

PFAS in Victorian waterfowl

Investigation of the presence of PFAS in 19 wetlands in Victoria



Environment
Protection
Authority Victoria

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Technical report

Executive summary

Investigating PFAS in the environment

Per- and Polyfluorinated alkyl substances (PFAS) are a group of manufactured chemicals that have been used for several decades in aqueous film-forming foams (AFFF) and other industrial and consumer products such as waterproof clothing, carpets and cookware. The presence of PFAS in the environment and their accumulation in wildlife has been reported worldwide. Concerns about PFAS contamination prompted Environment Protection Authority Victoria (EPA) to conduct a statewide assessment in 2018 into the nature and magnitude of PFAS concentrations in the environment and waterfowl to better understand the potential for ecological and human health impacts. Four common waterfowl species (Pacific Black and Pink-eared Duck and Chestnut and Grey Teal) were specifically targeted for the assessment because they are widely dispersed throughout Victorian wetlands.

In February 2018, EPA assessed waterfowl from three wetlands to better understand the extent and distribution of PFAS contamination ahead of the duck hunting season. PFAS was detected in waterfowl from all three wetlands, with concentrations exceeding trigger points for investigation in Heart Morass wetland, East Sale. As a result, EPA maintained its previous precautionary health advice (EPA publication 1672.2, 2 August 2018) to avoid the consumption of waterfowl from Heart Morass, and extended that advice to Dowd Morass, due to its proximity to a PFAS-contaminated site.

In May and June 2018, EPA conducted a more extensive study into PFAS concentrations in waterfowl from 19 wetlands around the state. This study aimed to identify potential risks associated with the consumption of waterfowl from popular recreational duck hunting sites. A human health risk assessment was conducted, based on PFAS concentrations in 41 composite samples from a total of 166 waterfowl specimens.

PFAS levels detected in soil, sediment, water and waterfowl

Variable concentrations of PFAS compounds were detected in waters, sediments and/or soils at nine of the 19 wetlands tested in May and June 2018. All others were below the analytical limits of reporting.

All **sediment** and **soil** concentrations detected were below the ecological guidelines and human health-based investigation levels for soil.

All concentrations in **water** were below the ecosystem 99% species protection levels, except for four wetlands and one marine site close to Jones Bay in Gippsland Lakes. These guidelines are based on the general potential for bioaccumulation in aquatic biota but were not derived specifically for bioaccumulation in waterfowl. PFAS concentrations at Reedy Lake on the Bellarine Peninsula exceeded drinking water standards.

Waterfowl tissue samples were found to contain variable PFAS concentrations. Perfluorooctane sulfonate (PFOS) and perfluorohexane sulphonic acid (PFHxS) concentrations in waterfowl from nine wetlands exceeded Food Standards Australia and New Zealand (FSANZ) trigger points for investigation. As a result, health risk assessments were undertaken on the samples that exceeded FSANZ trigger points for investigation, and health advisories issued.

Health advisories issued for consumption of waterfowl

EPA recommends restricting the consumption of recreationally-hunted waterfowl for the following wetlands:

- **Macleod Morass (Bairnsdale):** children should limit their consumption of waterfowl breast meat to one serve (one serve = 75g for children) per month and adults and children should not eat liver. Concentrations of PFAS in Macleod Morass did not exceed human health guidelines for recreation in waters, soils and sediments.



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- **Hospital Swamp (Bellarine Peninsula):** children should limit their consumption of waterfowl breast meat to one serve (one serve = 75g for children) per month and adults and children should not eat liver. Concentrations of PFAS in Hospital Swamp did not exceed human health guidelines in waters, soils or sediments.
- **Heart Morass and Dowd Morass wetlands (East Sale):** waterfowl should not be eaten, consistent with previous advice (EPA publication 1672.2, 2018).

EPA also recommend that people should exercise caution when consuming waterfowl hunted from wetlands that are close to those with current health advisories as waterfowl can freely move between wetlands. Given the proximity of Reedy Lake to Hospital Swamp, unless further evidence suggests otherwise, waterfowl harvested from Reedy Lake may be the same of those inhabiting Hospital Swamp.

Further investigation

EPA will conduct further work to better understand the characteristics and extent of PFAS concentrations in Victoria's wetlands and waterfowl. This will include the re-analysis of PFAS in individual specimens of Pacific Black Duck collected from Hospital Swamp, and further sampling for PFAS in sediments and waters to identify potential sources around Hospital Swamp, Reedy Lake and Macleod Morass. EPA will continue to review risks from PFAS and other emerging contaminants and investigate better ways to manage and communicate these risks to protect the environment and people from harm.

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Background

Key information regarding PFAS in the environment

- Per- and polyfluorinated alkyl substances (PFAS) are a large group of manufactured chemicals widely used for decades in aqueous film-forming foams (AFFF) and many industrial and consumer products such as waterproof clothing, new carpets, food packaging and non-stick cookware.
- PFAS are of concern as they can persist for decades in the environment and accumulate in animals and people. Most people have background levels of PFAS in their bodies.
- Waterfowl accumulate PFAS in their bodies through from continual consumption of contaminated food, water and sediment.
- At sites where AFFF was used for fire suppression (mostly for training and to control fires involving flammable liquids such as fuel and oil), PFAS can migrate into the environment and waterways.
- Investigations of relationships between PFAS exposure and health effects in humans have not shown consistent findings. Evidence of relationships between highly exposed occupational populations and health effects have also been inconsistent. Experimental studies on laboratory animals indicate possible effects on the immune system, liver, reproduction and development. However, PFAS behave differently in smaller animals compared with humans. Therefore, results from laboratory experiments may not reflect potential health impacts in humans.
- As a precaution, Environment Protection Authority Victoria (EPA) recommends minimising human exposure to PFAS wherever possible.
- An Interagency Working Group on Emerging Contaminants in Biota was established to build on the 2018 screening assessment of PFAS contamination in waterfowl to inform a greater understanding of the extent of emerging contaminants, including PFAS, in waterfowl and recreationally caught fish and in the environment (water, soils and sediment) in Victoria. The Interagency members include EPA; Parks Victoria; Department of Environment, Land, Water and Planning's Arthur Rylah Institute for Environmental Research (ARI); Game Management Authority; the Department of Jobs, Precincts and Regions and Agriculture Victoria; the Victorian Fisheries Authority; and the Department of Health and Human Services.
- Further information can be found in EPA's *Interim position statement on PFAS* (EPA publication 1669.2, 2018): <https://www.epa.vic.gov.au/our-work/publications/publication/2018/august/1669-2>.
- Further background information on PFAS and health is available from:
 - Victorian Department of Health and Human Services' (DHHS): <https://www2.health.vic.gov.au/public-health/environmental-health/per-and-poly-fluoroalkyl-substances-pfas>,
 - Australian Department of Health: <http://www.health.gov.au/pfas>,
 - Expert Health Panel (enHealth) for Per- and Poly-Fluoroalkyl Substances (PFAS), Report to the Minister, March 2018 <http://www.health.gov.au/internet/main/publishing.nsf/Content/ohp-pfas-expert-panel.htm>
- Further information on PFAS and agriculture is available from Agriculture Victoria: <http://agriculture.vic.gov.au/agriculture/animal-health-and-welfare/animal-health/faqs-pfas-in-livestock>

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Previous assessment of PFAS in waterfowl

The Department of Defence (DoD) identified Heart Morass and Dowd Morass, near East Sale, Gippsland as PFAS-contaminated sites due to AFFF used in fire-fighting training (EPA publication 1672.2, 2018). Subsequent investigations revealed PFAS concentrations in waterfowl exceeded thresholds for human consumption (DoD 2017). As an extension of this work, EPA conducted its own sampling and analysis of PFAS in waterfowl at three wetlands in February 2018: Heart Morass in East Sale; Lake Bolac, south of Ararat; and Hird Swamp, south west of Cohuna. The purpose of this sampling program was to see whether wetlands with no known PFAS sources would also show waterfowl with elevated PFAS concentrations (EPA publication 1669.2). PFAS was detected in waterfowl from all three locations, with elevated concentrations found only at Heart Morass. With the support of the Chief Health Officer, Department of Health and Human Services Victoria, EPA maintained its previous public health advice to avoid the consumption of waterfowl from Heart Morass and extended that advice to include Dowd Morass, due to its proximity to a PFAS-contaminated site. Waterfowl were further investigated due to previous known contamination issues from Heart Morass and because they are widely dispersed throughout Victoria and are not confined to a specific wetland.

Study aims

To improve understanding of PFAS contamination in waterfowl across the state, EPA conducted an additional PFAS sampling program in May and June 2018. This was a broader spatial study of PFAS concentrations in waterfowl from recreational wetlands across Victoria. The aims of this study were to:

- 1) identify potential environmental and human health risks from concentrations of PFAS in waterfowl, targeting the most popular wetlands used for hunting.
- 2) compare PFAS concentrations from water, sediment and soil samples with relevant guidelines and with concentrations in waterfowl.

Methods

Identification of sampling sites and species of waterfowl to be collected

EPA engaged the Arthur Rylah Institute for Environmental Research (ARI) to design the sampling program and ensure that the project gained ethics approval. Annual surveys of duck hunter success rates were used to identify the most popular wetlands for waterfowl hunting. These sites were targeted for sampling, along with wetlands close to areas previously sampled by EPA and DoD where PFAS concentrations in waterfowl had exceeded trigger points for investigation (ARI, 2018).

Analysis of PFAS concentrations in waterfowl from 2017 and February 2018 by EPA indicated that approximately six waterfowl should be collected for each species in each wetland for clear results. Consequently, the sampling plan targeted collection of six waterfowl specimens from each species.

In the 2017 hunting season, four species made up 75% of the total number of waterfowl harvested (Table 1). These four common game species were therefore chosen for sampling: Pacific Black Duck, Grey Teal, Chestnut Teal and Pink-eared Duck. However, the actual species and number of waterfowl specimens collected in May and June 2018 depended on the population of species in wetlands at the time of collection.

EPA and ARI partnered with licensed hunters Field and Game (Australia) (F&G), who harvested and delivered the waterfowl to ARI staff in the field for processing. In many wetlands, fewer than the target of six specimens per species were collected. Assessments using fewer waterfowl were made, therefore with reduced confidence in the conclusions.

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Table 1 – Total harvest of waterfowl based on 200 licence holders for 2017 and estimated percentage based on 2017 surveys of game hunting as well as species ecology.

Category	Reported harvest ¹	Percentage of harvest ¹	Habitat ^{2,3}	Movement behaviours ^{2,3}	Feeding and diet ³
Chestnut Teal, <i>Anas castanea</i>	108	3%	Coastal salt- and fresh-water and wetlands	Sedentary and vagrant	Dabbling on plants and invertebrates
Grey Teal, <i>Anas gracilis</i>	1,386	40%	Freshwater and saltwater wetlands	Opportunistic and nomadic	Dabbling on plants and invertebrates
Pacific Black Duck, <i>Anas superciliosa</i>	938	27%	Wetlands, ponds, sheltered estuaries and coastal waters	Sedentary; dispersive and nomadic	Dabbling on plants and invertebrates
Pink-eared Duck, <i>Malacorhynchus membranaceus</i>	159	5%	Shallow waters: lakes, swamps and wetlands.	Nomadic	Filtering small plants, algae and invertebrates

References: 1) Game Management Authority 2017; 2) Menkhorst et al 2017; 3) Museums Victoria 2018.

Notes: Typology of movement behaviours from Newton 2008: Sedentary - Remaining year-round in the same limited area, showing no direction bias in movements and generally over short distances (non-migratory).; Vagrant – An individual bird that appears outside its regular range and off their usual migration route.; Opportunistic – the ability to breed at any time of year, whenever food is sufficiently plentiful, unconstrained by season.; Nomadic – Species that have no fixed spatial or temporal pattern of migration, and no fixed directional preferences, leading to irregular changes in distribution.; and, Dispersive – Species that move with no fixed direction or distance from their breeding site.

Location of wetlands for testing

Waterfowl, sediment, soil and surface water samples were collected from 19 wetlands across Victoria (Figure 1). Licensed F&G members harvested four common, recreationally-hunted waterfowl species during the duck hunting season in May and June 2018.

EPA and ARI collected environmental samples (single surface water, soil and sediment samples) in May and June 2018 at most wetlands, with two exceptions: Newlands Lake in Aspley due to the extensive distance, associated additional costs, and low-likelihood of contamination; and Heart Morass, as DoD had already done extensive sampling there in 2017. Additional opportunistic samples were collected during routine EPA monitoring in Lake Wellington and Lake King North (near to Jones Bay).

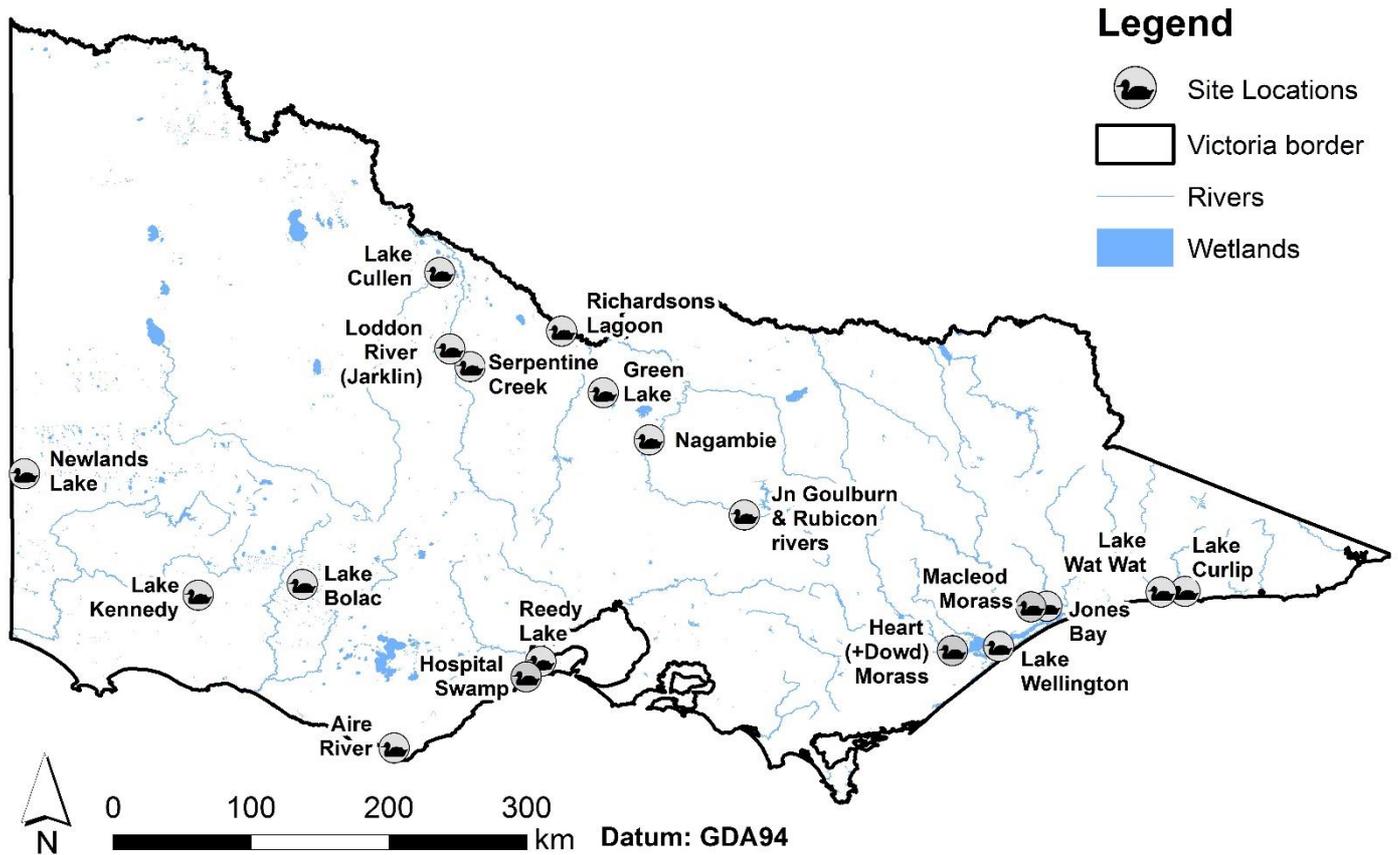


Figure 1 – Wetland sampling sites where waterfowl and environmental samples were collected across Victoria, May to June 2018.

Sample preparation and chemical analysis

Samples for waterfowl and environmental samples were stored on ice and accompanied by chain of custody documentation on transit from the field to the laboratory. For waterfowl, ARI dissected breast meat and liver from each specimen in their laboratory and stored these frozen in glass jars following handling protocols provided by the National Measurement Institute (NMI).

A staged approach was adopted for the analysis of the breast and livers. Given that PFAS contamination was not known or expected at most of the sites, composite samples (combined from individual waterfowl) within a species at each wetland were analysed. Composite sampling allowed for more wetlands and species to be analysed by combining multiple individual waterfowl specimens, reducing the overall number of samples requiring analysis by providing an average PFAS concentration for each species (FSANZ 2009). Where there was known contamination, or if the results of composite testing were close to or exceeded trigger points for investigation, then the individual specimens making up the composite sample were re-tested individually to better understand variation in PFAS concentrations. This data was used in the health risk assessment (FSANZ 2009). Using this approach, 11 individual ducks were analysed from Heart Morass (six) and Macleod Morass (five), while composite samples were used in all other wetlands.

Chemical analysis was conducted by NMI on all waterfowl breast and liver samples, as well as the water, sediment and soil samples. Thirteen common PFAS compounds were analysed in all sample types, including perfluoroalkyl sulfonic acids (such as PFOS and PFHxS) and perfluoroalkyl carboxylic acids (such as PFOA). The list of PFAS compounds, analytical limits of reporting (LORs) and methods used by NMI are reported online (2018a), with one exception that perfluorobutyrate (PFBA) was not analysed in waterfowl.

Data analysis

Concentrations below the limit of reporting (LOR) were assigned half the LOR for subsequent analyses as a conservative measure (enHealth 2012; FSANZ 2017). Waterfowl samples in the survey analysed as composites of multiple specimens provided average concentrations for each compound in each species (FSANZ 2017). For environmental decisions based on small sample sizes (<10), the use of a non-parametric approach based on intervals (median, 50th percentile) is appropriate (Goudey 2007). Presenting the concentration range and the median is typically used for dietary modelling where analytical data for individual samples are available (FSANZ 2017).

Screening of results against guidelines

The PFAS National Environment Management Plan (NEMP) developed by the Heads of EPAs Australia and New Zealand (HEPA 2018) establishes guideline concentrations for environmental sample types for public health and ecological investigations. PFOS or PFOA concentrations exceeding these guidelines indicate the need for further investigation. As there are no consumption guidelines for waterfowl, sample concentrations were compared against Food Standards Australian and New Zealand (FSANZ, 2017) trigger points for investigation in mammalian meat (breast) and mammalian offal (liver). Water samples were compared against guideline values for ecological protection and health-based guideline values for recreational and drinking water. Soil and sediment concentrations were compared against Health Investigation Levels (HILs), which aim to protect human health and indicate the need for further detailed risk assessment (Table 2).

As PFOS and PFOA bioaccumulate in wildlife, the national guidelines recommend using the 99% protection standard for species protection for 'slightly to moderately disturbed systems' (EPA publication 1633.2, 2017). As Australian laboratory analyses can only reliably detect higher concentrations of PFOS around 0.001 µg/L, EPA adopted the current LORs as the practical standards for 'slightly to moderately disturbed' and 'high conservation value systems', while the 95% protection standard will apply for highly disturbed systems (Warne et al., 2015).

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Table 2: Guideline values for environmental samples and trigger points for investigation for waterfowl and their sources.

Guidelines	Reference	PFOS	PFOS + PFHxS	PFOA
Drinking water	Australian Government Department of Health, 2017	-	0.07 ug/L	0.56 ug/L
Recreational water	Australian Government Department of Health, 2017	-	0.7 ug/L	5.6 ug/L
Environmental – 99% species protection level	EPA 2017, publication 1633.2	0.00023 ug/L	-	19 ug/L
Environmental – 95% species protection level	EPA 2017, publication 1633.2	0.13 ug/L	-	220 ug/L
Sediment and soil – public open space	EPA 2017, publication 1633.2 Based on 20% of FSANZ TDI, and National Environment Protection (Assessment of Site Contamination) Measure) (1999), Health Investigation Level C (HILs), Public Open Space	1 mg/kg	1 mg/kg	10mg/kg
Interim soil – ecological indirect exposure	EPA 2017, publication 1633.2 Based on Canadian Federal Environment Quality Guidelines (2017)	0.01 mg/kg	-	-
Food consumption – mammalian meat	Food Standards Australia New Zealand (FSANZ, 2017)	3.5 µg/kg	3.5 µg/kg	28 µg/kg
Food consumption – mammalian offal	Food Standards Australia New Zealand (FSANZ, 2017)	96 µg/kg	96 µg/kg	765 µg/kg
Tolerable Daily Intake (TDI)	Food Standards Australia New Zealand (FSANZ)	0.02 µg/kg bw/day	0.02 µg/kg bw/day	0.16 µg/kg bw/day

Note: bw=body weight, µg = micrograms (1 µg = 0.001 mg)

Human health risk assessment for consumption of waterfowl

FSANZ trigger points for investigation

Where PFAS concentrations in waterfowl exceeded the FSANZ trigger points for investigation, a human health risk assessment was completed to identify any potential risks associated with the consumption of waterfowl.

Waterfowl consumption scenarios

In 2017, the estimated upper range of individual waterfowl taken during the hunting season was 20.8 individuals per hunter (95th percentile) (Game Management Authority, 2017). This risk assessment used this upper range of harvested numbers (21 waterfowl per year) as a conservative estimate of consumption rates of waterfowl breast and liver by recreational hunters. The consumption scenario for waterfowl breast was one serve per week (based on 150 g for adult and 75 g for child). The consumption scenario for liver was 10 g per week (for adults and children) (enHealth, 2012).

Tolerable daily intake

The tolerable daily intake (TDI) is a level of intake for PFOS + PFHxS that is considered safe over a lifetime based on the findings of toxicological studies in laboratory animals. The consumption scenarios were used as the basis to derive tissue concentrations of PFOS + PFHxS in duck breast and liver that would result in a consumer reaching the TDI for PFOS + PFHxS of 0.02 µg/kg body weight / day (FSANZ 2017). The concentrations of PFOA were all well below the listed trigger points for investigation and therefore this compound was not included in the risk assessment.

Consumption thresholds

The concentration of PFOS + PFHxS in waterfowl breast for the consumption scenario of one serve per week was calculated as 36 µg/kg for children and 74 µg/kg for adults. The concentration of PFOS + PFHxS in liver for the consumption scenario of one serve per week was calculated as 268 µg/kg for children and 1,100 µg/kg for adults. These consumption thresholds should not be exceeded for adults and children. Thresholds were compared with tissue concentrations for composite samples (from all wetlands) and individual samples from Heart Morass and Macleod Morass to determine EPA's advice.

Results and discussion

PFAS in environmental samples

A summary of the environmental concentrations for PFAS in wetlands is shown below in Table 3, with only detected concentrations shown. All sediment and soil concentrations were below the ecological guidelines and human health investigation levels for soil (NEPM 2018). Concentrations of PFAS in sediment samples from all 19 wetlands were considerably lower than the Health Investigation Levels (HILs), indicating low risks to human health. Sites where no PFAS were detected in environmental samples included Greens Lake, Serpentine Creek, Jones Bay, Aire River, Lake Nagambie, Lake Kennedy, Junction of Goulburn and Rubicon rivers, Lake Wat Wat, and Lake Bolac. While no PFAS concentrations were detected in Jones Bay, PFOS + PFHxS was detected in waters nearby in Lake King North, Gippsland Lakes (Table 3).

PFAS concentrations in the surface waters of all but one of the 19 wetlands were below the drinking water quality guideline value (0.07 µg/L), and all sites were below the recreational water quality guideline value (0.7 µg/L). Water concentrations in Reedy Lake exceeded the drinking water guidelines for PFOS + PFHxS (>0.07 µg/L) (Table 3). This could pose potential risks if these waters are used for drinking by wildlife and other animals, as PFAS can accumulate and persist in the tissues of higher animals. PFAS concentrations in Reedy Lake did not exceed the recreational guidelines (<0.7 µg/L), indicating that waters are suitable for recreational uses such as kayaking.

Although no concentrations of PFAS were identified in environmental samples at Lake Curlip, waterfowl tissues collected at this site exceeded trigger points for investigation. This could either be a result of waterfowl moving from another area with higher concentrations of PFAS; or the single sediment, water and soil samples may not have fully characterised environmental concentrations of PFAS at the site.

Environmental samples from all wetlands in this study (excluding Heart Morass) had concentrations of PFOS and PFOA below ecosystem guideline values for highly modified ecosystems (95% species protection). However, ecological water quality guidelines for PFOS are set at levels designed to protect multiple species and prevent bioaccumulation across multiple trophic levels (Australian Government 2016). Any detection of PFOS concentrations in waters is deemed to exceed 99% protection levels for bioaccumulation, as there is the risk of uptake by aquatic biota. Guidelines do not include protection for air breathing animals which inhabit or prey on aquatic ecosystems and may not account for effects from bioaccumulation of toxicants (Australian Government 2016). Previous PFAS measurements in Heart Morass by the DoD in October to December 2016 showed elevated concentrations in sediments, waters and waterfowl close to the outlet from the RAAF Base East Sale. To specifically assess greater risks and uptake of PFAS on the environment including in waterfowl, a human health and ecological risk assessment was completed as part of the site assessment for Heart Morass (DoD 2017), involving measurement of PFAS concentrations in waterfowl food sources.

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Table 3 - Summary of environmental concentrations of PFAS detected in wetlands and guidelines for water (recreational, ecosystem guidelines 95% protection level and drinking water), sediment and soil (human health standards), and Waterfowl (yes/no exceeding FSANZ).

Guidelines		Sediment			Soil	Waters				Water-fowl
		PFOS + PFHxS	PFOA	PFOS	PFOS	PFHxS	PFOA	PFOS	PFOS + PFHxS	PFOS + PFHxS
Units		mg/kg	mg/kg	mg/kg	mg/kg	µg/L	µg/L	µg/L	µg/L	Exceeding Trigger points for investigation ^d
LORs		0.003	0.001	0.002	0.0003	0.001	0.001	0.002	0.003	
Drinking water standard ^a		-	-	-	-	0.07	0.56	0.07	0.07	
Recreational water quality ^b						0.7	5.6	0.7	0.7	
NEPM HILs ^c		1	10	1	1	-	-	-	-	
Interim soil – ecological ^c					0.01					
Ecological 99% protection ^c							19	0.00023		
Ecological 95% protection ^c		-	-	0.14	0.14	-	220	0.13	-	
Area	Wetland name	Sediment			Soil	Waters				Water-fowl
Sale	<i>Heart Morass† Min-Max (Median); n=30(water), n=32(sed)</i>	<0.0004 -1.93 (0.0574)	<0.0002- 0.0291 (0.0007)	<0.0002 -1.66 (0.0504)	N/A	<0.002- 0.31 (0. 16)	<0.002- 0.009 (0.004)	<i>0.004- 0.494 (0.124)</i>	0.004- 0.74 (0.29)	Y
Sale	Lake Wellington‡ (min-max) n=3(sed/water); n=2 (soil)	0.003	<LOR	0.003	<LOR	0.0011- 0.043	<0.003- 0.0012	<i>0.003- 0.004</i>	0.0043- 0.0472	Y
Kerang	Lake Cullen	<LOR	<LOR	<LOR	<LOR	0.0011	<LOR	<LOR	0.0013	N
Geelong	Reedy Lake	<LOR	<LOR	<LOR	0.006	0.028	<LOR	<LOR	0.082	Y
Geelong	Hospital Swamp	0.019	<LOR	0.016	0.0042	<LOR	<LOR	<LOR	<LOR	<LOR
Boort	Loddon River	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<i>0.011</i>	0.0152	N
Bairnsdale	Jones Bay	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	N
Gippsland Lakes§	Lake King North§	<LOR	<LOR	<LOR	-	0.0099	<LOR	<i>0.018</i>	0.0279	-
Bairnsdale	Macleod Morass	<LOR	<LOR	<LOR	<LOR	<LOR	0.015	<i>0.016</i>	0.030	Y
Echuca	Richardsons Lagoon	<LOR	<LOR	<LOR	<LOR	<LOR	0.001	<LOR	<LOR	Y
Marlo	Lake Curlip	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	Y
Apsley	Newlands Lake	-	-	-	-	-	-	-	-	N

Notes: <LOR = not detected; - Not sampled; Wetlands were excluded if no environmental concentrations of PFOS, PFHxS or PFOA were detected. No concentrations detected above LORs at: Greens Lake, Serpentine Creek, Aire River, Lake Nagambie, Lake Kennedy, Jn Goulburn & Rubicon rivers, Lake Wat Wat and Lake Bolac (data not shown).

Concentrations in **bold** exceed guideline values. Units are mg/kg (dry weight) for sediment and soil, and µg/L for waters. Unless stated otherwise, single samples were collected for sediment, soil and water. Concentrations **highlighted** exceed HIL (soil/sediment) or Recreational guidelines (water); **Bold** Exceeds Drinking Water; *Italics* exceed ecological 95% protection.

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†Data Source: Department of Defence (2017), PFAS Investigation, Heart Morass surface water and sediment results, Oct-Dec 2016;
‡Three samples for water and sediments from 2 locations, 1 from EPA fixed site, 2 from shoreline; soil samples = 2;
§ EPA (2018) Monitoring the environment: EPA's fixed marine monitoring sites (Gippsland Lakes, additional sampling site)
Guidelines: a, b Australian Government Department of Health, 2017; c EPA 2017 publication 1633.2; d FSANZ 2017

PFAS in waterfowl

A summary of concentrations of 13 PFAS measured in waterfowl are shown in Table 4. PFOS was the most frequently detected compound and also had the highest overall concentrations, with 33 µg/kg in breast and 340 µg/kg in liver for Pacific Black Duck at Macleod Morass (Table 4). The second and third most frequently detected compounds in both liver and breast were PFNA and PFDA, while PFDA also had the second highest maximum concentration in both tissues (Table 4). PFHxS was the fourth most frequently detected compound and had the next highest concentration.

PFOA was detected relatively infrequently in breast samples (5%) compared with liver samples (29%). The maximum concentrations of PFOA from waterfowl across all wetlands were 1.2 and 4.5 µg/kg in Grey Teal breast and liver, respectively, from Macleod Morass. Eleven out of the 13 PFAS compounds analysed were above LORs in liver from one or more waterfowl (Table 3). Both PFHxA (perfluoro hexanoic acid) and PFHpA (perfluoro heptanoic acid) were below the LORs (<0.5 µg/kg) for all samples in liver and breast.

Table 4 – Summary data on the occurrence (detection frequency) of PFAS compounds and concentrations in waterfowl across the 19 wetlands, May – June 2018.

Category		Breast			Liver		
PFAS type	LOR (µg/kg)	Detection Frequency	Median (µg/kg)	Max (µg/kg)	Detection Frequency	Median (µg/kg)	Max (µg/kg)
PFPeA	<0.5	0%	<0.5	<0.5	2%	<0.5	2.9
PFHxA	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5
PFHpA	<0.5	0%	<0.5	<0.5	0%	<0.5	<0.5
PFOA	<0.3	5%	<0.3	1.2	29%	<0.3	4.5
PFNA	<0.5	15%	<0.5	1.1	49%	<0.5	13
PFDA	<0.5	15%	<0.5	2.3	41%	<0.5	27
PFUnDA	<0.5	5%	<0.5	1.6	15%	<0.5	6.6
PFDoDA	<0.5	12%	<0.5	1.2	20%	<0.5	4.8
PFBS	<0.5	0%	<0.5	<0.5	2%	<0.5	1.3
PFHxS	<0.5	20%	<0.5	2.1	39%	0.5	7
PFOS	<0.3	68%	0.9	33	95%	9.5	340
6:2 FTS	<0.5	0%	<0.5	<0.5	2%	<0.5	1.3
8:2 FTS	<0.5	2%	<0.5	1	2%	<0.5	2.9
PFOS + PFHxS	<0.4†	68%	1.15	34.2	98%	10	350

Notes: Median and maximum concentrations for each compound; Units: µg/kg wet weight. Number of composite samples (n) = 41. PFPeA (Perfluoro pentanoic acid); PFHxA (Perfluoro hexanoic acid); PFHpA (Perfluoro heptanoic acid); PFOA (Perfluoro octanoic acid); PFNA (Perfluoro nonanoic acid); PFDA (Perfluoro decanoic acid); PFUnDA (Perfluoro undecanoic acid); PFDoDA (Perfluoro dodecanoic acid); PFBS (Perfluoro butane sulfonic acid); PFHxS (Perfluoro hexane sulfonic acid); PFOS (Perfluoro octane sulfonic acid); 6:2 FTS (C₂H₄-perfluorooctane sulfonate); 8:2 FTS (C₂H₄-perfluorodecane sulfonate); †PFOS + PFHxS (Σhalf LORs)

PFAS in Victorian waterfowl

Of the 13 PFAS compounds, only three have published guideline values for investigation (PFOS, PFHxS and PFOA). Across Victoria, PFOA was below the LOR in waterfowl sampled from 13 of the 19 wetlands, and concentrations were considerably lower than FSANZ (2017) trigger points for investigation in breast and liver at all sites (Table 4 and Table 5). PFOS + PFHxS concentrations in waterfowl were above the LOR in almost all wetlands (Table 5). Of the 19 wetlands sampled, nine had waterfowl with PFOS + PFHxS concentrations exceeding trigger points for investigation (Table 5).

Table 5 – Summary of waterfowl species harvested from wetlands and the number of wetlands where PFAS concentrations in waterfowl in composite samples exceeded trigger points for investigation, May - June 2018.

Category	Any waterfowl	Chestnut Teal	Grey Teal	Pacific Black Duck	Pink-eared Duck
Number of wetlands	19	9	13	14	5
Number of wetlands where PFOS + PFHxS† were detected	18	9	11	14	5
Number of wetlands where PFOS + PFHxS† trigger point for investigation‡ exceeded	9	3	3	5	2
Number of wetlands where PFOA was detected	6	3	3	2	4
Number of wetlands where PFOA trigger point for investigation‡ exceeded	0	0	0	0	0

Notes: †PFOS and PFOS+PFHxS – same number of exceedances. Half limit of reporting used when PFHxS was not detected. Detections and exceedances shown for breast and/or liver samples. ‡FSANZ (2017)

Concentrations of PFOS and PFOS + PFHxS were below trigger points for investigation in waterfowl from 12 of the 19 wetlands. These wetlands are shown below in Table 6 with no shading. As there was no evidence of PFAS contamination in waterfowl at these locations, no further advice or investigation is required at the time of publishing.

Concentrations of PFOS + PFHxS were close to or above trigger points for investigation in one or more species of waterfowl from several sites in the Gippsland Lakes region near the towns of Sale, Bairnsdale and Marlo, the south-west region in Geelong, and near Echuca in the north of the state (Table 6).

PFAS in Victorian waterfowl

Table 6 – Summary of exceedances of trigger points for investigation in waterfowl, the number of specimens per species for composite samples and the range of PFOS + PFHxS concentrations in breast and liver.

Area	Wetland name	Waterfowl numbers					PFOS + PFHxS (µg/kg)	
		Chestnut Teal	Grey Teal	Pacific Black Duck	Pink-eared Duck	Total Specimens	Breast	Liver
Sale	Heart Morass			6		6	11.4	131
Sale	Lake Wellington	8	8	2		18	2.8 – 4.8	14 – 20.9
Kerang	Lake Cullen	7	8	3	4	22	0.7 – 1.7	9.6 – 26.3
Geelong	Reedy Lake	2			1	3	1.8 – 12	16.3 – 87
Geelong	Hospital Swamp			6		6	16.3	182
Shepparton	Greens Lake			6		6	0.8	4.0
Boort	Serpentine Creek		4			4	<0.4	1.3
Boort	Loddon River, Jarklin			5		5	<0.4	8.6
Bairnsdale	Jones Bay	4	4	2		10	1.3 - 2.3	26 - 34
Bairnsdale	Macleod Morass	3	3	3	2	11	9.6 - 34	64 - 347
Colac	Aire River	4	5	5		14	<0.4 - 0.7	0.9 - 5.7
Echuca	Richardsons Lagoon†		2*	1*		3	5.4	55
Nagambie	Lake Nagambie		1	5		6	1.1 - 6.8	6.5 - 58
Penshurst	Lake Kennedy		6			6	<0.4	<0.4
Mansfield	Jn Goulburn & Rubicon rivers		2	1		3	0.7 - 11.3	3.5 - 9.8
Marlo	Lake Curlip	3	4	3	2	12	1.2 - 8.7	2.0 - 57
Marlo	Lake Wat Wat	9	3			12	<0.4 - 0.8	1.5 – 4.5
Lake Bolac	Lake Bolac	2	7	4		13	<0.4	0.8 – 4.6
Apsley	Newlands Lake				6	6	<0.4	2.3

Notes: †analysed as a single combined species composite of Grey Teal and Pacific Black Duck

Shading indicates PFOS + PFHxS concentrations in waterfowl exceeded trigger points for investigation in one or more species (grey), breast only (light yellow) and both breast and liver (orange). PFOS + PFHxS concentration range (min – max) for composite samples across species are shown with exceedances in bold. ‡Trigger points for investigation (FSANZ, 2017) for PFOS + PFHxS 3.5 µg/kg (breast) and 96 µg/kg (liver).

Relationships between environmental and waterfowl PFAS concentrations

There are several environmental factors which could be influencing PFAS concentrations in waterfowl. It is expected that the most likely factors causing PFAS contamination in waterfowl are proximity to a source, and ongoing exposure to PFAS through feeding and adsorption (Larson et al 2018). As most samples analysed were composites, it was not possible to relate PFAS concentrations to factors such as age or sex of ducks across Victoria. Analysis of individual samples collected from both Heart Morass (May 2017 February and May 2018) and Macleod Morass (May 2018) showed no apparent relationship between body weight and concentrations of PFOS + PFHxS (R^2 value <0.1).

However, individual waterfowl from Macleod Morass showed strong differences in PFAS concentrations, with higher contamination for PFOS + PFHxS in Pink-eared Duck and Pacific Black Duck compared with the two species of Teal. Uncertainty exists in all chemical analysis, and PFAS concentrations in the same sample determined by the same laboratory can vary by ±20% or more (NMI 2018c). While composite samples for waterfowl provide a useful way to assess averaged PFAS concentrations in many wetlands and waterfowl species, there is uncertainty in the distribution of concentrations in individual species of waterfowl. For wetlands where risk to humans from consumption of waterfowl are elevated, this is addressed by analysing individual waterfowl specimens.

Other factors related to waterfowl ecology – particularly feeding, habitat preferences, migratory habits and breeding behaviour – are relevant to understanding the influence of potentially threatening processes such as pollution (Kingsford and Norman 2002). Yet there is currently insufficient evidence to determine if or how PFAS concentrations in different species of waterfowl are influenced by ecological factors. As all species of waterfowl exceeded trigger points for investigation, there is no indication to date that any of these autecological factors make a significant difference to the risk of accumulation of PFAS.

Human health risk assessment for consumption of waterfowl

From the 19 wetlands assessed in this study, concentrations of PFAS in waterfowl from three wetlands required health advisories for human consumption. Concentrations of PFAS in composite samples at Macleod Morass, Hospital Swamp and Heart Morass exceeded the FSANZ trigger points for investigation and were close to or exceeded consumption thresholds for children. This prompted the testing of individual ducks at Macleod Morass (Pacific Black Duck and Pink-eared Duck) and Heart Morass (Pacific Black Duck).

Concentrations of PFOS + PFHxS in waterfowl were above the LOR but below trigger points for investigation at most wetlands. Close to half of the wetlands also had concentrations of PFOS + PFHxS in waterfowl exceeding the FSANZ trigger points for investigation in one or more species, as shown in Figure 2. The highest concentrations of PFOS + PFHxS were in Pacific Black Duck and Pink-eared Duck at Macleod Morass, Pacific Black Duck from Heart Morass, and Hospital Swamp, respectively (Figure 2).

PFAS in Victorian waterfowl

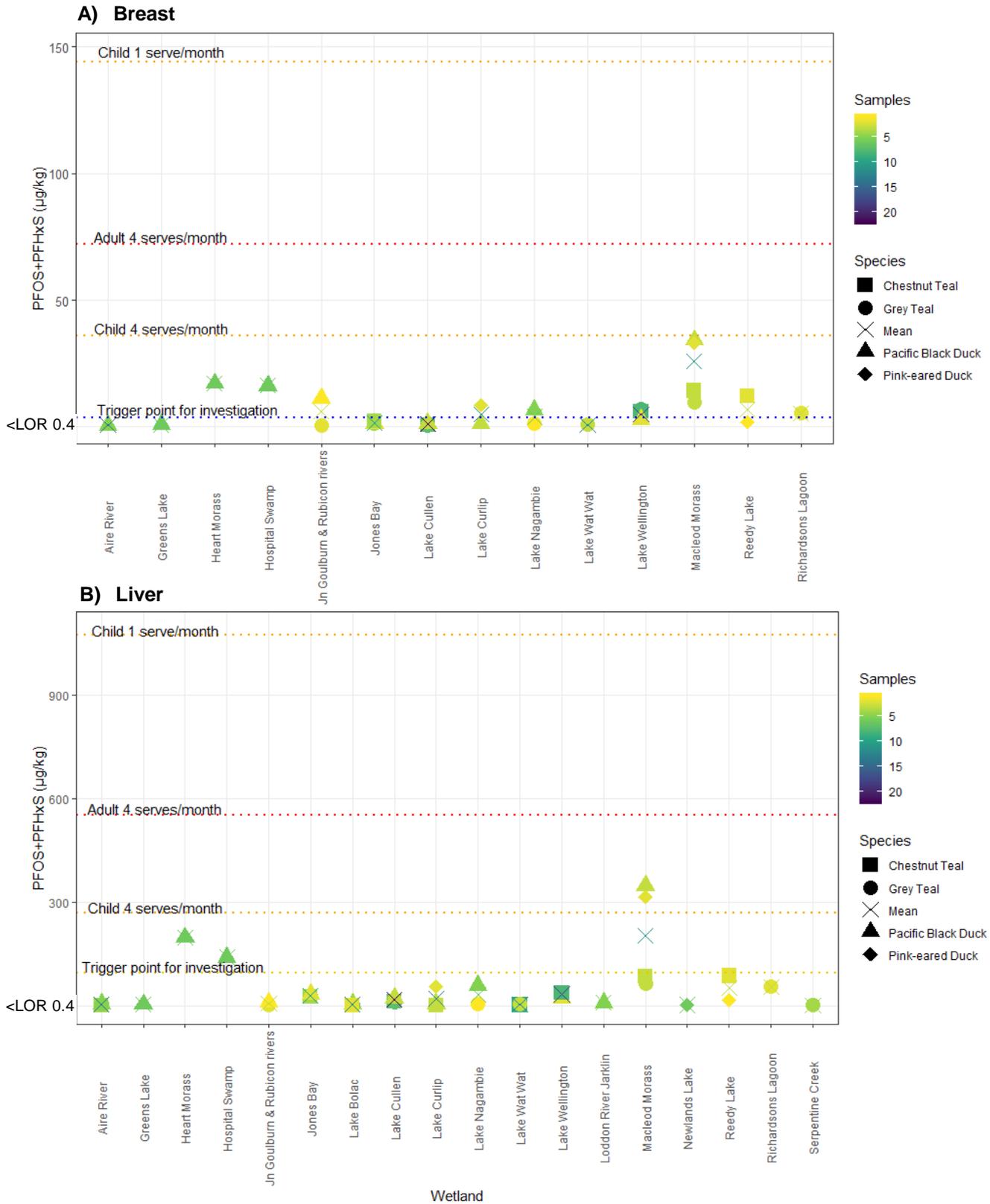


Figure 2 - Concentrations of PFOS + PFHxS in waterfowl A) Breast and B) Liver samples for those wetlands where they were detected above limits of reporting in relation to consumption thresholds for number of serves per month for children and adults. Colour of symbols indicates the number of individual waterfowl collected for each species (and total waterfowl for the mean). LOR = Limit of reporting.

PFAS in Victorian waterfowl

EPA's consumption advice for waterfowl from wetlands across Victoria, based on concentrations of PFOS + PFHxS in liver and breast is summarised in Figure 3. Consumption of waterfowl from Heart Morass and the adjacent Dowd Morass should be avoided. Heart Morass and surrounding areas are affected by off-site runoff from the RAAF Base East Sale. Consumption should also be restricted at two other wetlands: Macleod Morass and Hospital Swamp. In both wetlands, concentrations of PFOS + PFHxS were close to or slightly exceeded the 'child four serves per month' consumption threshold for breast and livers.

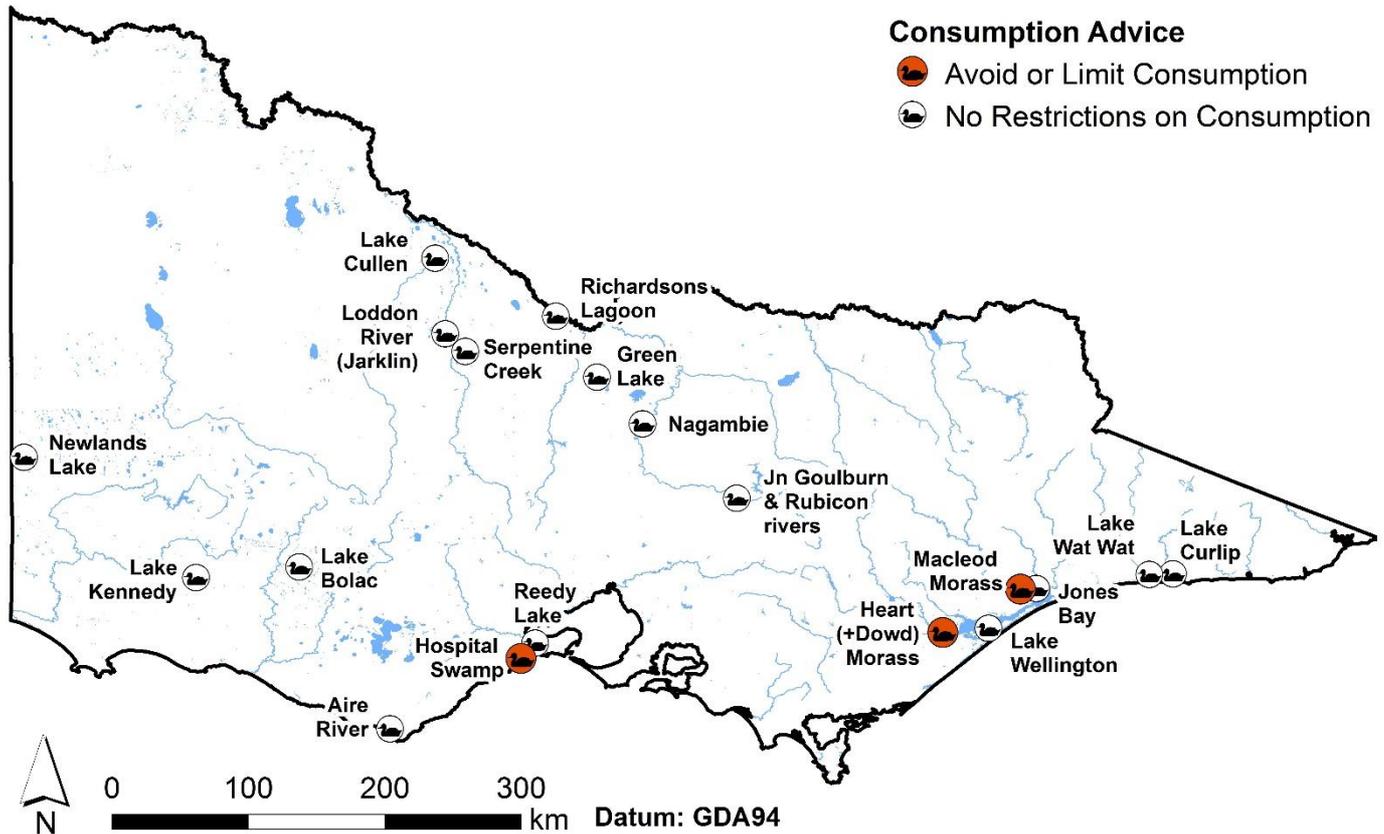


Figure 3 - Risk map of PFOS + PFHxS in waterfowl across Victorian wetlands. Symbols based on risk assessment and consumption.

Waterfowl from Macleod Morass

Macleod Morass had higher concentrations of PFAS in waterfowl compared with other wetlands across Victoria (Figure 2 and Figure 3). All four waterfowl species from Macleod Morass had PFOS + PFHxS concentrations exceeding trigger levels for investigation in breast meat; Pacific Black Duck slightly exceeded the child four serves per month consumption, while Pink-eared Duck was slightly below (Figure 2). Liver concentrations in only two species at Macleod Morass – Pacific Black Duck and Pink-eared Duck – exceeded the trigger point for investigation, but concentrations in these species also exceeded four serves per month consumption for children (Figure 2B).

It is estimated that children consuming four serves of waterfowl per month from Macleod Morass will reach or come close to reaching the TDI when consumption is averaged over a year. As a precaution, EPA recommends that for children consumption of waterfowl sourced from Macleod Morass is limited to one serve of breast meat per month (one serve = 75 g for children). EPA also recommends that adults and children do not eat liver from waterfowl sourced from Macleod Morass. By limiting their consumption to one serve of breast meat per month, children can safely consume waterfowl while not exceeding the TDI recommended by FSANZ.

Waterfowl from Hospital Swamp

Hospital Swamp had concentrations of PFAS exceeding trigger points for investigation in waterfowl (Pacific Black Duck) (Figure 2 and Figure 3).

EPA recommends that for children consumption of waterfowl breast meat should be limited to one serve (one serve = 75 g for children) per month of waterfowl collected from Hospital Swamp. EPA recommends adults and children should not eat waterfowl liver from Hospital Swamp. Concentrations of PFAS in Hospital Swamp did not exceed human health and ecological guideline values in waters, soils or sediments.

While PFOS + PFHxS concentrations in Reedy Lake exceeded drinking water guidelines, the evidence on which to base advice for consumption of waterfowl from Reedy Lake is not as strong, as there were only a small number of Chestnut Teal and Pink-eared Ducks collected. Given the proximity of these two wetlands, it would be prudent to similarly limit consumption of waterfowl (including Pacific Black Duck) from Reedy Lake until more evidence is available.

Waterfowl from Heart Morass

PFAS compounds PFOS + PFHxS were detected in the breast and liver composite samples for Pacific Black Duck from Heart Morass with both concentrations exceeding the trigger points for investigation (Figure 2 and Figure 3). Composite samples from multiple specimens accurately represent the distribution of individual waterfowl specimens in Heart Morass. PFOS + PFHxS concentrations in the breast and liver composite samples (17.1 and 197 µg/kg; Figure 2) were comparable with the arithmetic mean (16.1 and 183 µg/kg) of the individual samples. This enhances confidence in results based on PFAS concentrations in composite samples, comparison with previous sampling in Heart Morass and assessments in other wetlands.

Spatial and temporal variability in PFAS in Heart Morass

Within Heart Morass, three sampling events from different locations have been conducted. Most recently in May 2018, waterfowl were collected in the western area of Heart Morass. In February 2018, waterfowl were collected in the east of Heart Morass game reserve (Figure 4). The earliest waterfowl sampling by DoD in 2017 occurred in the middle of the wetland close to run-off from the RAAF Base East Sale (Figure 4). A map of Heart Morass showing the locations and dates where waterfowl and environmental samples were collected is shown in Figure 4. Concentrations of PFAS in sediments and waters varied markedly across Heart Morass. There were substantially lower concentrations towards the fringes of Heart Morass, both to the east and west (Figure 4). Higher concentrations were observed in 2017 in the middle of Heart Morass close to off-site runoff from the RAAF Base East Sale.

No additional environmental samples for PFAS were collected by EPA in 2018. The closest sites to the three waterfowl sampling locations where waters and sediments were collected are shown in Figure 4. Data collected by DoD (2017) suggest concentrations in waterfowl reflect concentrations in water, sediment and/or food sources. This corresponds with uptake from adsorption and consumption of contaminated food as the main biotic pathway, while exposure from sediment-associated PFAS was predicated as the main abiotic source of exposure rather than water-associated PFAS (Larson et al 2018).

Waterfowl species collected also varied slightly over these three events, although Pacific Black Duck was common to all. There may be differences in species, due to foraging behaviour, diet or habitat preferences, which may influence PFAS concentrations in waterfowl. Concentrations of PFAS in waterfowl across the Heart Morass may be highly variable both spatially or temporally. However, waterfowl sourced from the central part of Heart Morass (Field and Game Australia hunting reserve) is likely to pose a greater risk if consumed than those sourced from the edges. It is unclear whether spatial differences with disparate sampling locations would have a greater influence on PFAS concentrations in waterfowl compared with temporal changes, such as a decrease in PFAS concentrations due to the elimination of PFAS in the days and weeks after exposure. Given this uncertainty regarding PFAS concentrations in waterfowl across the wetland and surrounding areas, a precautionary approach is strongly advised to avoid consumption of waterfowl from Heart Morass and Dowd Morass as previously noted.

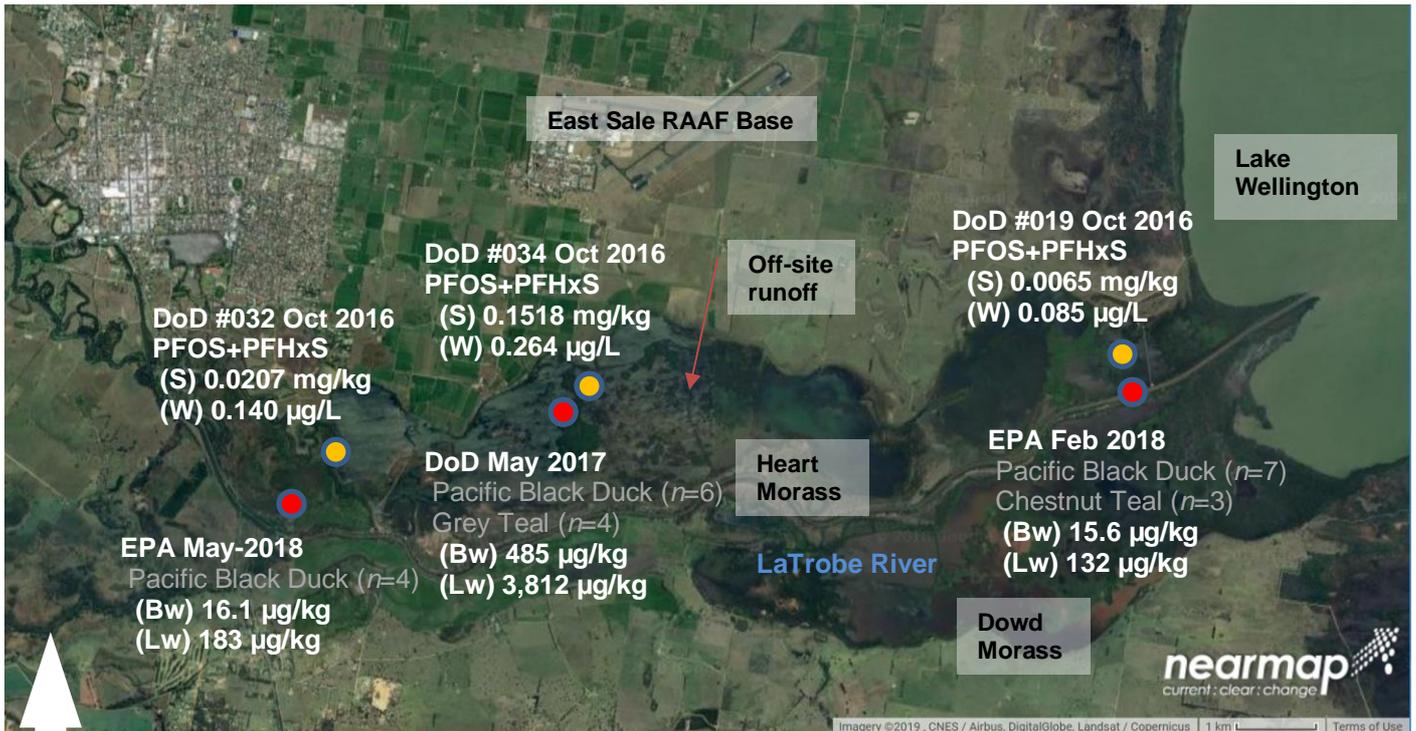


Figure 4 – Satellite imagery of Heart Morass and Dowd Morass. Markers show collection sites and concentrations of PFOS + PFHxS: mean waterfowl Lw = Liver and Bw = Breast (red); and DoD environmental site-specific samples, S = Sediment; W = Water (yellow); Data Sources: EPA May 2018, EPA Feb 2018, and Department of Defence, (2017), East Sale PFAS investigations. Imagery Source: nearmap, CNES / Airbus, Digital Globe, Landsat / Copernicus. Datum: GAD94.

Waterfowl ecology

In southern Australia, waterfowl typically breed when there is an abundance of food and water following rainfalls, typically in spring (Kingsford and Norman 2002). Above average rainfalls across Victoria in December 2017 may have encouraged waterfowl dispersion and breeding (Figure 5). However, the climate across Victoria in 2018 was at its driest since 1997, with approximately 25% less rainfall than the long-term (1961-1990) annual average (BOM 2019). Rainfalls were especially low during later summer and autumn leading up to and during collection of waterfowl in May, particularly in the Mallee, northern and central Victoria and the Gippsland region (Figure 6) (BOM 2019).

Waterfowl movements appear as a response to variation in resources that affect survival or alter breeding success (Roshier et al 2006). While Pacific Black Duck appear more sedentary (McEvoy et al 2015), Grey Teal and Pink-eared Duck display more nomadic and highly dispersive movements (Roshier et al 2008). Modelling suggests a smaller home range and more sedentary nature could attribute towards a higher uptake of PFOS in birds at sites impacted by AFFF (Larson et al 2018). Of those nine sites where PFAS in waterfowl exceeded trigger points for investigation, five were for Pacific Black Duck, which included the four highest concentrations in composite samples of waterfowl. However, the species and the number of specimens varied between wetlands. In wetlands where PFAS concentrations exceed guidelines, certain ecological traits in waterfowl may have an influence on exposure, but further research and assessment is required

Waterfowl populations are impacted by several threatening processes including water supply, drought, pollution, climate change, weeds and exotic species, and over-harvesting, yet limited information exists to assess the impacts and relationships between these processes (Kingsford and Norman 2002). Further research priorities for guiding the management of waterfowl and wetlands include: understanding waterfowl movements within Victoria; monitoring and assessment of wetland habitat; and understanding effects of pollution and hunting (Kingsford and Norman, 2002). New research on waterfowl ecology and tracking studies across Victoria would provide greater knowledge to better understand the distribution, diet and ecology of waterfowl (e.g. <https://feathermap.ansto.gov.au/>).

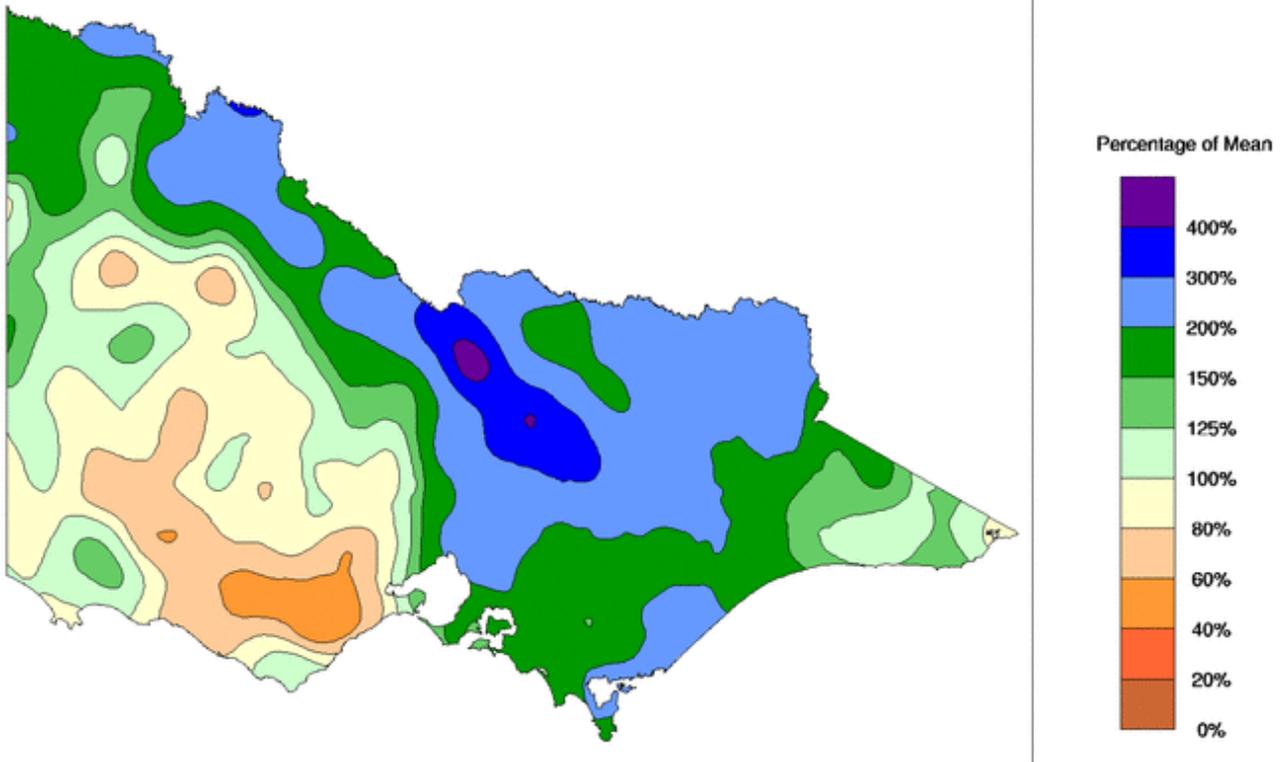


Figure 5 – Victorian rainfall totals for December 2017 as a percentage of the long-term (1961-1990) mean rainfall (BOM 2019).

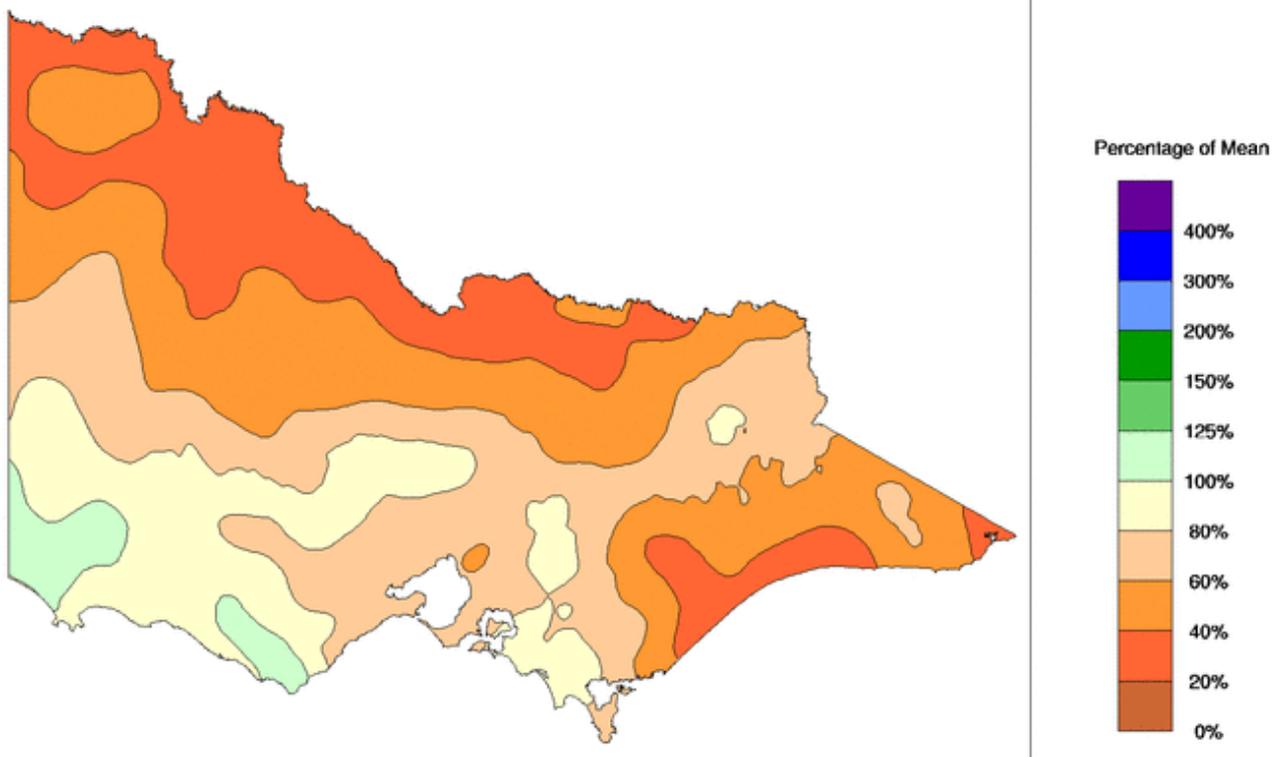


Figure 6 – Victorian rainfall totals for March - May 2018 as a percentage of the long-term (1961-1990) mean rainfall (BOM 2019).

PFAS toxicity, bioaccumulation and depuration

There are potential ecological impacts to aquatic ecosystems where elevated concentrations exceed the 99% species protection level for bioaccumulation. However, these default guideline values were not derived for air breathing animals nor are they protective of bioaccumulation in waterfowl (Australian Government 2016). However, the presence of PFAS in the environment or waterfowl tissues does not necessarily indicate an ecological impact, and similarly, contaminant concentrations in tissues do not directly relate to toxicity.

Depuration (elimination rates) in waterfowl were estimated using elimination kinetic models to estimate half-life of PFOS in the blood of two species of birds (Newsted et al 2007). Estimated depuration rates for waterfowl and other birds were much shorter than in mammals, with Mallards (closely related to Pacific Black Duck) and quail having estimated half-lives of 14 and 21 days, respectively. Depuration in chickens was determined from experiments for PFOS (16 – 125 days) and PFOA (4 – 5 days) (Yoo et al 2009, Yeung et al 2009). By comparison, depuration half-lives for PFOS in mammals range from 100 days in rats, 150 days in monkeys and 5.5 years for humans (CRC CARE, 2018). Depuration rates and half-lives vary between species, but PFOS and PFOA cannot be metabolised by mammals and are subsequently excreted in urine and faeces (Stahl et al 2011). PFAS uptake and depuration also differs between various organs (Yoo et al 2009). Assuming no additional PFAS exposure, once animals are removed from contamination sources PFAS will gradually be eliminated with times dependent on the initial concentration in different organs for each species.

Concentrations of PFOS have been decreasing in biota globally following the voluntary phase out by four of the five main PFOS manufacturers in the USA since 2002 (Armitage et al 2009), while concentrations of alternative PFAS, including shorter and long-chain perfluorinated carboxylic acids (PFCAs), continue to be used and may be increasing (Brendel et al 2018, Wang et al 2013). Further information on PFAS bioaccumulation in aquatic ecosystems will provide a greater ability to determine its environmental fate and transport to better assess and manage risks from emerging contaminants (Pi et al 2017).

Sources of PFAS

There is no clear evidence of any major source of PFAS at wetlands other than Heart Morass and Lake Wellington. Hospital Swamp and Macleod Morass are downstream of urban areas where stormwater may transport PFAS from industrial, commercial and residential areas. Similarly, Reedy Lake receives water from the Barwon River downstream of Geelong, where PFOS + PFHxS was elevated compared with water drinking water guidelines. Low but detectable concentrations of PFAS in wetlands away from developed areas such as Lake Cullen and the Loddon River near Jarklin indicate the widespread distribution of these compounds in the environment.

Except for the Loddon River, all sites with PFAS residues detected in soils, sediment and/or waters also had concentrations of PFOS + PFHxS in waterfowl above the trigger points for investigation (Table 3). This is despite environmental sample concentrations being relatively low in most sites except Reedy Lake where PFOS exceeded drinking guideline values for PFOS + PFHxS. While initial PFAS concentrations in waterfowl in Reedy Lake appear below the consumption thresholds, only a few specimens ($n = 3$) of Grey Teal and Pink-eared Duck were analysed, and concentrations of PFAS in Pacific Black Duck collected nearby from Hospital Swamp were elevated.

Conclusions

PFAS is widespread and concentrations in waterfowl, sediment, soil and water were highly variable between different wetlands across Victoria. Higher concentrations of PFAS appear to be related to either point sources or other unknown potential sources in urban runoff. EPA will continue to work to identify sources and manage risks relating to PFAS and other emerging contaminants. In wetlands where PFAS was detected, waterfowl also appeared to have PFAS concentrations exceeding FSANZ screening points for investigation.

The risk assessment suggests a consumption advisory to avoid eating waterfowl sourced from Heart Morass and Dowd Morass continues to be necessary, consistent with earlier EPA advice. For consumption of waterfowl at Macleod Morass and Hospital Swamp, EPA advises that adults and children do not eat waterfowl liver, and to limit consumption of breast meat for children to one serve per month (75 g). While PFAS concentrations were higher in Pacific Black Duck and Pink-eared Duck in Macleod Morass compared with Chestnut Teal or Grey Teal, sampling numbers were not high enough to draw conclusions as to the differences between species.

It was only possible to collect waterfowl for testing from a limited number of wetlands. It is therefore recommended that consumers of waterfowl should generally exercise caution when consuming waterfowl from sites near wetlands where current health advisories exist. For example, Reedy Lake is within 2 km of Hospital Swamp and waterfowl can freely move between these wetlands. Unless further evidence demonstrates otherwise, waterfowl harvested from Reedy Lake may be the same of those inhabiting Hospital Swamp. Further analysis of individual waterfowl will be completed by mid-2019 to determine the range of PFAS concentrations in waterfowl at this site to better inform advice for human consumption. In the interim, EPA recommends a precautionary approach for adults and children in restricting consumption of all species sourced from the affected wetlands

EPA is committed to providing ongoing advice to better understand the risk of exposure to PFAS and other emerging contaminants. Further investigation will continue to improve our understanding and management of the potential risks of PFAS to the environment and human health. Under the direction of EPA's Chief Environmental Scientist, EPA will continue to assess PFAS in the environment. This includes re-analysis of PFAS in individual waterfowl specimens from Hospital Swamp; further sampling for PFAS in sediments and waters to identify potential sources around Hospital Swamp and Macleod Morass; assessing ecological impacts; and engaging with the Interagency Working Group for Emerging Contaminants.

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