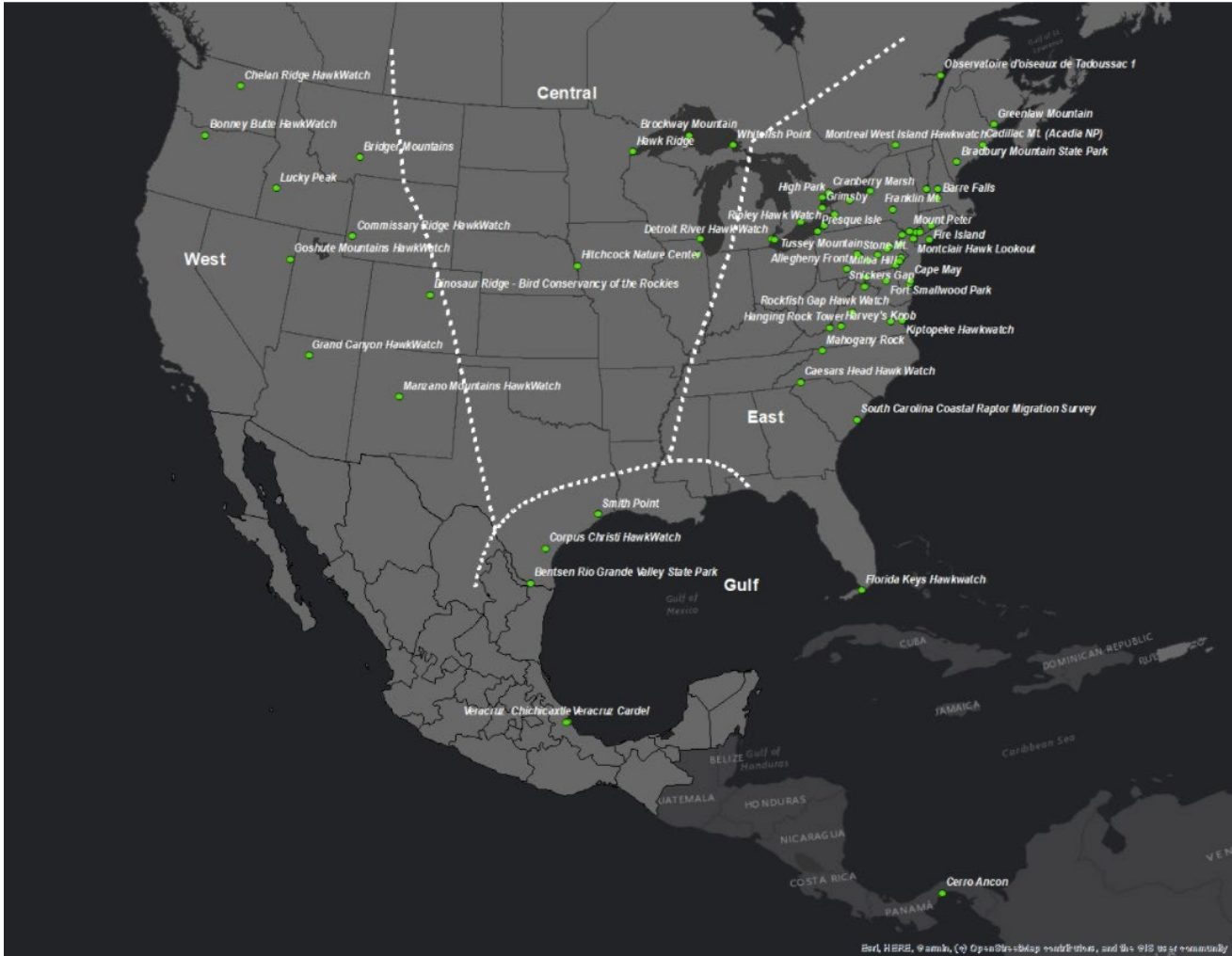
Trapping & Banding



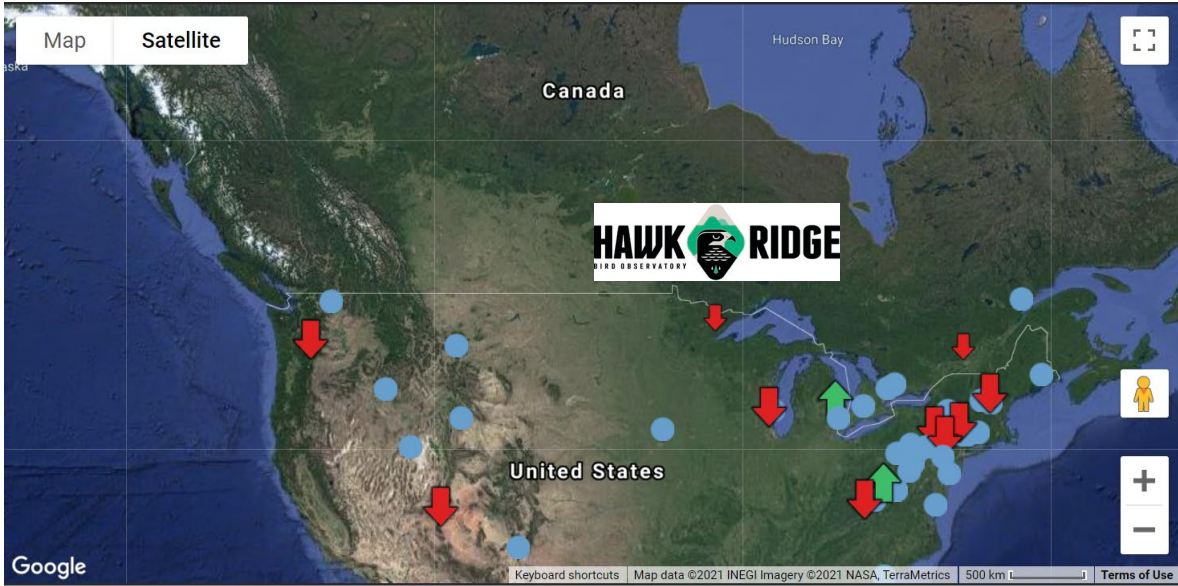
Raptor Population Index



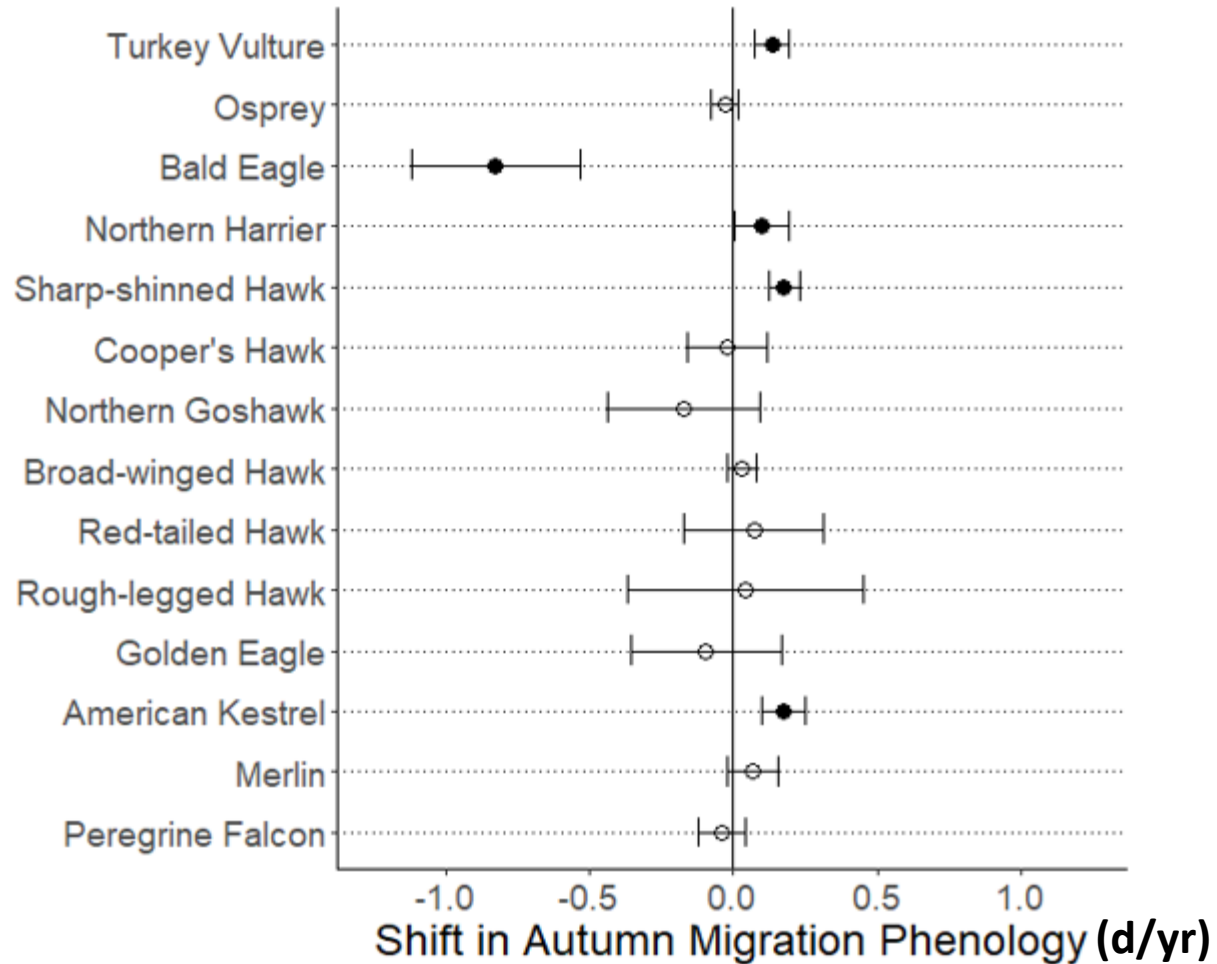
HOME	2019 RPI ANALYSIS	SPECIES ASSESSMENTS	PUBLICATIONS	RESOURCES	PARTICIPATING SITES	DATA COLLECTION	FAQ	HISTORY	RPI CONTACTS
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American Kestrel: photos H. Lambeau

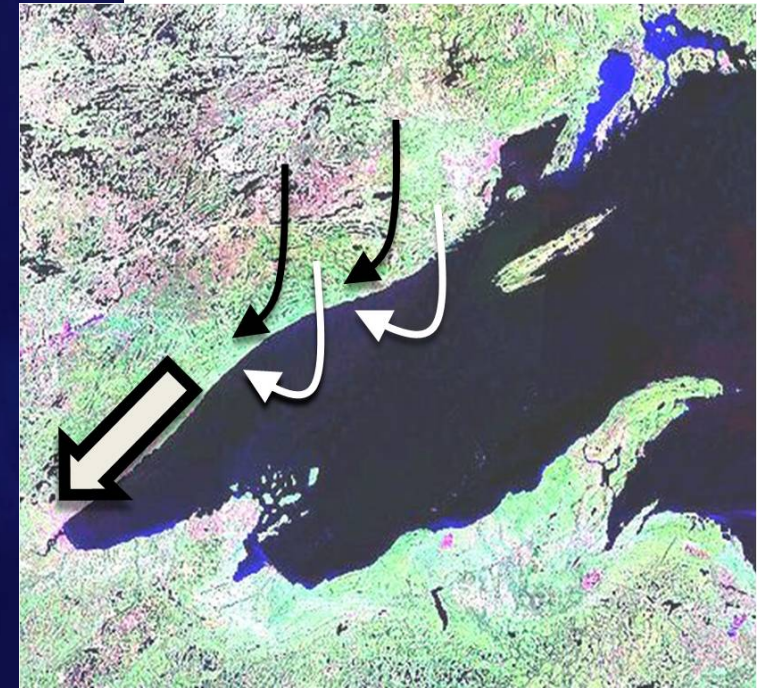


Migration phenology

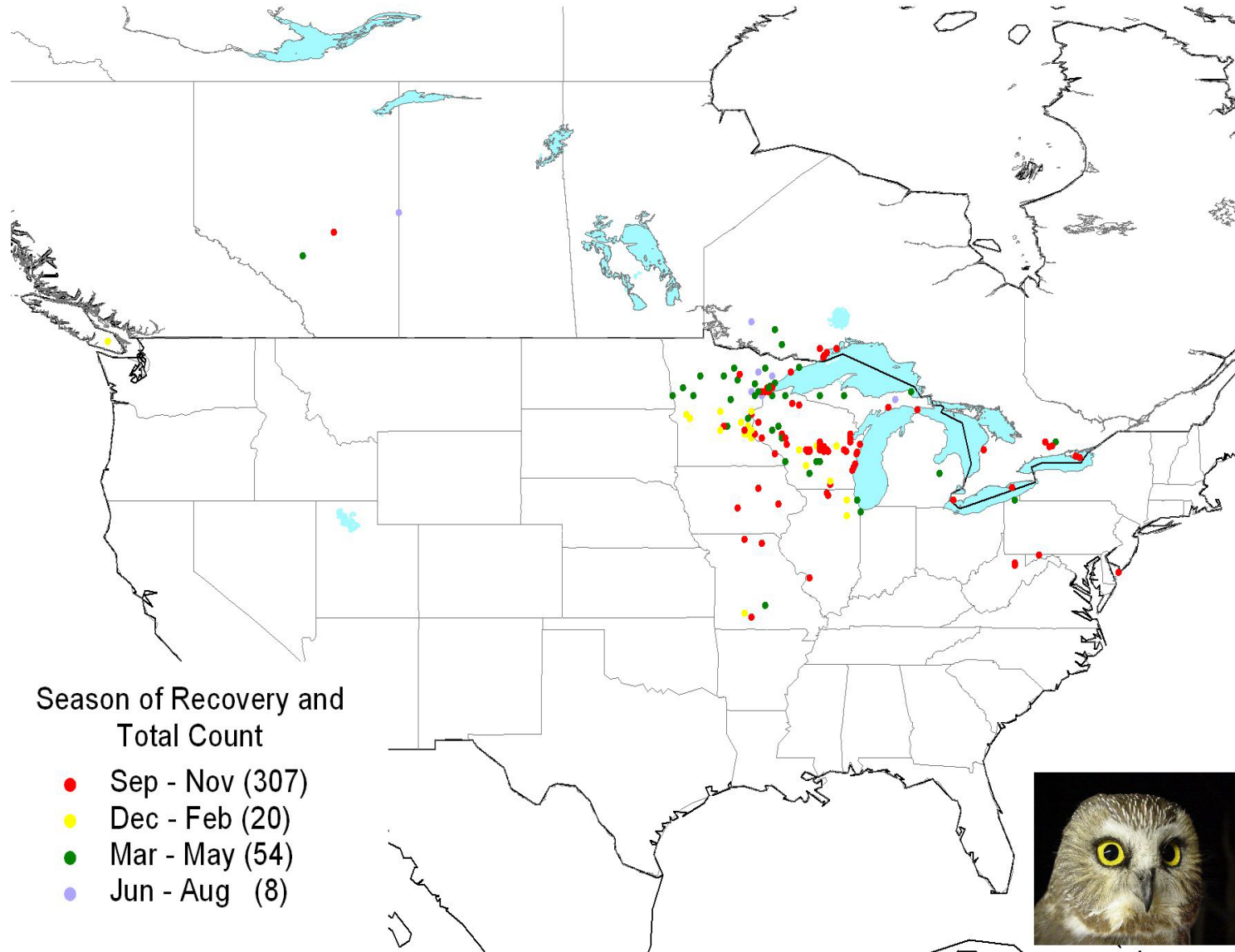


Steiner et al. In Press

Where are the birds coming from?



What can band returns tell us?



What about other technologies?

- Stable Isotopes?
 - E. Pavlovic - Determining natal origins and migratory patterns of raptors using stable isotope analysis ($\delta^2\text{H}$) (Sharp-shinned Hawk, Red-tailed Hawk, Northern Saw-whet Owl).
- Genetics?
 - A. Pesano - Determining Geographic and Phylogenetic Origins of Dark Morph Red-tailed Hawks in Eastern North America
- Telemetry?
 - H. Toutonghi - Using high-resolution telemetry to describe daily and seasonal activity and movements of Northern Hawk Owl (*Surnia ulula*) in winter

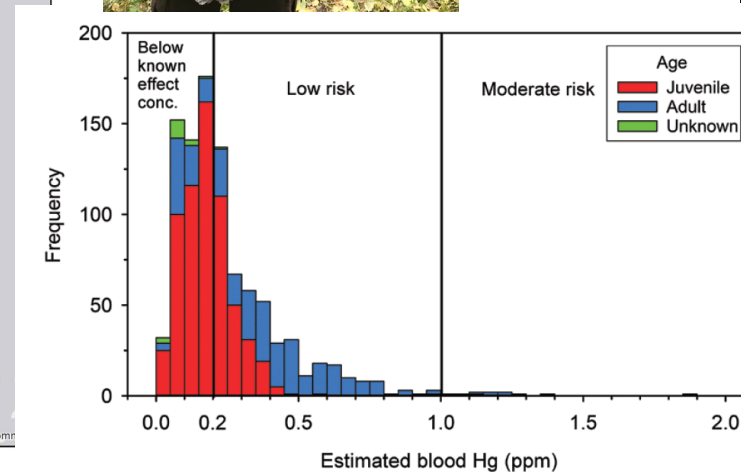
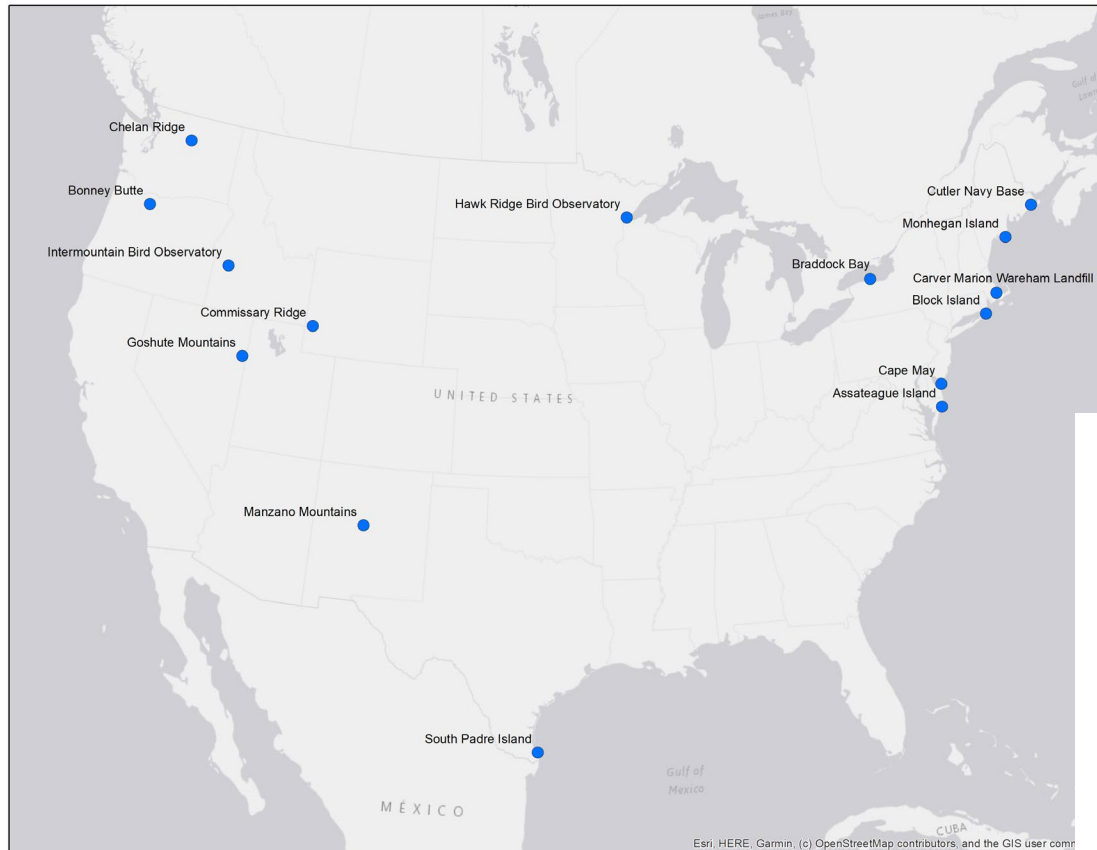


Tomorrow night, 185 LSci (7:30 pm):

“Flap-Flap-Glide into the Future: Ongoing Migration Research at Hawk Ridge”

The raptor flyway project

- Tens of thousands of samples
- 13 sites
- 10 species





Not just autumn any more

- Fall

- Migration monitoring
- Environmental contaminants (Hg & PFAS)
 - Songbirds (with BRI)
 - Hg-flyway (with BRI)
 - PFAS (with Raptor Ctr)
 - Hg + oxidative stress (with BRI)
- Migration phenology
- Diet metabarcoding (with EPA)
- Population genetics (with EPA)
- Microbiome (with Raptor Ctr)
- Stable isotopes
- Avian influenza & covid19 (with USDA)
- Population cycles

- Winter

- Ecology and habitat use of northern owls

- Spring

- Migration monitoring

- Summer

- American Kestrel productivity (with Friends of Sax Zim Bog)
- Songbird productivity



HRBO = People + Partners (+ Birds)

D. Alexander, K. Bardon, M. Durbin,
L. Brouellette, D. & M. Evans, J.
Green, T. Keyel, S. Kolbe, H.
Lambeau, J. Long, F. Nicoletti, G.
Niemi, E. Pavlovic, A. Pesano, R.
Steiner, M. Thiel, H. Toutonghi, A.
Valine

- Biodiversity Research Institute
- Friends of Sax Zim Bog
- The Raptor Center
- University of Minnesota Duluth
- US Environmental Protection Agency
- USDA

Funding & Acknowledgments

HRBO Members



*The views expressed in this presentation are those of the author
and do not necessarily reflect the views or policies of the U.S. EPA.*



Mercury Study

- 966 Individual Birds
- 11 Species
- Breast feathers

