Assessment of Contaminant Risks to Seabirds and Waterfowl - San Diego Bay Bioaccumulation Study, 2013-2014

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photo: Mark Pavelka/USFWS

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Partners

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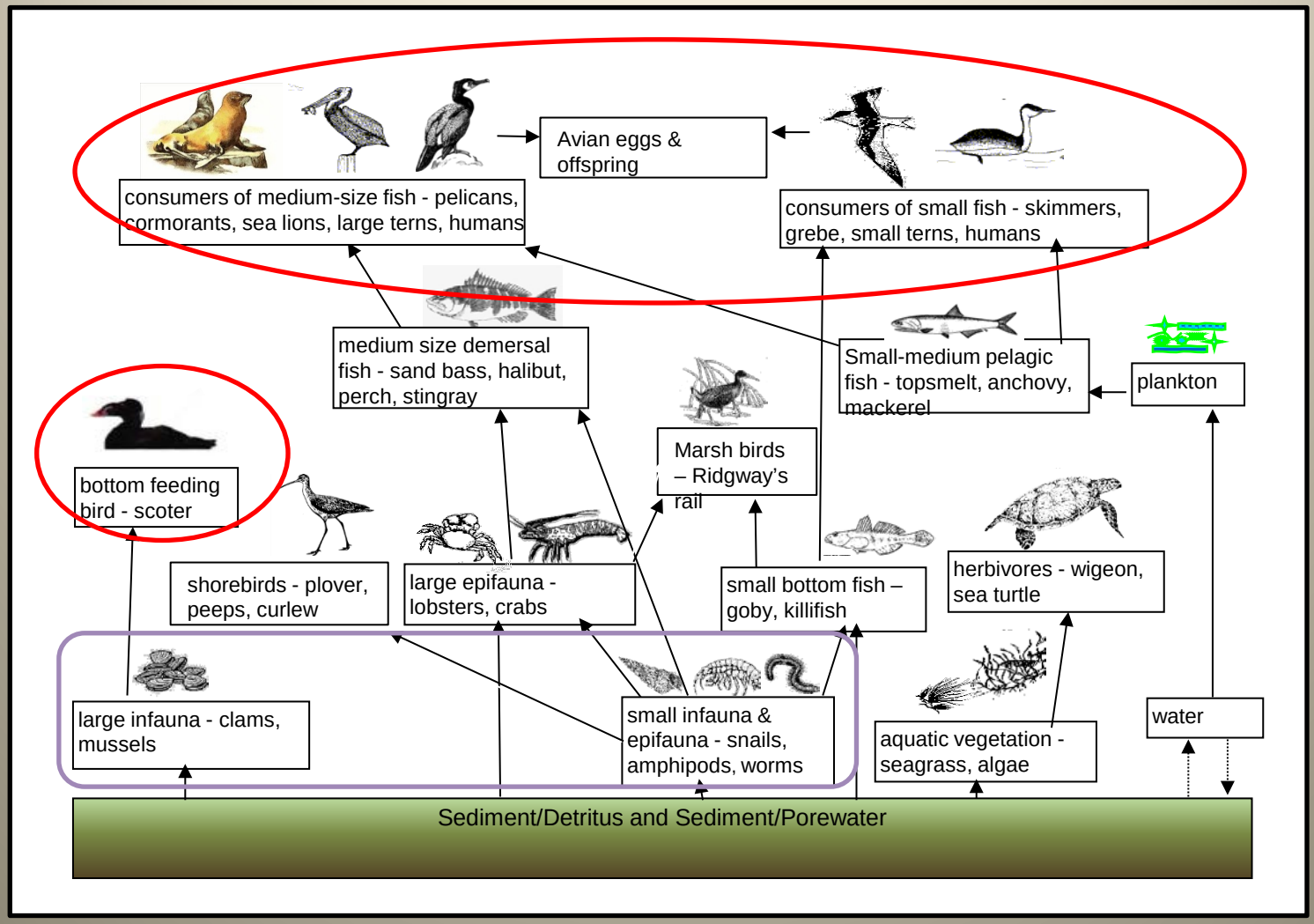
Worst Case Approach for Bioaccumulative Contaminants

Focus on top consumers of the aquatic food web

- Diet consists of aquatic food web organisms with the highest concentrations of contaminants (contaminant-specific)

  - Species that consume fish
    - contaminants that bioaccumulate and biomagnify (e.g., organochlorines)
  - Species that consume benthic invertebrates
    - contaminants that bioaccumulate but with little or no biomagnification, and may be present at high concentrations in environmental media (e.g., PAHs)
  - Species that consume aquatic vegetation
    - Some inorganics (not done here)

Focus on Avian Species as Key Receptors



For wildlife, impacts of exposure to contaminants from San Diego Bay are potentially most significant (or noticeable) for birds

Features of Avian Receptors in San Diego Bay Food Webs Reasons for Concern

- Exposure during critical phase of the life cycle
  - Breeding season or year-round residents
    - Impacts on adults
      - Behavior, survival, growth, reproductive output
    - Impacts on embryos and/or post-hatch offspring
      - Contaminants in parental diet transferred to eggs
      - Embryo death or deformities, poor hatchling survival, impaired reproductive behavior of offspring once mature

photo: USFWS/San Diego Bay NWR

  - Overwintering or migratory stopover
    - Adult body condition and survival
      - Predator avoidance at wintering grounds
      - Survival during migration
      - Reproductive output at breeding grounds

photo: Rinus Baak/USFWS

Features of Avian Receptors in San Diego Bay Food Webs

- Potential to impact significant numbers
  - Species of conservation concern
    - Few in number, or numbers recovering but with limitations
    - Managed to recover populations
    - California least tern
      - nesting pairs increased 8x since listing, but reproductive output (number eggs laid and number fledged per nest) appears to be sensitive to stressors and may be declining.
  - Bay used by large segment of regional populations
    - Continentally significant numbers
      - Breeding Caspian & other terns
      - Wintering surf scoter

Photo: Brian Collins/USFWS

Avian Risks Evaluated Two Ways

- Risks to seabird embryos and offspring from *in ovo* exposure to contaminants
  - Measure concentrations in eggs
  - Compare with literature-based screening levels (as concentrations in eggs).

- Risks to adult birds from diet composed of aquatic biota from San Diego Bay
  - Measure contaminant levels in forage species,
  - Estimate daily dietary dose (intake rate) for adult birds
  - Compare with literature-based screening levels

Representative Species

Representative sp.	Receptor category - feeding guild	Presence		Conservation Concern	Significant population
		Breeding season	Wintering		
California least tern	small piscivore shallow pelagic	✓		✓	
Caspian tern	large piscivore shallow-mid pelagic	✓			✓
Double-crested cormorant	large piscivore all depths & benthic	✓	✓		
Western gull	large generalist shallow pelagic & terrestrial	✓	✓		
Surf scoter	consumer of benthic invertebrates		✓		✓

photo: Peter Pearsall/USFWS

photo: Eric Davis/USFWS

Samples

- Samples Collected

San Diego Bay seabird egg samples collected in 2013 for chemical analyses (each least tern sample is a composite of two or more eggs)

Species	Location	N
California least tern	Lindbergh Field	5
	D-Street fill	6
	Chula Vista Wildlife Reserve	4
	S. Bay Salt Works	3
Double-crested cormorant	S. Bay Salt Works	8
Caspian tern	S. Bay Salt Works	10
Western gull	Naval Air Station/North Island	8

Forage fish and benthic invertebrate samples collected from San Diego Bay in 2013-2014 (whole body samples only)*

Forage fish species	N	Forage fish species	N
Arrow goby	2	Shiner perch	6
Barred sand bass	12	Slough anchovy	12
Black perch	2	Spotted sand bass	12
California halibut	22	Topsmelt	6
California killifish	2		
Deepbody anchovy	18	**Invertebrates**	**N**
Goby sp.	3	Crustacea	16
Northern anchovy	2	Mollusks	11
		Polychaetes	21

* One fish sample not included due to size (all individuals in the composite >20 cm)

- Biota Sample Locations

Sample and Data Processing

- Sample features measured & recorded
  - Aquatic biota (size & species), Eggs (length, breadth, weight, volume, shell thickness)
- Chemical analyses
  - PCBs (41 congeners), Chlordane (4 constituents & metabolite), DDT and metabolites, PBDEs (15 congeners), PFCs (6 compounds), PAHs (12 LPAH, 12 HPAH), Mercury
- Contaminants that occur as mixtures - evaluated as mixtures
- All results = parts per billion (ng/g) wet weight (aquatic biota) or fresh weight (eggs)

Exposure Point Concentrations (EPCs)
(concentrations in avian diets)

- Concentrations in eggs as reported
- Concentrations in diet were estimated
  - Diet composition is species-specific and varies with location and year
  - General diet preferences used to select aquatic biota samples for average and maximum dietary EPCs

Species	General Features	Common constituents	Assumed for San Diego Bay 2013/2014*
California least tern	YOY fish <6 cm long, shallow water (<1 m water)	anchovy and silversides, but also surfperch, sculpin, herring, rockfish & others	topsmelt, slough anchovy, northern anchovy, shiner perch, black perch, killifish and gobies
Caspian tern	1+Yr fish, 5 to 25 cm long, surface-mid depth (< 5 meters water)	silversides, surfperches, anchovy but also sculpin, gobies, flatfish and others	topsmelt, slough anchovy, deepbody anchovy, northern anchovy, shiner perch, black perch, barred sandbass and spotted sandbass
Double-crested cormorant	slow moving, schooling inshore fish 5 - 15 cm long, surface to bottom	silversides, midshipmen, perch, anchovy, croaker, and others	topsmelt, slough anchovy, northern anchovy, deepbody anchovy, black perch, shiner perch, spotted sandbass, barred sandbass, and California halibut
Western gull	small fish and marine invertebrates in <2 m water, and non-aquatic species	Squid, euphausiids, small surface fish, young of other birds and human refuse	topsmelt, northern anchovy, slough anchovy and deepbody anchovy
Surf scoter	Benthic invertebrates in <11 m water	primarily mollusks	Clams, mussels, polychaetes, and crustaceans

* selections based on what was collected in 2013 and 2014

Exposure Estimates

- Seabird Eggs = measured concentrations
  - $ng_{contaminant}$ /g_{egg} fresh weight (fw)
    - Mean – assumes diet is a mix of aquatic biota
    - Max – assumes diet is all one species (with highest concentrations)
- Adult bird exposure = daily dietary dose rate
  - $ng_{contaminant}$ /$g_{Body\ Weight}$ - day
  - Based on species-specific food ingestion rate
  - Incorporates some basic assumptions
    - Diet composition
    - Fraction of daily food intake from the site (San Diego Bay)
    - Percentage of ingested contaminant that is absorbed
    - Seasonal use

Literature-Based Screening Values

- Screening levels for eggs as concentrations
  - No Observed Adverse Effect Concentration (NOAEC)
  - Lowest Observed Adverse Effect Concentrations (LOAECs)
- Dose rates for dietary exposure
  - No Observed Adverse Effect Level (NOAEL)
  - Lowest Observed Adverse Effect Levels (LOAELs)
- Conservative approach used to identify reference values that are both credible and protective
- Focus = effects related to population-level impacts
  - Survival, growth, reproduction and behavior

Literature-Based Screening Values - Interpretation

<NOAEC/NOAEL = Below levels of concern

>NOAEC/NOAEL = Of concern, further consideration indicated

>LOAEC/LOAEL = Increased potential for measurable adverse effects in the field

Photo: John C. Mitchell

Multiple LOAECs/LOAELs considered for perspective

Sensitive Adverse Effects – Concentrations In Eggs NOAECs and LOAECs

Sensitive effects associated with contaminant levels in eggs

Analyte	Effects
Mercury	Reduced hatchability, embryo mortality, parental behavior
DDT	Reduced productivity, eggshell thinning
PCBs - total	Reduced hatching/fledging success and productivity
PCB - TEQ	Embryo lethality, edema
PBDEs	Reduced egg hatchability, reduced fertility of male offspring
PFCs (PFOS)	Reduced hatchability and survival of offspring

Analyte	Screening value	ng/g fw	notes
Mercury	NOAEC(s) - estimated	300	
	LOAEC(s) - most sensitive	800	egret
	- least sensitive	3,700	includes common tern
DDT - productivity	NOAEC(s) - estimated	1,000	
	LOAEC(s) - most sensitive	3,000	pelican
	- less sensitive	5,000	includes cormorant & tern
DDT - shell thinning	NOAEC(s) - estimated	200	
	LOAEC(s) - most sensitive	600	pelicans
	- less sensitive	10,000	incl. cormorants
PCBs - total	NOAEC(s) - estimated	100	most sensitive (chickens)
	- estimated	2,300	all but most sensitive spp.
	LOAEC(s) - most sensitive	1,000	chickens
	- less sensitive	6,000	perching birds (songbirds)
	- least sensitive	23,000	terns, gulls, raptors
PCBs - TEQ	NOAEC(s) - estimated	0.018	most sensitive (chickens)
	- estimated	0.400	waterbirds
	LOAEC(s) - most sensitive	0.180	chickens
	- less sensitive	1.00	pigeon, pheasant, quail
	LOAEC(s) - less sensitive	4.00	cormorant, heron, wood duck
PBDEs	NOAEC(s) - bounded	180	sensitive species
	LOAEC(s) - sensitive	288	kestrel (incl. common tern)
PFCs (PFOS)	NOAEC(s) - estimated	1,000	sensitive (of two species)
	LOAEC(s) - sensitive	62,000	sensitive (of two species)

Sensitive Adverse Effects – Dietary NOAELs and LOAELs

Sensitive adverse effects associated with dietary exposure to contaminants

Analyte	Effects
Mercury	Impaired parental behavior, fertility, egg production, hatchability & chick survival
DDT	Reduced productivity, survival, growth
PCBs - total	Reduced fertility, egg production and hatchability
PCB - TEQ	Reduced egg production and hatchability
PBDEs	Impaired reproductive behavior, egg quality and productivity
Chlordane	Reduced survival
LPAH	Reduced weight and food consumption
HPAH	Reduced fertility

Analyte	Screening value	ng/g_{BW}-day	notes
Mercury	NOAEL(s) - estimated	7.0	sensitive species (non-seabirds)
	- estimated	21.0	less sensitive (seabirds)
	LOAEL(s) - most sensitive	10	white ibis
	- mid-range	180	all species (based on mallard)
DDT	NOAEL(s) - estimated	9.0	most sensitive, pelican
	- bounded	227	less sensitive species
	LOAEL(s) - most sensitive	27	pelican
	- mid-range	1,500	all species
PCBs - total	NOAEL(s) - estimated	90	most sensitive
	LOAEL(s) - mid range	1,270	all species (primarily waterbirds)
PCBs - TEQ	NOAEL(s) - estimated	0.0011	most sensitive (chickens)
	LOAEL(s) - less sensitive	0.0495	all but most sensitive species
	- mid-range	0.178	all species
PBDEs	NOAEL(s) - estimated	9.6	sensitive species (kestrel)
	LOAEL(s) - sensitive	96	
Chlordane	NOAEL(s) - estimated	160	sensitive species
	LOAEL(s) - sensitive	7,000	
LPAH	NOAEL(s) - estimated	295	uncertain of relative sensitivity
	LOAEL(s) -	4,730	uncertain of relative sensitivity
HPAH	NOAEL(s) - estimated	14.3	uncertain of relative sensitivity
	LOAEL(s) -	1,430	uncertain of relative sensitivity

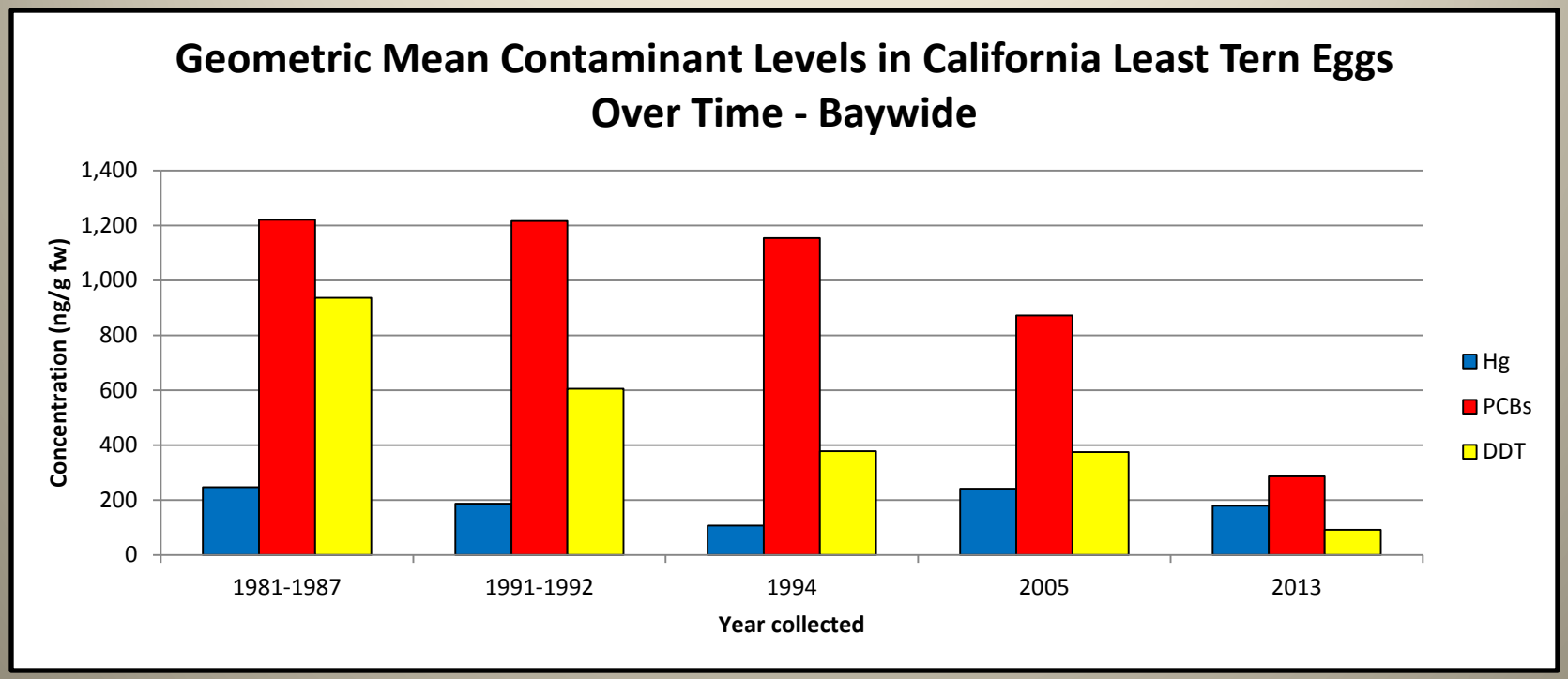
Results – Eggs
General

Contaminant levels as ng/g fw (Mean and SD) seabird eggs from San Diego Bay, 2013

Species	California least tern		Caspian tern		Double-crested cormorant		Western gull	
Number of samples →	18*		10		8		8	
total PCBs	150	(164)	636	(315)	927	(837)	599	(273)
DDTs	100	(43)	1,478	(866)	1,276	(1,096)	426	(270)
Chlordanes	5.7	(3.6)	9.5	(6.6)	1.4	(1.4)	1.7	(1.5)
PBDEs	48	(21)	244	(110)	89	(99)	176	(96)
PFC (PFOS)	27	(19)	29	(18)	not done		not done	
Mercury	184	(46)	451	(204)	71	(56)	61	(37)

* data missing for mercury in one least tern egg sample

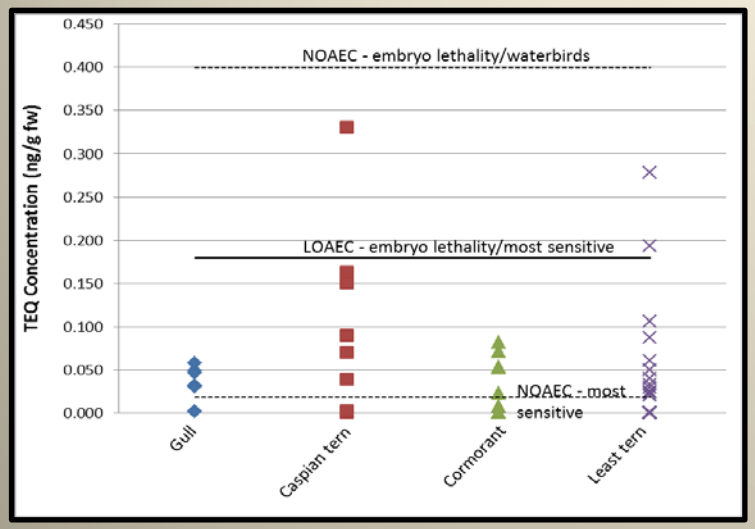
Results – Eggs
Monitoring Perspective



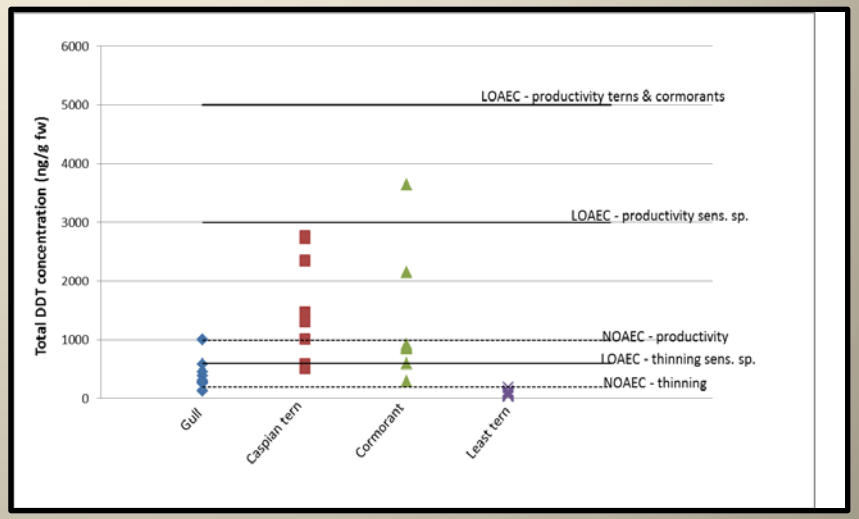
1981-1987: from Ohlendorf et al. 1985; Hothem & Zador 1995 (North & Central colonies)
1991-1992: from USFWS 1995; Roberts 1997 (North, Central & one sample from South colonies)
1994: from Hothem & Powell 2000 (North & Central colonies)
2005: from Zeeman et al. (2005) (South colony)
2013; from Bight '13 (North, Central & South colonies)

Concentrations in Eggs vs Screening Levels

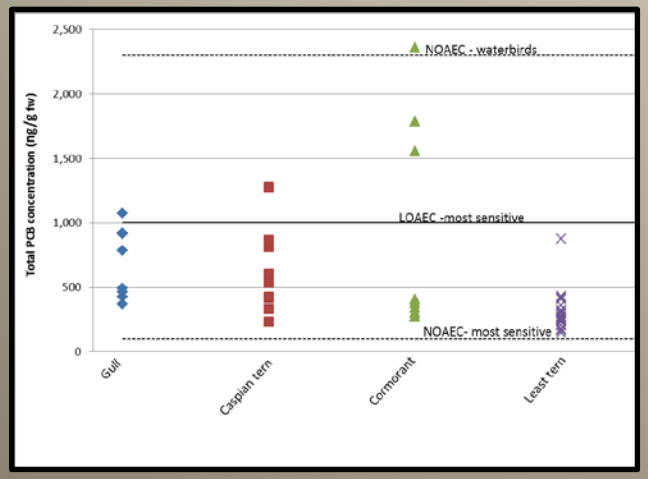
PCBs - total



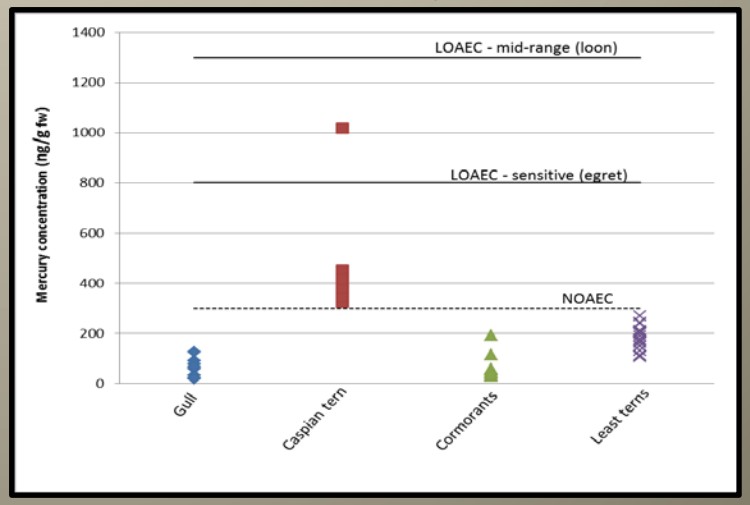
DDT



PCB-TEQs



Mercury



Egg Results Summary

- >NOAEC = Of concern (further consideration indicated)
- > LOAEC = Adverse effects may be observed

	Mercury		DDT - Thinning		DDT - Productivity		PFOS
Species	NOAEC	LOAEC (sensitive sp)	NOAEC	LOAEC (sensitive sp.)	NOAEC	LOAEC (sensitive sp.)	NOAEC
Least tern	No	No	No	No	No	No	No
Caspian tern	Yes	Yes (1 of 10)	Yes	Yes (7 of 10)	Yes	No	No
Cormorant	No	No	Yes	Yes (7 of 8)	Yes	Yes (1 of 8)	No
Gull	No	No	Yes	Yes (1 of 8)	No	No	No

	Total PCBs		PCBs -TEQ		PBDEs		Chlordanes
	NOAEC (sensitive)	LOAEC (most sens./waterbirds)	NOAEC (sensitive)	LOAEC (most sens./waterbirds)	NOAEC	LOAEC	Not done
Least tern	Yes	No/No	Yes	Yes (2 of 8)/No	No	No	
Caspian tern	Yes	Yes (1 of 10)/No	Yes	Yes (1 of 10)/No	Yes	Yes (3 of 10)	
Cormorant	Yes	Yes (3 of 8)/No	Yes	No/No	Yes	No	
Gull	Yes	Yes (1 of 8)/No	Yes	No/No	Yes	No	

Dietary Exposure - Initial Screen

Maximum concentrations in aquatic biota samples vs NOAEL-based screening concentrations for seabird diets

Example

DDTs		Concentrations (ng/g ww)		Surf scoter	least tern	Caspian tern	cormorant	Western gull
Sample type	N	Mean	Max	(29)	(11)	(21)	(30)	(57)
Arrow goby	1	0.050	0.050	-	-	-	-	-
Goby sp.	3	10.6	10.9	-	-	-	-	-
Barred sand bass	9	16.1	40.3	+	++	+	+	-
Spotted sand bass	11	10.8	16.0	-	+	-	-	-
Deepbody anchovy	11	20.8	46.4	+	++	++	+	-
Northern anchovy	2	8.9	9.6	-	-	-	-	-
Slough anchovy	10	12.2	30.9	+	++	+	+	-
Black perch	2	13.3	20.1	-	++	-	-	-
Shiner perch	6	14.5	22.1	-	++	+	-	-
California halibut	20	11.7	37.7	+	++	+	+	-
California killifish	2	6.5	11.2	-	-	-	-	-
Topsmelt	9	6.8	11.7	-	+	-	-	-
Round stingray	1	0.6	0.55	-	-	-	-	-
Brown shrimp	2	2.4	3.2	-	-	-	-	-
Crabs	1	5.1	5.1	-	-	-	-	-
Crustacea	13	6.1	21.5	-	+	+	-	-
Mollusks	11	6.1	33.1	+	+	+	+	-
Polychaetes	18	7.1	21.5	-	+	+	-	-

- no exceedances, + screening level exceeded by maximum, ++ screening level exceeded by maximum and mean

Summary

Analyte	Surf scoter	least tern	Caspian tern	cormorant	Western gull
Mercury	✓	✓	✓	✓	✓
DDTs	✓	✓	✓	✓	-
PCBs	✓	✓	✓	✓	-
PCB TEQs	✓	✓	✓	✓	✓
PBDEs	✓	✓	✓	✓	✓
Chlordane	-	-	-	-	-
HPAHs	✓	✓**	✓**	✓**	✓**
LPAHs	-	-	-	-	-

- no exceedances, ✓ = exceedance by max,
**** Exceedances by benthic invertebrates only**

Risks from Dietary Exposure by Avian Receptors
A Closer Look

- More site-specific than initial screen
  - Daily exposure (dose) rates consider local diet composition and use of San Diego Bay for foraging

- Hazard Quotient (HQ) approach
  - HQ = estimated daily dose/reference dose (NOAEL or LOAEL)
  - Helps visualize the extent of a NOAEL or LOAEL exceedance
  - HQs for multiple contaminants with similar modes of action can be summed

Exposure Point Concentrations and Hazard Quotients for Dietary Exposure by Avian Receptors - Examples

- Mercury

species	Analyte	EPC - Mean	EPC - Max		HQ - NOAEL (sensitive)	HQ - LOAEL (sensitive)
California least tern	Hg	29	62	HQ - mean	3.4	2.4
				HQ - max	7.2	5.1
Caspian tern	Hg	51	154	HQ - mean	1.6	1.1
				HQ - max	4.8	3.3
Double-crested cormorant	Hg	52	239	HQ - mean	2.2	1.5
				HQ - max	10	7.1
Surf scoter	Hg	63	429	HQ - mean	3.1	2.2
				HQ - max	21	15
Western gull	Hg	37	109	HQ - mean	2.0	1.4
				HQ - max	5.6	4.0

- HPAHs

species	Analyte	EPC - Ave	EPC - Max		HQ - NOAEL (sensitive)	HQ - LOAEL (sensitive)
California least tern	HPAH	5.96	14.3	HQ - mean	0.34	0.003
				HQ - max	0.82	0.008
Caspian tern	HPAH	4.33	14.3	HQ - mean	0.07	0.001
				HQ - max	0.22	0.002
Double-crested cormorant	HPAH	2.77	14.3	HQ - mean	0.06	0.001
				HQ - max	0.30	0.003
Surf scoter	HPAH	346	12,430	HQ - mean	7.74	0.077
				HQ - max	273	2.73
Western gull	HPAH	11.0		one sample	0.29	0.003

Average Case Hazard Quotients for Dietary Exposure by Avian Receptors – Baywide Summarized

(using mean exposure point concentrations)

Receptor	Analyte	HQ - NOAEL (sensitive)	HQ - LOAEL (sensitive)
Least tern	mercury	3.4	2.4
Caspian tern	mercury	1.6	1.1
Cormorant	mercury	2.2	1.5
Scoter	mercury	3.1	2.2
Gull	mercury	2.0	1.4

Receptor	Analyte	HQ - NOAEL	HQ - LOAEL
Least tern	HPAHs	0.34	0.003
Caspian tern	HPAHs	0.07	0.001
Cormorant	HPAHS	0.06	0.001
Scoter	HPAHs	7.74	0.077
Gull	HPAHs	0.29	0.003

Receptor	Analyte	HQ - NOAEL (lowest)	HQ - LOAEL (mid-range)
Least tern	Total PCBs	1.73	0.12
Caspian tern	Total PCBs	0.54	0.04
Cormorant	Total PCBs	0.71	0.05
Scoter	Total PCBs	0.31	0.02
Gull	Total PCBs	0.92	0.07

Receptor	Analyte	HQ - NOAEL
Least tern	PBDEs	0.45
Caspian tern	PBDEs	0.074
Cormorant	PBDEs	0.090
Scoter	PBDEs	0.208
Gull	PBDEs	0.115

Receptor	Analyte	HQ - NOAEL (sensitive)	HQ - LOAEL (sensitive)
Least tern	PCB-TEQ	11	0.24
Caspian tern	PCB-TEQ	6	0.12
Cormorant	PCB-TEQ	9	0.19
Scoter	PCB-TEQ	2	0.04
Gull	PCB-TEQ	11	0.24

Conclusions
(at reported concentrations in eggs and aquatic biota)

- Mercury
  - In eggs – exceed levels of concern, but likelihood of detecting measurable effects in the field may be low
  - In aquatic biota – exceed levels of concern for small piscivores and species that consume benthic invertebrates. Likelihood of detecting effects in gulls and terns is low, but may be greater for more sensitive species (e.g. egrets)

Photo: Lisa Cox/USFWS

- DDT
  - In eggs – exceed levels of concern for sensitive species but likelihood of detecting measurable effects in the field may be low.
  - In aquatic biota – as evaluated, below levels of concern for impacts on adult birds

Conclusions
(at reported concentrations in eggs and aquatic biota)

- PCBs (total & TEQs)
  - In eggs and in aquatic biota – at levels of concern for very sensitive species (not necessarily waterbirds). Likelihood of detecting measurable effects in the field is low.
  - Potential for interaction with dioxins/furans and PBDEs
- PBDEs
  - In eggs – at levels of concern, but likelihood of detecting measurable effects in the field may be low.
  - In aquatic biota – as evaluated, below levels of concern for impacts on adult birds
- PFCs (PFOS)
  - In eggs and aquatic biota – appear to be below levels of concern

Conclusions
(at reported concentrations in eggs and aquatic biota)

- Chlordane
  - In eggs – concentrations appear to be low, risk undetermined
  - In aquatic biota - as evaluated, appears to be below levels of concern for impacts on adult birds
- PAHs
  - LPAH concentrations in aquatic biota appear to be below levels of concern for impacts on adult birds
  - HPAHs in aquatic biota are of concern for avian species that forage on benthic invertebrates. Likelihood of detecting measurable effects in the field is uncertain but may be low.
    - Primarily for species present during the breeding season

Uncertainties

- Inherent in study design, data analysis, and assessment protocols
- Each may result in over- or underestimate of risk
- Uncertainty evaluation provided in the report text
  - Not enumerated here, but some highlighted with the presentation
- Awareness of uncertainties helps inform decisions based on risk assessment results


Questions
Photo:Brian Collins/USFWS