Assessment of pesticides in aquatic organisms – Ord River WA

Looking after all our water needs

Water resource technical series

Report no. 40

October 2008

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October 2008

ISSN 1327-8436 (print)
ISSN 1449-8901 (online)

ISBN 978-1-921508-79-0 (print)
ISBN 978-1-921508-80-6 (online)

Recommended reference

The recommended reference for this publication is:

Fredericks, DJ and Palmer, D W 2008, *Assessment of Pesticides in Aquatic Organisms - Ord River WA.,* Department of Environment, Government of Western Australia, Water Resource Technical Series Report No 40.

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Acknowledgements

This report was prepared by Consultant David Fredericks and Duncan Palmer from the Department of Water with the assistance of the Miriuwung Gajerrong Community. The Department of Water would like to thank the Miriuwung Gajerrong Aboriginal community for their input and advice during the development of this project and David Newry and KJ Olawsky from the Mirima Dawang Woorlab-gerring Language and Cultural Centre for the organisation and participation in field trips.

This project was funded by the Rangelands NRM Coordinating Group using National Action Plan for Salinity and Water Quality funding. Rangelands NRM Coordinating Group contracted the Department of Water (Kimberley Region) to undertake the project.

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When irrigation began in the Ord River irrigation area (ORIA) around Kununurra in the early 1960s, organochlorine pesticides (OCs) were commonly used and application on cotton crops reached very high levels. The last year that commercial cotton was grown in the ORIA was 1974.

Local people from the Miriuwung Gajerrong Aboriginal community utilise the Ord River and riparian area for food and local residents and visitors fish the lower Ord River immediately downstream of the irrigation area. In July 2003, the Department of Water and the local community catchment group, Ord Land and Water, met with the Miriuwung Gajerrong Aboriginal community and agreed that the best method to determine whether or not pesticides were a significant contaminant was through a program of sampling and chemical analysis.

The objective of this study was to provide a snapshot of organochlorine pesticide residues in bush foods both in and downstream of the irrigation area. The survey was exploratory in nature and did not include all species identified as forming part of the human diet of the local community. The results showed that persistent organochlorine and their breakdown products are still present in fish and plant material in trace amounts.

The major findings of this study are listed below.

- A wide range of OCs were detected in aquatic samples. Residue concentrations were at or below typical levels reported for agricultural areas of North America.
- The total concentrations of DDT and related substances were significantly higher than other OCs.
- The residual levels of ΣDDT compounds present in fish flesh, wallaby meat and plant species analysed in this study were all lower than the extraneous residue limits prescribed by Food Standards Australia New Zealand (FSANZ).
- Median levels of ΣDDT in (usually non-edible) fish offal are less than the extraneous residue limits set by the FSANZ for edible mammalian offal, although one sample of fish offal exceeded the limit.
- The concentrations of all other OC compounds in fish were less than the maximum extraneous residue limits prescribed by FSANZ.
- Dieldrin levels in wallaby meat were found to be elevated in the few samples collected, compared to the reference sample.
- Concentrations of OCs, including ∑DDT, have decreased by approximately two orders of magnitude since the 1970s.

- Concentrations of the DDT congeners in other fish species are unlikely to vary significantly from that measured in the barramundi, catfish and bream in this survey.

Recommendations

It is recommended that:

- People should avoid eating large qualities of offal (guts, gills, liver, and brain) from fish caught down stream of the Diversion Dam on the Ord River and bottom end of the Dunham River. Based on the highest recorded pesticide concentration, the safe limit for consumption of fish offal is 17g per day, every day, can be consumed. This is based on a 70kg adult.
- if any further sampling of traditional foods is undertaken, species not collected in this project should be targeted. This particularly applies to filter feeders such as freshwater mussels, benthic species such as red claw and cherabin and aquatic predators such as turtles and water monitors and especially those with high lipid contents.
- future sampling of fish and shellfish should use composite samples and follow protocols outlined by the United States Environmental Protection Agency for preliminary investigations. The number of samples to be collected for each species can be estimated using the data provided in this report.

1 Introduction

1.1 Regional setting

The Ord River is 650 km long and is located in the east Kimberley region of Western Australia. The Ord River is regulated by two dams which provide and regulate water for the Ord River Irrigation Area. The Kununurra Diversion Dam, located immediately upstream of the ORIA, was built in 1962. The Ord River Dam is located 50 km upstream of the Kununurra Diversion Dam and was completed in 1972. Construction of the dams created two water bodies, Lake Argyle and Lake Kununurra. Lake Argyle is impounded by the Ord River Dam and has a surface area of approximately 980 km^2 when full and has a maximum depth of 60 m in drowned gorge areas. Lake Kununurra is impounded by the Kununurra Diversion Dam and is approximately 50 km long with a maximum width of only 400 m. The lower Ord River lies downstream of the Kununurra Diversion Dam and stretches 150 km to the Cambridge Gulf. The Dunham River enters the lower Ord River approximately 2 km downstream of the Kununurra Diversion Dam, and is the only major tributary into the Lower Ord Figure 1.

Water stored in Lake Argyle is released to maintain a constant high level of water in Lake Kununurra which is then diverted through a series of channels for irrigation within the ORIA. The stable water levels of Lake Kununurra also support recreation and tourism activities. Water released from Lake Argyle is utilised by the hydro-electric power station at the Ord River Dam, which supplies power to the townships of Kununurra and Wyndham and to the Argyle Diamond Mine.

The irrigation areas are located in the Ivanhoe Valley (approximately 13 000 ha) and on the Packsaddle Plains (approximately 2500 ha). They are gravity-fed by a network of supply channels operated and maintained by the Ord Irrigation Cooperative. A single large supply channel (known as the M1) distributes water via a network of smaller supply channels which serve most of the irrigation area. Irrigators divert water directly from the supply network on to farm blocks through furrows in the paddock. Excess water flows off farms into a drainage channel network which discharges back into the Dunham River and the lower Ord River at various locations.

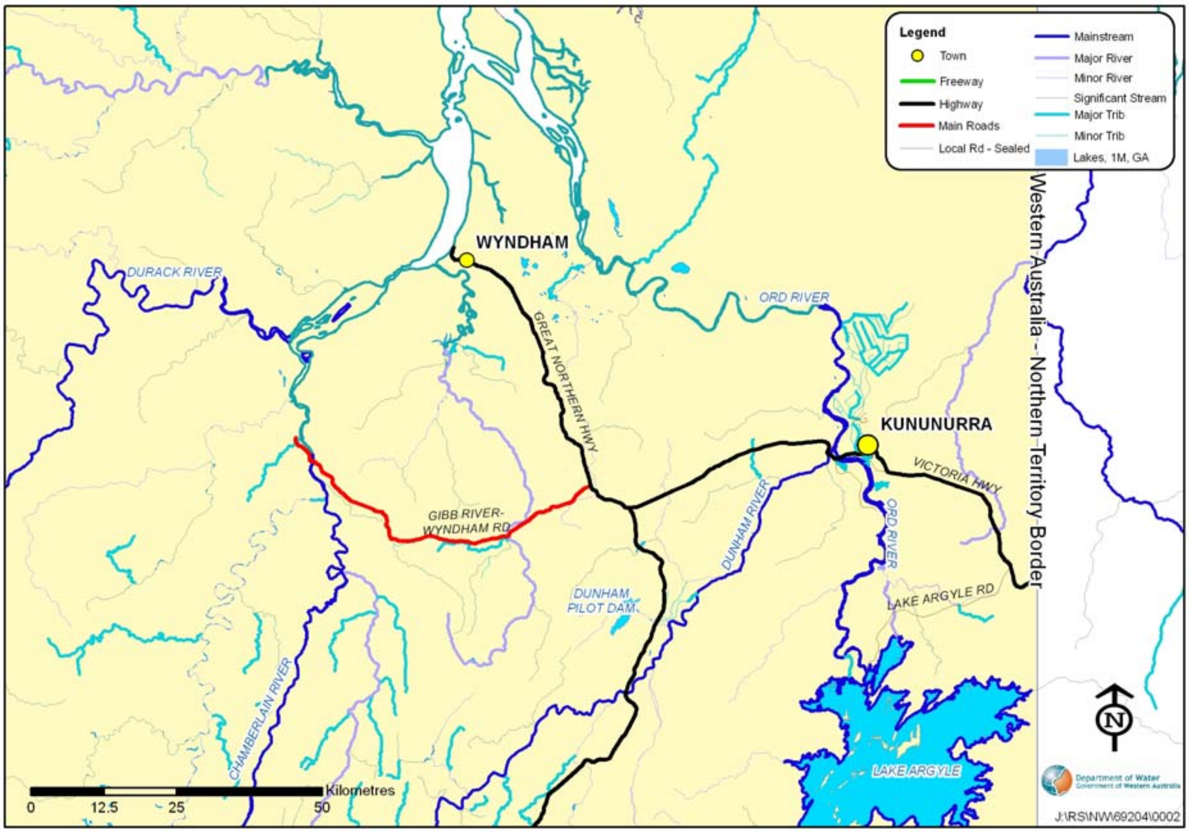

Figure 1 Regional map

1.2 The issue

While pesticide use today is closely controlled and consists mainly of compounds with relatively short half-lives in the environment, a number of significantly more persistent pesticides have been used in the past, sometimes at very high application rates. When irrigation began in Kununurra in the early 1960s, organochlorine pesticides were commonly used on crops. Application on cotton crops reached very high frequency (ten or more applications per year) and quantity, with some 128 t of DDT and 117 t of camphechlor applied to cotton crops in 1974, the last year that commercial cotton was grown in the ORIA (GCL 1979).

Monitoring of pesticides in the aquatic environment in the 1960s and 1970s not surprisingly found high levels of organochlorine pesticides (GCL 1979). While the monitoring found that levels of these pesticides in the environment declined after the collapse of the cotton industry, with the subsequent dramatic decrease in pesticide application (GCL 1979), little monitoring of residue levels in soils, sediments or biota and no assessment of bioaccumulation and biomagnification of OCs in the environment was undertaken. Pesticide monitoring virtually ceased between 1978 and 1997, when it was restarted.

Local people from the Miriuwung Gajerrong Aboriginal community utilise the Ord River and riparian area as an important source of food and local residents and visitors fish the lower Ord River immediately downstream of the ORIA. The Miriuwung Gajerrong Aboriginal community have expressed concern about the potential for high levels of agricultural chemicals (specifically pesticides from the irrigation area) in Ord River food-webs, especially in species used as a direct food source. In July 2003, the Department of Water and Ord Land and Water (the local community catchment group) met with the Miriuwung Gajerrong Aboriginal community to discuss these longstanding concerns. All parties agreed the best method to determine whether or not pesticides were a significant contaminant of bush food used by the Indigenous community in the region was through a program of sampling and chemical analysis.

In 2005 the then Department of the Environment (now Department of Water) undertook a pilot study (Palmer and Kennedy 2006), working with the Aboriginal community, to identify the presence or absence of ‘current-use’ and discontinued pesticides in organisms within the Ord River environment. The study found no detectable levels of ‘current use’ pesticides in the collected samples. However, the study found one specimen, a water monitor *Varanus mertensi*, had low but detectable levels (120 ng/g) of *p,p’*-DDE, an organochlorine compound which is both a component and a degradation product of commercial DDT, last used in the ORIA nearly 30 years prior to the sampling.

Following the detection of DDT congeners in this specimen, an analysis targeting OCs at ultra-trace levels was undertaken on a single sample of barramundi flesh. The analysis confirmed the presence of organochlorines and found DDT (10 ng/g) was the major OC present, with ultra-low trace amounts of HCB, HCH, lindane, dieldrin, heptachlor, chlordane, and mirex also detected. These results suggested that OCs used in the 1960s and 1970s are still present in the environment today. While the levels recorded were low and were not of concern from the perspective of human health (that is, they were below the FSANZ extraneous residue limits), the Department of Water decided that further investigations were warranted.

1.3 Objective

The objective of this program was to investigate the levels of persistent OC pesticides in a wider variety of plants and animals collected in and along the Ord River using ultra-trace analytical methods. Ultra-trace analytical methods are capable of detecting extremely low levels of contaminant. The sampling program was targeted at the plants and animals used by local Indigenous people as food sources, but focused particularly on aquatic food sources as these were expected to have the highest levels of persistent pesticide residues.

A broader objective of the project was to continue the involvement of local Indigenous people in water quality issues. An Indigenous person was employed during the project to participate in the sampling program and to liaise with the local Indigenous community.

1.4 Sampling design

The current survey was designed as a reconnaissance of OC levels in biological samples in the ORIA region. The survey includes a variety of sample types and site locations but has a low number of samples and replicates because of the limitations imposed by the cost of the ultra-trace analyses of samples. The survey therefore provides only an indication of the concentration and distribution of persistent agricultural chemicals in the plants and animals sampled, rather than a full scale survey with enough replication of analyses and samples to enable statistical validation.

A list of important bush foods and food gathering sites was developed in consultation with members of the local Miriuwung-Gajerrong Aboriginal community. This was used to design a sampling program that included target species and sampling sites. Additional locations that were considered to be heavily affected by agricultural drainage were also sampled. Some remote sites were sampled to provide background levels or reference conditions.

The target species identified with the Indigenous community were:

- fish – barramundi, black bream, bony bream, catfish, salmon
- crustaceans – red claw (freshwater crayfish) and cherabin (giant freshwater prawn)
- gastropods – fresh water mussels
- reptiles – water monitors (goannas), freshwater turtles
- mammals – agile wallaby
- plants – wild melon, wild passion fruit, bush cucumber, bush banana, fig tree, jiliyinybeng (bush goose berries), cane grass, and lily pads and roots.

Sites visited during the survey are listed in Table 1 and their locations are shown in Figure 2

Table 1 Locations from which samples were collected

Site	Site Code	Classification*
Kununurra Diversion Dam	OKDD	Reference
Lake Argyle – Revolver Creek	OLARVCK	Reference
Lake Argyle dam wall	OLADW	Reference
Lake Argyle middle	OLAMID	Reference
Lake Argyle north	OLANTH	Reference
Lake Argyle Ord mouth	OLAOM	Reference
Lake Argyle Remote Is	OLAREMI	Reference
Lake Argyle Ulysses Bay	OLAUSS	Reference
Pentecost BBQ Hole	PBBQH	Reference
Pentecost River – The Ledge	PLEDGE	Reference
supermarket – reference meat sample	OTOWN	Reference
Valentines Crossing	OVCRX	ORIA
Agricultural research station	OKRS	ORIA
Buttons Gap	OBUGAP	ORIA
D4 drain	OD4D	ORIA
Forbes Beach	OFORB	ORIA
Ivanhoe Crossing	OIVANX	ORIA
Ord–Dunham confluence	OODC	ORIA

*Reference – sample sites that are not affected by irrigation drainage water

ORIA – samples collected within or downstream of the ORIA

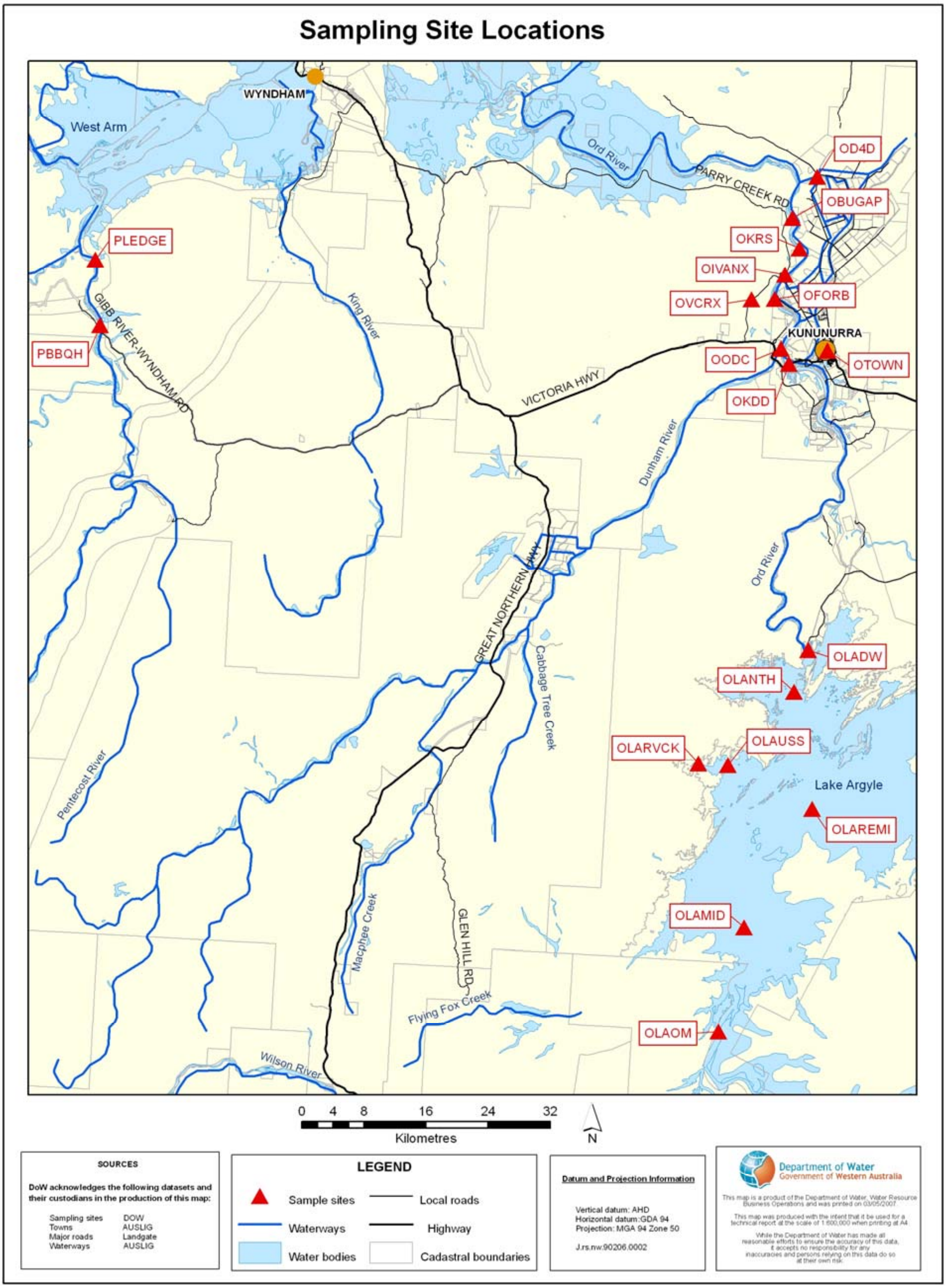

Figure 2 Map of the Ord River region showing sampling locations

1.5 Samples collected

A total of 38 biological specimens were collected for analysis from 13 sites (see Table 2) which included both reference sites located upstream or distant from the ORIA and ORIA sites located within, immediately adjacent to or downstream of the ORIA. In total, 29 fish specimens, 6 specimens of edible plant material and 2 wallaby specimens were collected in this study. One sample of meat (beef) was obtained from the local supermarket as a reference sample. Sampling was, of necessity, opportunistic and not all target specimens or species could be collected at the time of the survey.

Table 2 Sampling details for each food type

Class	Site name	Site code	No. of specimens	No. of samples
Fish				
ORIA	Buttons Gap	OBUGAP	3	8
ORIA	D4 drain	OD4D	2	4
ORIA	Ivanhoe Crossing	OIVANX	3	10
ORIA	Ord–Dunham confluence	OODC	3	17
Subtotal fish – ORIA			**11**	**39**
Reference	Kununurra Diversion Dam	OKDD	1	5
Reference	Lake Argyle Remote Is	OLAREMI	1	1
Reference	Lake Argyle – Revolver Creek	OLARVCK	1	3
Reference	Lake Argyle Ulysses Bay	OLAUSS	1	1
Reference	Pentecost BBQ Hole	PBBQH	1	2
Reference	Pentecost River – The Ledge	PLEDGE	2	10
Subtotal fish – reference			**7**	**22**
Bush food – meat				
ORIA	Ag research station	OKRS	2	4
Reference	supermarket – reference	OTOWN	1	1
Subtotal bush food – meat			**3**	**5**
Bush food – vegetable material				
ORIA	Buttons Gap	OBUGAP	2	2
ORIA	Forbes beach	OFORB	2	2
ORIA	Ivanhoe Crossing	OIVANX	1	1
ORIA	Valentines Crossing	OVCRX	1	1
Subtotal bush food – vegetable			**6**	**6**

Class	Site name	Site code	No. of specimens	No. of samples
Total samples			**27**	**72**

The fish species collected and the sub-samples of tissue analysed are listed in Table 3. The plant and animal material collected and analysed is listed in Table 4 and a detailed itemisation of the water and sediment samples collected and analysed is given in Table 5.

Table 3 Details of fish species collected and tissue samples analysed

Sample description	Sample type	ORIA	Reference	Total
barramundi	flesh	3	4	7
(*Lates calcarifer*)	gills	3	2	5
	liver	2	3	5
	visceral fat	2	2	4
barramundi total		**10**	**11**	**21**
bony bream	flesh	4		4
(*Nematalosa erebi*)				
	liver	1		1
	whole fish	3		3
bony bream total		**8**		**8**
bull shark	brain	1		1
(*Carcharhinus leucas*)	flesh	1		1
	liver	1		1
bull shark total		**3**		**3**
catfish	brain	1	1	2
(*Arius midgleyi*)	flesh	4	5	9
	gills	3	2	5
	liver	3	2	5
	visceral fat	2	1	3
catfish total		**13**	**11**	**24**
mullet	flesh	2		2
(*Liza vaigiensis*)	gills	1		1
	liver	1		1
mullet total		**4**		**4**
Total fish samples		**38**	**22**	**60**

Table 4 Terrestrial plant and animal material collected and sampled for chemical analysis

Sample description	Sample type	No. of samples		
		ORIA	Reference	Total
Plant material				
Wild passionfruit (*Passiflora foetida*)	Plant	1		1
Bush Peanut (*Brachychiton tuberculatus*)	Plant	1		1
Cluster fig (*Ficus racemosa*)	Plant	1		1
Flueggea (*Flueggea virosa*)	Plant	2		2
Leichhardt pine (*Nauclea orientalis*)	Plant	1		1
Total plant samples		**6**	**0**	**6**
Animal products				
Agile wallaby	Flesh – leg	2		2
(*Macropus agilis*)	Flesh – tail	2		2
beef (*Bos Taurus*)	Flesh		1	1
Total animal products samples		**4**	**1**	**5**

Table 5 Water and sediment samples collected for chemical analysis

Class	Site name	Site code	No. of samples
Sediment			
Reference	Lake Argyle Remote Is	OLAREMI	1
Reference	Pentecost River – The Ledge	PLEDGE	1
Total sediment samples			**2**
Water samples			
ORIA	Buttons Gap	OBUGAP	1
ORIA	D4 drain	OD4D	1
Reference	Lake Argyle dam wall	OLADW	1
Reference	Lake Argyle middle	OLAMID	1
Reference	Lake Argyle north	OLANTH	1
Reference	Lake Argyle Ord mouth	OLAOM	1
Reference	Lake Argyle Remote Is	OLAREMI	2
Reference	Lake Argyle Ulysses Bay	OLAUSS	1
Reference	Pentecost River – The Ledge	PLEDGE	1
Total water samples			**10**

1.6 Sample collection methods

Fish were caught using the following methods[1]:

- Gill nets (2, 4 and 8 inch aperture size) were used at the river sites to catch small to medium sized fish. Each net was approximately 30 m in length and was used by draping across the river for approximately 30 minutes.
- Lures, hooks and line were used to catch larger fish.

Each fish was identified, weighed and recorded in the field. Where size of the specimen permitted, samples of brain, muscle tissue and liver were collected from each fish.

Two wallabies were shot by a Department of Agriculture professional shooter.[3]

A minimum of 150 g of the edible component of each plant species was collected by hand.

All biological samples were double wrapped in aluminium foil, placed on ice and air-freighted to the National Measurement Institute laboratory for analysis.

1.7 Sample analysis

Concentrations of organochlorines were determined by High Resolution Gas Chromatography/High Resolution Mass Spectrometry using the institute's standard method (laboratory code AUTL_04). The prepared sample was freeze-dried then spiked with a range of isotopically-labelled surrogate standards. The sample was exhaustively extracted with an organic solvent, and the extract cleaned up using column chromatography on florisil. Immediately prior to injection, internal standards were added to each extract, and an aliquot of the extract injected into the gas chromatograph. The analytes were separated by the chromatograph and detected by a high-resolution (>10 000) mass spectrometer. Levels of OCs are reported in ng/g

[1] An 'Authority to take Fish for Scientific Purposes – SPA 7/05' was obtained from the Department of Fisheries.

[2] A 'Licence for Scientific or other prescribed purposes – SW010163' was obtained from the Department of Conservation and Land Management.

[3] A 'Licence to take Fauna for Scientific Purposes – SF005465' was obtained from the Department of Conservation and Land Management.

(lipid) and ng/g (fresh weight) for biological samples, ng/L for water samples and pg/g for sediments. All results were corrected for labelled surrogate recoveries and are reported on a dry weight basis.

Descriptions of the pesticide mixtures and the individual compounds determined are given in Table 6.

Table 6 Description of organochlorine compounds analysed by National Measurement Institute

Pesticide	**Description**	**Analytes**
lindane	Hexachlorocyclohexane (HCH) is a manufactured chemical that exists as eight chemical isomers. One of these isomers, gamma-HCH (or γ-HCH), has the common name lindane and is used as an insecticide on fruit, vegetables, and forest crops.	beta (β)-and gamma (γ)-HCH
aldrin and dieldrin	Organochlorine insecticides with similar chemical structures and very similar toxicological properties. The extraneous residue limits from the Australia New Zealand Food Standards Code are set for the combined concentration of both compounds (see Appendix 3).	aldrin dieldrin
heptachlor	An organochlorine insecticide used in buildings and on food crops. Heptachlor rapidly breaks down to heptachlor epoxide. Heptachlor and heptachlor epoxide are generally treated together in toxicological and environmental assessment. Heptachlor is also both a degradation product and component of the pesticide chlordane.	heptachlor and heptachlor epoxide
chlordane	An organochlorine insecticide. Technically chlordane is not a single chemical but is a mixture of many related chemicals including *trans*-chlordane, *cis*-chlordane, β-chlordene, heptachlor and *trans*-nonachlor. Oxychlordane is an oxidation product of chlordane that persists in the body.	oxychlordane *trans*-chlordane *cis*-chlordane *trans*-nonachlor
DDT	A pesticide that was used widely to control insects on agricultural crops and insects that carry disease (malaria and typhus). Technical-grade DDT is a mixture of two isomers – *p,p'*-DDT (85%) *o,p'*-DDT (15%) and trace amounts of the related compounds (congeners) DDE and DDD. DDE is the major breakdown product of DDT.	*p,p'*-DDE *p,p'*-DDD *o,p'*-DDT *p,p'*-DDT
mirex	An organochlorine pesticide mostly used to control termites.	mirex
hexachlorobenzene (HCB)	A widely used organochlorine pesticide. It is also formed as a by-product during the manufacture of chemicals used as solvents, other chlorine-containing compounds, and pesticides. Small amounts of hexachlorobenzene can also be produced during combustion processes such as burning of city wastes and as a by-product of chlor-alkali and wood-preserving industries.	hexachlorobenzene

2 Results

The results of the chemical analyses for fish and meat are given in Appendix 1 and for the plant samples in Appendix 2. A total of 60 fish samples, 6 vegetable samples, 5 (non-fish) animal samples, 2 sediment samples and 10 water samples were analysed for OC levels. The following discussion therefore focuses largely on OC levels in fish.

3 Discussion

3.1 Organochlorine pesticides that were detected

A wide variety of organochlorine compounds were detected in trace levels in aquatic samples (see Table 7), largely because of the very low detection limits achieved by the analytical methods used in this survey.

The DDT congeners were the most commonly detected with highest concentrations found in fish samples (see Table 7). The DDT congeners were detected in all fish samples analysed. Of these congeners, *p,p'*-DDE was in the highest concentrations. Maximum levels of *p,p'*-DDE recorded in this study were 7930 ng/g fresh weight found in the visceral fat (fat from inside the body cavity) of an 84 cm catfish caught at the confluence of the Ord and Dunham rivers on 16 August 2006. By comparison, the muscle tissue sampled from the same fish recorded a *p,p'*-DDE concentration of 85 ng/g. This preferential accumulation within the fatty tissue of fish was commonly observed in this survey (see figures 5 and 6).

As expected, the OC content of all fish samples was dominated by *p,p'*-DDE which had a median concentration of 12.5 ng/g fresh weight. The DDT congenor with the next highest concentration was *p,p'*-DDT with a median concentration of 0.185 ng/g fresh weight, approximately two orders of magnitude lower than *p,p'*-DDE. The major contribution to the concentration of *p,p'*-DDE isomer is most likely from degradation of DDT. Its dominance over the other components is consistent with the distribution of DDT congeners from degraded technical grade DDT, which was banned from use in Australia in the 1970s.

Dieldrin was the next most commonly detected pesticide in fish after *p,p'*-DDE and *p,p'*-DDT, with a median concentration of 0.27 ng/g fresh weight and a maximum concentration of 6.3 ng/g fresh weight. The highest dieldrin concentration was 62 ng/g fresh weight measured in the wallaby sample. While dieldrin and the other pesticides were widely detected, concentrations were generally at least two orders of magnitude lower than *p,p'*-DDE.

All other OCs, whilst detected in most samples of plant, meat and fish, were present at trace levels only and well below allowable limits in food.

Table 7 Concentrations of organochlorine pesticides measured in all fish samples

Substance name	Number of samples	Number of samples > detection limit	Percent samples > detection limit	Median ng/g fresh weight	Maximum ng/g fresh weight
p,p'-DDE	60	60	100	12.5	7930
p,p'-DDT	60	60	100	0.205	32
dieldrin	60	58	97	0.28	6.3
p,p'-DDD	60	58	97	0.26	25
trans-nonachlor	60	57	95	0.041	2.0
o,p'-DDT	60	56	93	0.0185	2.8
mirex	60	54	90	0.021	2.1
HCB	60	47	78	0.046	1
heptachlor epoxide	60	45	75	0.014	0.36
oxychlordane	60	45	75	0.016	0.63
aldrin	60	43	72	0.017	0.96
cis-chlordane	60	39	65	0.036	0.89
beta-HCH	60	26	43	0.023	1.9
trans-chlordane	60	24	40	0.265	8.4
heptachlor	60	16	27	0.0051	0.11
gamma-HCH	60	11	18	0.0225	0.03

3.2 Concentrations of organochlorine pesticide in the sample types

Total DDT congener concentrations – ΣDDT – and most other OCs were highest in the fish samples (Figure 3) followed by terrestrial animal samples (wallabies), concentrations of which were an order of magnitude lower than in fish samples. The lowest levels of ΣDDT were detected in terrestrial vegetation, which had levels approximately an order of magnitude lower than in terrestrial meat samples. Although the number of terrestrial meat and vegetation samples analysed was relatively small compared with the number of fish samples, low concentrations of ΣDDT in the terrestrial samples supports the expectation that there are few mechanisms for bioaccumulation or biomagnification within terrestrial species.

This study found no apparent differences in the levels of ΣDDT between fish species and that all fish species collected showed elevated levels of ΣDDT in at least one sample. DDT and other OC pesticides are highly soluble in fat and as expected, the highest levels of OCs were found in fatty tissues of fish, including visceral fat, liver, brain, and gills. The concentrations of DDE measured in fish flesh (muscle tissue) were comparatively low (see Figure 5).

In contrast, dieldrin, the next most commonly detected organochlorine after DDT, occurred in the highest concentration in terrestrial meat samples. The highest concentration was 350 ng/g lipid[2], [3] (0.350 mg/kg). In comparison, the concentration of the reference sample (supermarket beef) was 2.1 ng/g.

OCs were largely undetectable in water samples even using ultra-trace analytical methods. The highest concentration of the DDT congeners measured was 2.3 ng/L (or approximately 0.0023 ng/g or 2.3 pg/g) in water collected in the D4 drain of the ORIA.

Most OCs tested were detected in the reference sediment samples, but only at very low concentrations. The highest concentration of OCs in the two sediment samples was of *trans*-chlordane at 830 pg/g (0.83 ng/g). The highest level of *p,p'*-DDE was 250 pg/g (0.25 ng/g) and the highest level of dieldrin was 240 pg/g (0.24 ng/g).

3.3 Locations of with the highest levels of organochlorine pesticide

The levels of ΣDDT in fish were significantly higher in sites within and immediately downstream of the ORIA in comparison to the upstream and reference sites (Figure 6). This reflects the very high levels of DDT application in the ORIA. The five highest levels of ΣDDT were detected in fish caught at the confluence of the Ord and Dunham Rivers, Ivanhoe Crossing, the D4 drain and at Buttons Gap. Elevated levels of OC found in fish collected downstream of the ORIA probably reflect a combination of OC transport from the ORIA by runoff erosion and sediment transport but may also result from the movement of fish into and out of the ORIA during their lifecycles (fish are prevented from moving upstream of the ORIA by the Kununurra Diversion Dam).

Aldrin, dieldrin, heptachlor and chlordane concentrations in fish showed a similar geographic distribution to ΣDDT but the relative differences between ORIA and reference sites were smaller since these OCs were only detected at ultra-trace levels.

3.4 Results of this survey compared with other recent studies in the ORIA

A recent study of organochlorines in freshwater and saltwater crocodiles in the Ord River (Yoshikane et al. 2006) also found very high levels of DDT congeners (mainly

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[2] Concentration in lipid extract from meat is not directly comparable to concentrations in fat and will tend to overestimate concentrations.

[3] This is calculated from the concentration expressed as ng/g fresh weight in Table 15 by dividing by the lipid content.

p,p'-DDE). Visceral fat and liver samples from specimens collected in the upper Ord, the ORIA and the lower Ord were analysed for a wide range of organochlorines. The highest concentrations of DDE were found in the visceral fat of freshwater crocodiles collected from the lower Ord and drains of the ORIA (see Table 8). Very high concentrations were also found in the livers.

The study also detected trace levels of camphechlor and heptachlor but concentrations of these OCs were orders of magnitude lower than *p,p'*-DDE levels.

Table 8 Concentrations of *p,p'*-DDE in visceral fat and livers of freshwater crocodiles collected from ORIA drains and the Ord River downstream of the ORIA

	DDE in visceral fat ng/g fresh weight[1]		DDE in liver ng/g fresh weight[1]	
	mean	max	mean	max
Lower Ord	~28 000	~66 000	~500	~3200
ORIA	~14 000	~33 000	~3000	~8000

Source: Yoshikane et al. 2006

Concentrations have been converted from ng/g lipid to fresh weight using average lipid concentrations reported by authors.

Significantly higher levels of ΣDDT have also been found in freshwater crocodiles collected in the ORIA (Yoshikane et al. 2006, see Table 9). Levels of ΣDDT in saltwater crocodiles were lower than in freshwater crocodiles, and high levels of ΣDDT are not expected to be found in freshwater crocodiles from locations away from the ORIA.

Table 9 Median concentration of ΣDDT in freshwater crocodile collected in the ORIA drains and downstream of the ORIA and the maximum allowable daily consumption (kg) for adults

	Mean concentration of ΣDDT in crocodile sample ng/g fresh weight	Tolerable daily intake of foodstuff for adults weighing 60 and 80 kg kg	
		60	80
Lower Ord			
crocodile visceral fat	28 200	0.02	0.03
crocodile liver	507	1.2	1.6
Ord drains			
crocodile visceral fat	13 548	0.04	0.06
crocodile liver	3 023	0.20	0.27

Source: Yoshikane et al. 2006

Pesticide concentrations in fish today are an order of magnitude lower than levels measured by GCL in 1979. The median concentration of DDT in fish muscle sampled in the lower Ord River near the ORIA in the 1970s was 420 ng/g, with a maximum level of 8800 ng/g recorded in a bony bream. The median concentration of DDT in fish flesh sampled from the ORIA in this survey was 6.7 ng/g (fresh weight) which represents two orders of magnitude reduction in DDT levels over a period of 30 years.

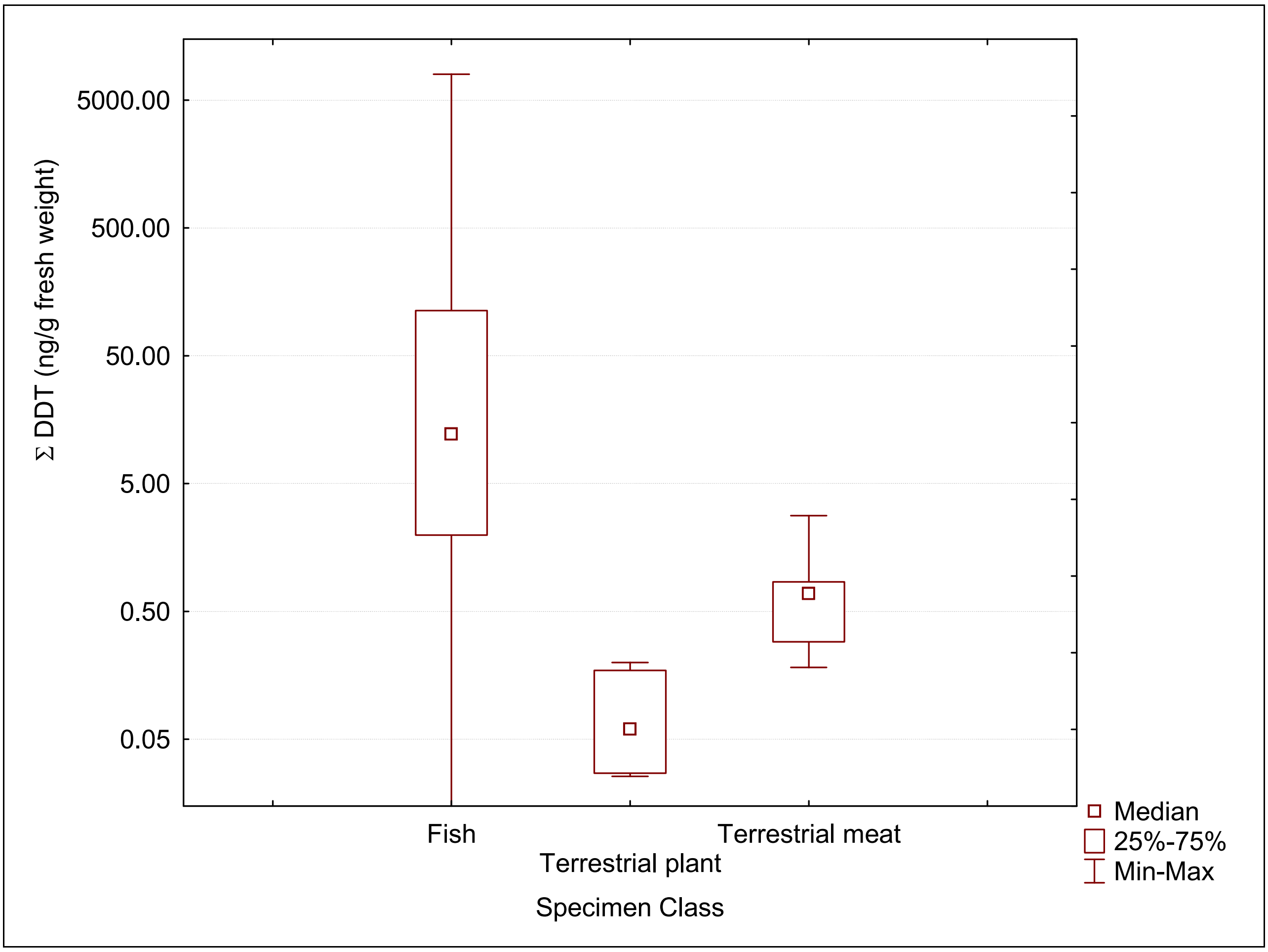

Figure 3 Comparison of the sum of DDT congeners (ΣDDT) levels in fish, plant and meat samples from all samples and all locations. Note the ΣDDT is expressed on a logarithmic scale

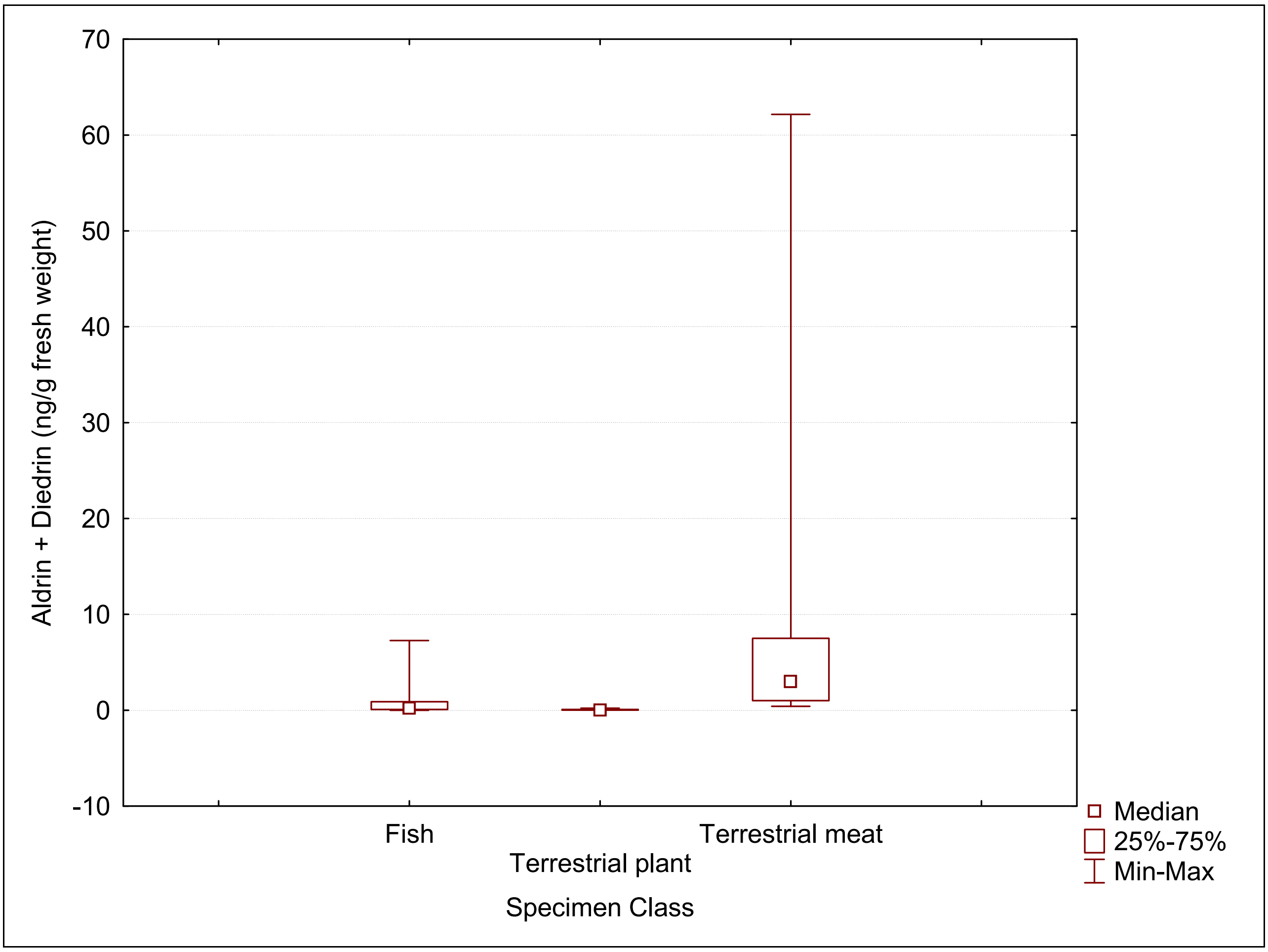

Figure 4 Comparison of aldrin and dieldrin levels in fish, plant and meat samples from all samples and all locations

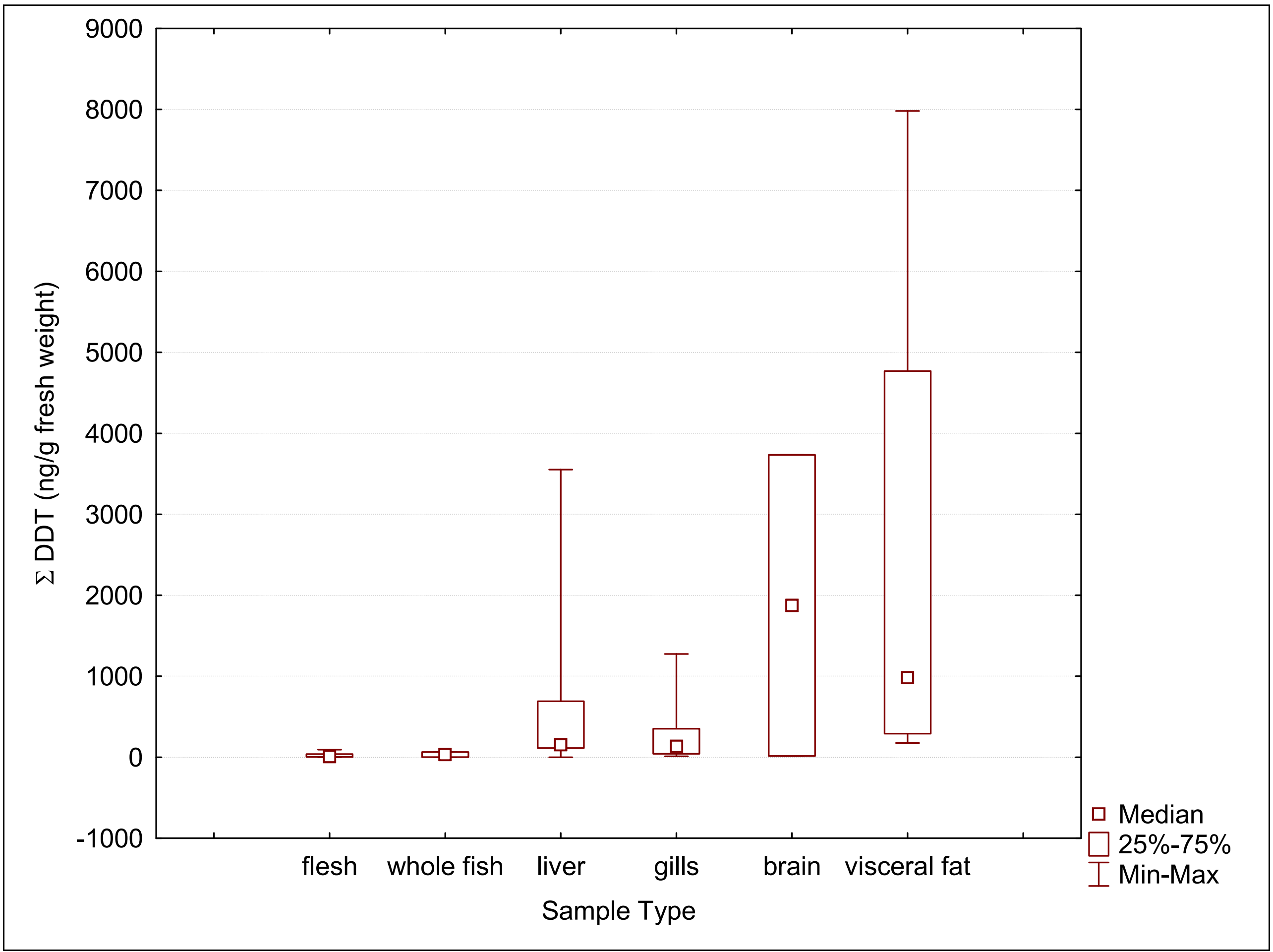

Figure 5 Concentrations of ΣDDT in flesh, gills, liver visceral fat, brain and in whole fish samples collected in this study.

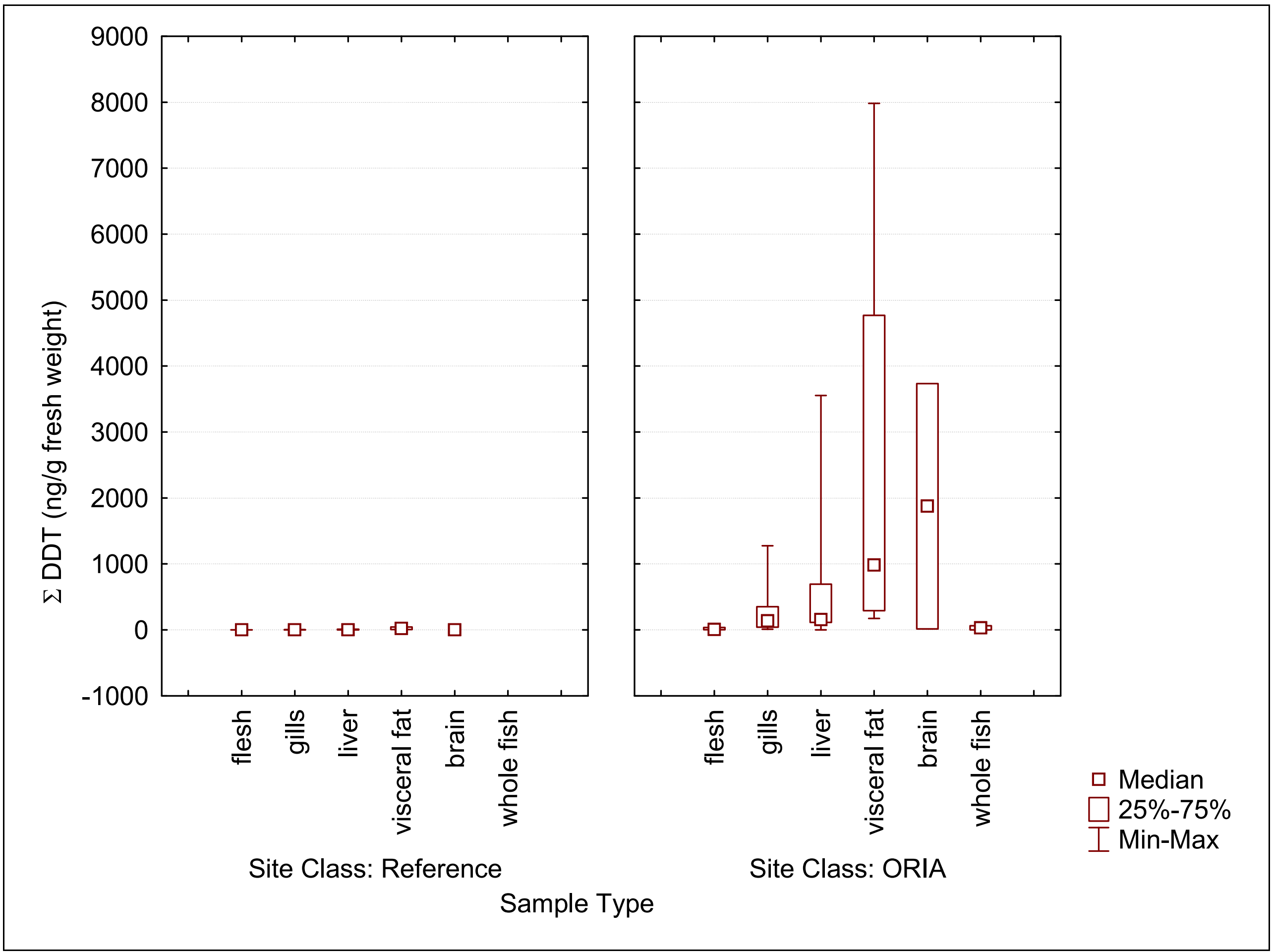

Figure 6 Comparison of ΣDDT levels in fish samples collected at reference sites and sites within or immediately downstream of the ORIA

3.5 Human health consequences

The allowable limit of pesticide residue in food products in Australia is set in Part 1.4 (Contaminants and Residues) of the Australia New Zealand Food Standards Code. There are two different standards for pesticide residues, based on their type and application. These two standards are the extraneous residue limit (ERL) and the maximum residue limit (MRL).

Extraneous residue limit

This is the maximum permitted limit of a pesticide residue arising from environmental sources other than the use of the pesticide directly or indirectly on the food, expressed in milligrams of the chemical per kilogram of the food (mg/kg).

Maximum residue limit

This is the maximum level of a chemical which is permitted to be present in a food, expressed in milligrams of the chemical per kilogram of the food (mg/kg) unless otherwise stated.

This study found that the mean concentration of ΣDDT in fish flesh in the ORIA was 22 ng/g (median 6.7 ng/g), substantially less than the ERL of 1000 ng/g for fish. Five samples taken from fish specimens collected in this survey contained ΣDDT in excess of this ERL(see Table 10). All of these samples were collected from usually non-edible portions of the fish (the brain, liver, visceral fat or gills) for which there is no direct standard. One of these samples, collected from a fork-tailed catfish (Sample ID 200604916) contained a concentration of ΣDDT of 7891 ng/g in the visceral fat, which also exceeded the ERL for edible offal and meat fat (5000 ng/g) which is the most similar food type to the sample analysed.

Table 10 Samples with ΣDDT concentrations above the extraneous residue limit

Sample	Location	Specimen	Sample description	ΣDDT
200507324	Buttons Gap	catfish	brain	3734
200507350	Ivanhoe xing	bull shark	liver	3553
200604912	Ord–Dunham confluence	catfish	visceral fat	1558
200604916	Ord–Dunham confluence	catfish	visceral fat	7981
200604919	Ord–Dunham confluence	catfish	gills	1275

The levels of DDT found in crocodiles by Yoshikane et al, (2006), were extremely high compared to all ERL standards. While the FSANZ does not prescribe pesticide residue limits for crocodile, the measured values exceeded both the Australian ERLs for fish (1000 ng/g) and the highest ERL prescribed, that is for edible offal from mammalian and poultry meat (5000 ng/g fresh weight in the fat)

An acceptable daily intake (ADI) is an estimate of the amount of a chemical that can be ingested daily over a lifetime without appreciable risk to health. The ADI for DDT according to Food Standards Australia New Zealand is 0.002 mg/kg body weight/day (FSANZ 2003). Estimates of the allowable quantity of crocodile offal which may be consumed were calculated, even though neither freshwater nor saltwater crocodile form part of the diet of the local population at present. These calculations, based on the results from Yoshikane et al. (2006) and using an ADI of 0.01 mg/kg body weight are shown in Table 9. Allowable quantities for adult human consumers range from as little as 40 g of visceral fat from crocodiles collected from the Ord drains to 1.6 kg of liver collected from crocodiles in the Lower Ord.

Dieldrin had a median concentration of 0.27 ng/g fresh weight and a maximum concentration of 6.3 ng/g fresh weight. These concentrations are well below the ERL for dieldrin and aldrin combined, namely 100 ng/g fresh weight.

All other OCs in meat and fish samples were well below ERLs and were of no health concern. OC levels in plant material were even lower and also present no health risks. For example, the median concentration of HCB was 0.046 ng/g fresh weight compared to the ERL of 100 ng/g fresh weight. The maximum measured value in the fish samples was 1 ng/g.

3.6 Source of the organochlorine pesticides

The highest concentrations of DDT congeners were detected in samples from the ORIA. Large amounts of DDT were applied to cotton crops that were grown in the area during the 1960s and early 1970s. A total of 128 tons of DDT and 117 tons of camphechlor were applied in the ORIA, mainly to cotton, prior to 1974 (GCL 1979). The widespread application of persistent OCs ceased after this date following the collapse of the cotton industry.

Studies undertaken during the 1970s (GCL 1979) noted high levels of both DDT and camphechlor in soils and particularly in sediments collected from drains, but relatively low levels of OCs in soils in areas not growing cotton and only exposed to spray drift. These studies also found high levels of pesticides in fish collected in the ORIA drains and in the lower Ord River, with some samples in excess of present day ERLs for fish.

3.7 Persistence of DDT congeners in environmental samples

Organochlorines such as the DDT congeners have a high affinity for soil and sediment particles and a relatively low solubility in water and are therefore retained within the soils and sediments of the ORIA. Monitoring undertaken in the 1970s (GCL 1979) found that levels of pesticides in the soils and sediments in the tail drains decreased greatly, largely as a result of bacterial activity (biotransformation and biodegradation) and loss of volatile compounds to the atmosphere (evaporation). While OCs are largely bound to soil particles and mostly retained within the ORIA itself, soil erosion and the transport of sediments represent the probable pathway by which these compounds were transported away from their point of application and delivered into the aquatic environment.

Organochlorines that remain bound to sediments in the aquatic environment will continue to degrade microbially, but loss of volatile compounds to the atmosphere is reduced. The presence of DDT congeners in fish and crocodile samples collected in 2005 and 2006, some 30 years after the use of DDT pesticides was banned in Australia reflects the properties of DDT compared to other OCs.

Some of the factors which may be responsible for the high levels of DDE found in recent samples collected from the ORIA are discussed below.

The high fat content of samples

DDT and its primary degradation product DDE are highly insoluble in water (hydrophobic) but highly soluble in oils and fats (lipophilic). The highest concentrations of the DDT congeners are therefore found in samples and specimens with highest fat contents (such as visceral fat and liver). These tissues do not usually form a major component of the human diet, but they can under some circumstances, such as in some traditional Indigenous food preparation methods.

Bioaccumulation

Lipophilic substances cannot be excreted in urine, a water-based medium, and so accumulate in fatty tissues of an organism if the organism lacks enzymes to degrade them.

Biomagnification

When eaten by another organism, the fats present in the prey are absorbed into the gut of the predator, carrying with it lipophilic substances such as DDT. If the biology of the predator precludes it from eliminating these substances, they will accumulate in higher concentrations in their lipids than they did in those of the prey. High level predators such as crocodiles, barramundi, sharks and omnivorous species such as fork-tailed catfish can contain very high concentrations of bio-pollutants as they are accumulated from one trophic (energy) level to the next. For example from algae to fish, to predator fish, to top level predators such as birds of prey, sharks, barramundi and crocodiles.

Exposure to DDT in drains

Direct accumulation of DDT from fine grained organic sediments particularly by bottom-dwelling species or individual organisms that enter the drainage network, such as catfish and bream.

Limited home range

Species or individual organisms that remain in close proximity to pollutant sources will tend to accumulate higher levels of pollutants than migratory species or species that have a wider home range and which therefore spend less time accumulating pollutants.

Long lifespan

Species such as crocodiles and barramundi are sufficiently long-lived to have been exposed to high levels of DDT present during the 1970s and early 1980s

3.8 How do these levels compare to other areas?

It is difficult to make detailed comparisons of pesticide residue concentrations between different areas and between different studies due to differences in the design of the surveys. These differences include the species collected, sample tissue type (for example, whole fish, muscle visceral fat), analytical methods, detection levels, reporting and the date at which different studies are undertaken. Despite these difficulties some very general but useful comparisons can be made between results from other studies and those from this study.

In general, DDT congeners persist in a wide range of organisms all over the world. In Australian-based studies, detectable levels of DDE in eels (20–70 ng/g) and mullet roe (20 ng/g) have been reported in Queensland rivers (anon. 2003). Similar levels (40 ng/g) were found in fish flesh near a sewage outfall in Sydney (Miskiewicz and Gibbs 1994). The National Residue Survey (NRS) <http://www.daff.gov.au/agriculture-food/nrs> in Australia tests for pesticide residues in a wide range of export food products. In 2003 the NRS reported detections of ΣDDT (where detection is defined as ΣDDT > 10 per cent of the ERL) in 20 out of the 1863, or 1.1 per cent, of animal food samples it had tested, although no samples exceeded the ERL.

As discussed earlier, the highest concentrations of DDT congeners are frequently found in top level predators because DDT both bioaccumulates and biomagnifies. For example, in 2000 ΣDDT concentrations reported in top predator fish in the Great Lakes in the USA were approximately 1000 ng/g which was approximately 6 per cent of the level recorded in the 1970s. The USEPA website has details of their monitoring results. See <http://www.epa.gov/glnpo/monitoring/fish/contaminant_concentrations.html>. ΣDDT levels in fish muscle in the ORIA (median = 6.7 ng/g and maximum = 95 ng/g) are roughly comparable with levels reported elsewhere in Australia but lower than levels reported for top level predator fish in the Great Lakes of North America. Very high concentrations of DDT compounds have been found in crocodiles in the ORIA probably because of their longevity, direct environmental exposure and position in the food chain as a top level predator.

Dieldrin is another commonly reported OC of environmental concern. The limited number of samples of wallaby meat in the ORIA prevented detailed assessment but dieldrin levels were elevated in the wallaby meat samples compared to the fish samples and the single meat reference sample (supermarket beef). Dieldrin, like DDT and other OCs, is relatively persistent in the environment and is one of the residues monitored by the NRS. Recent reporting (NRS 2004–05) of residues in beef found dieldrin at >10 per cent of the ERL in six out of 1096 samples tested and in two of these cases levels exceed the ERL. The NRS data show that it is unusual but not unprecedented to detect dieldrin in export beef (the export beef industry is specifically monitored and managed to minimise residue levels to protect Australia's export industry).

3.9 Other traditional foods not analysed for levels of OC pesticides

Target species identified in this study but not sampled were:

- Black bream (*Hephaestus jenkinsi)*
- Salmon (*Eleutheronema tetradactylum)*
- Red claw (freshwater crayfish) (*Cherax quadricarinatus*)
- Cherabin (giant freshwater prawn) (*Macrobrachium rosenbergii*)
- Freshwater mussels
- Water monitors (*Varanus mertensi*)
- Freshwater turtles

In this study we found that the levels of DDT congeners did not vary greatly between fish species although the number of samples analysed was limited. Similar pesticide studies undertaken in the ORIA in the 1970s (GCL 1979) also found that the differences in DDT levels between fish species was relatively small, but with the highest levels of DDT being found in fork-tailed catfish and barramundi. Studies of DDT and other pesticides in Lake Kariba on the Zambesi River in central Africa (Berg et al. 1992) found some significant variations between DDT levels in invertebrates, fish and crocodile species. Highest levels of DDT congeners were found in bottom dwelling, filter feeding mussels (10 100 ng/g fat), bottom-feeding fish (5700 ng/g fat) and predatory tigerfish (5000 ng/g fat).

The data reported above suggest that the concentration of DDT and other OCs in fish does not vary greatly between species, and that tissues from invertebrate filter feeders, other filter feeders and crocodiles are expected to contain elevated levels of DDT. Within the ORIA, it is therefore likely that freshwater mussels growing within or immediately downstream of drain outlets would be expected to have somewhat higher levels of OCs than that found in fish in the same environment.

Appendix 1 Pesticide levels in fish samples

Table A1 Pesticide levels (ng/g in lipid fraction) in fish collected in or downstream of ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507321	Buttons Gap	3/2/06	bony bream	flesh	5.3	<0.2	<0.03	0.39	5.4	<0.2	0.33	0.31	<5	0.78	0.77	750	9.8	1.3	19	0.099	0.99
507322	Buttons Gap	3/2/06	bony bream	liver	9.2	<0.9	0.067	6.2	21	1.2	2.2	4.3	44	7.8	8.4	1 580	20	1.2	32	0.29	1.8
507323	Buttons Gap	3/2/06	bony bream	whole fish	0.9	<0.4	0.046	0.24	5.9	0.5	0.41	0.23	14	1.5	2.4	3 570	33	2.5	56	0.37	1.7
507324	Buttons Gap	3/2/06	catfish	brain	31.5	<0.3	<0.02	2.1	12	<0.5	1.1	2	16	2.8	5.6	11 800	36	0.6	42	1.9	1
507325	Buttons Gap	3/2/06	catfish	Gills	3.4	<0.3	<0.90	<0.09	5.7	<0.1	<0.8	<0.3	<3	0.32	1.9	10 300	28	0.77	33	1.6	0.45
507326	Buttons Gap	3/2/06	catfish	liver	7.9	<0.4	<0.05	<0.30	5.3	<0.3	0.61	0.84	<10	1.4	2.1	3 330	16	0.074	1.8	0.51	0.62
507327	Buttons Gap	3/2/06	catfish	flesh	1.4	<0.1	<0.50	<0.04	3.6	<0.2	0.28	<0.2	<6	0.57	1	2 770	11	0.24	7.7	<0.5	0.36
507328	Buttons Gap	3/2/06	mullet	flesh	1.1	<0.2	<0.04	0.22	4.8	<0.3	0.53	0.3	10	1.4	1.5	300	5.1	1	4.5	<0.1	0.68

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507346	Ivanhoe xing	10/2/06	barramundi	flesh	0.4	0.41	<0.08	1.5	13	<0.6	3	0.28	29	4	3.2	720	9.4	0.86	6.5	0.25	3.4
507348	Ivanhoe xing	10/2/06	barramundi	gills	9.3	0.17	<0.20	0.65	4.9	<0.1	<0.6	<0.06	<4	<0.6	0.94	1 400	28	1.3	16	0.47	<1
507349	Ivanhoe xing	10/2/06	bull shark	flesh	0.6	0.34	<0.04	0.93	12	<0.6	2.1	0.17	22	3.7	3.3	1 230	23	0.17	2.8	0.34	2.6
507350	Ivanhoe xing	10/2/06	bull shark	liver	76.5	<0.2	0.031	0.44	6.2	<0.1	0.31	0.48	4.5	1.1	2.4	4 580	15	0.38	41	2.8	1.4
507351	Ivanhoe xing	10/2/06	bull shark	brain	6.3	0.37	0.064	0.76	7.1	<0.4	1.6	0.25	13	1.9	1.8	240	3.7	0.24	3.9	0.22	<1
604864	Ivanhoe xing	9/5/06	barramundi	liver	29.3	<0.9	<0.10	0.33	4.8	<0.2	0.4	0.21	<6	<0.7	0.66	430	12	0.8	6	0.17	0.72
604865	Ivanhoe xing	9/5/06	barramundi	visceral fat	82.6	<0.4	0.036	0.13	3.6	<0.1	<0.2	0.18	<3	<0.4	0.33	470	13	0.97	6.1	0.15	0.74
604866	Ivanhoe xing	9/5/06	barramundi	gills	8.0	0.49	<0.07	0.15	4.6	<0.1	0.17	0.19	<4	0.58	0.64	490	5.7	0.91	6.4	0.24	0.79
604867	Ivanhoe xing	9/5/06	barramundi	flesh	3.2	<0.3	<0.04	0.34	4.7	<0.3	0.36	0.3	<6	0.64	0.54	450	5.1	1	5.9	0.19	0.96

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604904	D4 drain	16/8/06	bony bream	whole fish	2.0	0.28	<0.06	<0.10	12	<0.10	0.36	0.27	<5	0.87	0.63	2 700	37	5	29	<0.2	1.5
604905	D4 drain	16/8/06	mullet	gills	1.8	0.44	<0.20	2.9	10	0.32	0.62	0.68	12	<4	1.9	5 660	77	17	65	0.13	1
604906	D4 drain	16/8/06	mullet	liver	14.5	<0.6	<2.0	<0.05	6.4	<0.01	0.94	0.57	<10	1.3	1.4	5 390	170	20	69	<0.2	1.4
604907	D4 drain	16/8/06	mullet	flesh	3.4	1.1	<0.09	4.6	17	<1.0	1.2	0.68	51	5.1	4.8	2 650	66	6.2	28	<0.7	1.1
604908	Ord–Dunham conflnce	16/8/06	bony bream	whole fish	2.1	0.24	0.15	1.1	6.2	0.17	0.18	<0.1	5.6	0.53	0.42	75	7.9	1.3	8.7	0.13	0.93
604909	Ord–Dunham conflnce	16/8/06	bony bream	flesh	0.7	1.2	<0.09	1.2	12	0.39	0.51	0.18	14	<3	1.4	250	9.6	0.72	6.3	0.13	0.89
604910	Ord–Dunham conflnce	16/8/06	bony bream	flesh	1.6	0.75	<0.50	<2.00	15	0.42	0.48	<0.1	12	1.5	1.1	140	8.6	0.77	7.8	0.23	0.93
604911	Ord–Dunham conflnce	16/8/06	bony bream	flesh	2.6	0.99	<0.20	<0.60	20	0.89	0.5	0.26	13	1.4	1.2	140	7.5	0.48	5.3	0.13	1.2
604912	Ord–Dunham conflnce	16/8/06	catfish	visceral fat	84.2	0.15	<0.02	0.95	6.3	<0.1	0.16	0.2	5.1	0.38	1.1	1 810	22	0.16	23	1.1	0.4

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604913	Ord–Dunham conflnce	16/8/06	catfish	liver	7.9	0.46	<0.07	<2.00	8.1	<0.5	0.35	<0.3	<10	1.5	1.4	1 420	29	0.1	7.2	0.75	0.5
604914	Ord–Dunham conflnce	16/8/06	catfish	gills	14.7	0.15	<0.01	0.78	5.3	0.16	0.11	0.17	3.4	0.31	0.67	1 410	26	0.18	17	0.73	0.33
604915	Ord–Dunham conflnce	16/8/06	catfish	flesh	0.6	<0.3	<0.10	<0.20	7.4	0.45	0.7	<0.04	<10	<0.9	<1	1 240	4.5	0.14	11	0.65	0.68
604916	Ord–Dunham conflnce	16/8/06	catfish	visceral fat	82.2	0.11	0.027	1.2	7.7	<0.1	0.1	0.26	<3	0.28	2.4	9 650	27	0.46	34	1.5	0.31
604917	Ord–Dunham conflnce	16/8/06	catfish	liver	9.4	<3.0	<3.0	<4.00	6.3	<0.3	<0.3	<1	<4	<0.4	1.5	7 310	15	<0.4	12	1.2	0.57
604918	Ord–Dunham conflnce	16/8/06	catfish	flesh	1.3	<1.0	<2.0	<1.00	8.3	0.31	0.52	<0.6	<9	1	1.7	6 750	8	0.34	20	0.77	0.58
604919	Ord–Dunham conflnce	16/8/06	catfish	gills	17.7	<0.2	0.039	<0.10	5.9	<0.2	<0.2	0.24	<4	<0.3	1.5	7 170	9.5	1.9	22	1.3	0.37
604920	Ord–Dunham conflnce	16/8/06	catfish	flesh	1.3	<0.2	<0.10	<0.09	4.5	0.28	0.38	0.12	<8	0.68	0.96	460	2.3	0.083	3.9	0.71	0.4
604921	Ord–Dunham conflnce	16/8/06	barramundi	gills	7.8	1	<0.08	<0.05	2.6	<0.2	<0.2	0.092	<3	<0.3	<0.3	150	6.6	1.7	7.3	0.3	0.59

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604922	Ord–Dunham conflnce	16/8/06	barramundi	flesh	1.1	<2.0	<0.30	0.97	<7	<2.0	<2	<0.1	<80	<4	<2	260	9.1	3.9	13	0.39	<1
604923	Ord–Dunham conflnce	16/8/06	barramundi	liver	33.8	0.51	<0.10	0.63	2.9	<0.2	<0.07	<0.08	<4	0.37	0.24	180	33	2.7	12	0.26	0.69
604924	Ord–Dunham conflnce	16/8/06	barramundi	visceral fat	82.5	0.24	<0.02	<0.20	2.6	<0.2	0.12	<0.007	3.3	0.4	0.22	170	29	3.1	12	0.26	0.65

Table A2 Pesticide concentration in fish (ng/g lipid fraction) collected at reference sites upstream of ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507300	Lake Argyle Ulysses Bay	29/9/05	catfish	flesh	0.6	<0.8	<0.06	0.35	7.1	<1.0	0.96	0.39	<30	2.3	1.8	15	1.1	0.34	0.98	0.29	<2
507301	Lake Argyle – Revolver Creek	29/9/05	catfish	flesh	1.9	<0.2	<0.07	0.43	4.7	<0.5	0.96	0.4	<20	<1	1.5	12	1.1	0.2	0.89	0.29	<1
507302	Lake Argyle – Revolver Creek	29/9/05	catfish	gills	2.9	<0.3	<0.06	0.33	2.4	<0.4	<0.6	0.47	<10	<1	0.81	11	<0.3	<0.08	0.35	0.73	<1
507303	Lake Argyle – Revolver Creek	29/9/05	catfish	liver	3.0	<0.5	<0.05	0.47	3.6	<0.7	0.78	0.68	<20	<2	1.3	11	<0.7	0.2	0.62	0.26	<0.8
507304	Lake Argyle Remote Is	30/9/05	catfish	flesh	0.9	<0.6	<0.10	0.18	6.4	<1.0	1.1	0.18	<30	2.5	2.7	16	3.9	0.35	1	0.41	<1
507307	Pentecost River – The Ledge	7/10/05	catfish	visceral fat	8.6	<0.4	<0.20	1.3	5	<0.6	1.1	1.4	<20	2.4	2.5	87	5.1	0.37	2.1	2.5	<2
507308	Pentecost River – The Ledge	7/10/05	catfish	gills	3.7	<0.2	<0.02	0.43	2.4	<0.3	<0.4	0.43	<8	<1	1.3	53	3.4	0.18	1.3	0.84	<2
507309	Pentecost River – The Ledge	7/10/05	catfish	liver	2.2	<0.4	<0.04	0.78	4.2	<0.6	0.77	0.88	<10	<1	1.4	42	2.6	0.28	1.1	1.5	<3
507310	Pentecost River – The Ledge	7/10/05	catfish	brain	12.3	<1.0	<0.80	0.6	4.5	<1.0	<1	<0.5	<30	<2	1.4	16	1.3	0.48	1.8	<0.7	<1

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507311	Pentecost River – The Ledge	7/10/05	catfish	flesh	1.4	<0.2	<0.04	0.044	2.4	<0.2	0.37	0.022	7	0.56	0.55	11	1	0.1	0.29	0.53	0.61
507314	Pentecost River – The Ledge	7/10/05	catfish	flesh	1.4	<0.3	<0.03	0.21	3.2	<0.3	<0.6	0.26	<10	<0.9	0.89	52	1.9	0.13	0.58	0.75	<2
507352	Pentecost BBQ Hole	24/2/06	barramundi	Flesh	0.3	0.52	0.11	1.5	17	<0.9	3.7	0.34	38	5.5	4.7	82	5.3	0.29	1.7	0.91	2.8
507353	Pentecost BBQ Hole	24/2/06	barramundi	Liver	4.1	0.44	0.13	2.3	14	1	2.7	1.1	27	3.4	3.9	60	4.3	0.28	2.5	1.8	2
604868	Kununurra Diversion Dam	9/5/06	barramundi	flesh	1.9	0.71	0.038	0.59	5.5	0.47	0.77	0.57	8.4	1.2	1	17	0.72	0.13	0.7	0.18	1.3
604869	Kununurra Diversion Dam	9/5/06	barramundi	liver	49.1	<0.5	<0.05	0.19	3.4	<0.4	0.48	<0.2	17	1.2	0.66	58	4.6	0.33	1.8	0.15	0.96
604870	Kununurra Diversion Dam	9/5/06	barramundi	visceral fat	76.1	<0.4	<0.05	0.13	2.4	<0.2	<0.2	0.15	<3	<0.3	0.24	52	4.2	0.19	1.4	0.11	0.8
604871	Kununurra Diversion Dam	9/5/06	barramundi	gills	6.0	0.48	<0.03	0.15	3.6	0.21	0.4	0.21	5.4	0.64	0.56	54	2.7	0.22	1.7	0.14	0.86
604872	Kununurra Diversion Dam	9/5/06	barramundi	flesh	1.0	1.3	<0.06	0.72	9.3	0.43	1.5	0.66	16	2.3	2	63	3	0.3	2.3	0.12	1

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604874	Pentecost River – The Ledge	20/7/06	barramundi	liver	55.4	<0.9	<0.07	0.12	2.6	<0.3	<0.3	0.12	<6	<0.5	0.38	17	2.5	<0.1	1.5	0.32	0.85
604875	Pentecost River – The Ledge	20/7/06	barramundi	flesh	3.0	0.72	<0.06	<0.20	4.1	<0.2	0.24	0.27	<5	0.68	0.71	24	1.7	0.13	1.6	0.38	0.85
604876	Pentecost River – The Ledge	20/7/06	barramundi	visceral fat	94.5	2	<0.10	<0.09	3.1	<0.04	<0.3	<0.3	<3	<0.3	0.34	18	2.5	<0.2	1.7	0.35	0.75
604877	Pentecost River – The Ledge	20/7/06	barramundi	gills	11.0	6.6	<0.03	0.086	3.2	<0.07	0.081	0.092	<2	<0.2	0.3	17	1.9	0.1	1.6	0.55	0.84

Table A3 Pesticide concentration in fish (ng/g fresh weight) collected in or downstream of ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507321	Buttons Gap	3/02/06	bony bream	flesh	5.3	<0.01	<0.002	0.021	0.29	<0.01	0.018	0.017	<0.3	0.042	0.041	40	0.52	0.072	1	0.0053	0.053
507322	Buttons Gap	3/02/06	bony bream	liver	9.2	<0.08	0.0062	0.57	1.9	0.11	0.2	0.4	4	0.72	0.77	150	1.9	0.11	2.9	0.026	0.16
507323	Buttons Gap	3/02/06	bony bream	whole fish	0.9	<0.004	0.00041	0.0021	0.053	0.0045	0.0037	0.002	0.12	0.013	0.021	32	0.29	0.022	0.49	0.0033	0.015
507324	Buttons Gap	3/02/06	catfish	brain	31.5	<0.09	<0.006	0.66	3.8	<0.2	0.36	0.63	5.2	0.89	1.8	3710	11	0.19	13	0.61	0.33
507325	Buttons Gap	3/02/06	catfish	gills	3.4	<0.01	<0.03	<0.003	0.2	<0.003	<0.03	<0.01	<0.1	0.011	0.066	350	0.97	0.027	1.1	0.054	0.015
507326	Buttons Gap	3/02/06	catfish	liver	7.9	<0.03	<0.004	<0.02	0.42	<0.02	0.049	0.066	<0.8	0.11	0.16	260	1.2	0.0058	0.15	0.041	0.049
507327	Buttons Gap	3/02/06	catfish	flesh	1.4	<0.001	<0.007	<0.0006	0.051	<0.003	0.004	<0.003	<0.08	0.008	0.015	39	0.16	0.0033	0.11	<0.007	0.005
507328	Buttons Gap	3/02/06	mullet	flesh	1.1	<0.002	<0.0004	0.0024	0.052	<0.003	0.0057	0.0032	0.11	0.015	0.016	3.2	0.055	0.011	0.048	<0.001	0.0073
507346	Ivanhoe xing	10/02/06	barramundi	flesh	0.4	<0.0015	<0.0003	0.0052	<0.002	0.001	0.011	0.047	0.1	0.014	0.012	2.6	0.034	0.0031	0.023	0.00088	0.012

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507348	Ivanhoe xing	10/02/06	barramundi	gills	9.3	0.016	<0.02	0.061	0.46	<0.009	<0.06	<0.006	<0.4	<0.06	0.087	130	2.6	0.12	1.5	0.044	<0.09
507349	Ivanhoe xing	10/02/06	bull shark	flesh	0.6	0.0019	<0.0002	0.0053	0.07	<0.003	0.012	0.00097	0.13	0.021	0.019	7	0.13	0.00099	0.016	0.0019	0.015
507350	Ivanhoe xing	10/02/06	bull shark	liver	76.5	<0.2	0.023	0.34	4.7	<0.08	0.23	0.37	3.5	0.83	1.9	3510	11	0.29	32	2.1	1
507351	Ivanhoe xing	10/02/06	bull shark	brain	6.3	0.024	0.0041	0.048	0.45	<0.03	0.098	0.016	0.84	0.12	0.12	15	0.23	0.015	0.25	0.014	<0.06
604864	Ivanhoe xing	9/05/06	barramundi	liver	29.3	<0.3	<0.03	0.098	1.4	<0.06	0.12	0.06	<2	<0.2	0.19	130	3.5	0.24	1.8	0.051	0.21
604865	Ivanhoe xing	9/05/06	barramundi	visceral fat	82.6	<0.3	0.03	0.11	3	<0.08	<0.2	0.15	<2	<0.3	0.27	390	11	0.8	5.1	0.12	0.61
604866	Ivanhoe xing	9/05/06	barramundi	gills	8.0	0.041	<0.006	0.013	0.39	<0.008	0.014	0.016	<0.3	0.049	0.054	41	0.48	0.077	0.54	0.021	0.067
604867	Ivanhoe xing	9/05/06	barramundi	flesh	3.2	<0.01	<0.001	0.011	0.15	<0.01	0.012	0.0094	<0.2	0.02	0.017	14	0.16	0.032	0.19	0.0061	0.031
604904	D4 drain	16/08/06	bony bream	whole fish	2.0	0.0065	<0.001	<0.002	0.27	<0.002	0.0083	0.0061	<0.1	0.02	0.014	62	0.85	0.11	0.66	<0.005	0.034

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604905	D4 drain	16/08/06	mullet	gills	1.8	0.0078	<0.004	0.052	0.18	0.0057	0.011	0.012	0.22	<0.07	0.033	100	1.4	0.31	1.2	0.0023	0.018
604906	D4 drain	16/08/06	mullet	liver	14.5	<0.09	<0.3	<0.007	0.92	<0.001	0.14	0.083	<1	0.19	0.2	780	25	2.8	9.9	<0.03	0.21
604907	D4 drain	16/08/06	mullet	flesh	3.4	0.037	<0.003	0.16	0.58	<0.03	0.041	0.023	1.8	0.17	0.16	91	2.3	0.21	0.95	<0.02	0.037
604908	Ord–Dunham confl	16/08/06	bony bream	whole fish	2.1	0.0051	0.0032	0.024	0.13	0.0037	0.0038	<0.002	0.12	0.011	0.0089	1.6	0.17	0.028	0.18	0.0027	0.02
604909	Ord–Dunham confl	16/08/06	bony bream	flesh	0.7	0.0081	<0.0006	0.0081	0.081	0.0026	0.0034	0.0012	0.092	<0.02	0.009	1.6	0.063	0.0047	0.042	0.00085	0.0059
604910	Ord–Dunham confl	16/08/06	bony bream	flesh	1.6	0.012	<0.008	<0.03	0.23	0.0065	0.0075	<0.002	0.19	0.024	0.017	2.3	0.13	0.012	0.12	0.0035	0.015
604911	Ord–Dunham confl	16/08/06	bony bream	flesh	2.6	0.025	<0.005	<0.02	0.52	0.023	0.013	0.0067	0.34	0.036	0.029	3.5	0.19	0.012	0.14	0.0032	0.03
604912	Ord–Dunham confl	16/08/06	catfish	visceral fat	84.2	0.13	<0.02	0.8	5.3	<0.08	0.13	0.17	4.3	0.32	0.88	1520	19	0.14	19	0.93	0.34
604913	Ord–Dunham confl	16/08/06	catfish	liver	7.9	0.037	<0.006	<0.2	0.64	<0.04	0.028	<0.02	<0.8	0.12	0.11	110	2.3	0.0079	0.57	0.06	0.039

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604914	Ord–Dunham confl	16/08/06	catfish	gills	14.7	0.021	<0.001	0.11	0.78	0.023	0.016	0.024	0.49	0.045	0.099	210	3.8	0.026	2.5	0.11	0.049
604915	Ord–Dunham confl	16/08/06	catfish	flesh	0.6	<0.002	<0.0006	<0.001	0.044	0.0026	0.0041	<0.0002	<0.06	<0.005	<0.006	7.3	0.026	0.0008	0.066	0.0038	0.004
604916	Ord–Dunham confl	16/08/06	catfish	visceral fat	82.2	0.094	0.023	0.96	6.3	<0.08	0.083	0.21	<2	0.23	2	7930	23	0.38	28	1.3	0.25
604917	Ord–Dunham Confl	16/08/06	catfish	liver	9.4	<0.3	<0.3	<0.4	0.59	<0.03	<0.03	<0.09	<0.4	<0.04	0.14	690	1.4	<0.04	1.1	0.11	0.054
604918	Ord–Dunham confl	16/08/06	catfish	flesh	1.3	<0.01	<0.03	<0.01	0.1	0.0039	0.0065	<0.008	<0.1	0.013	0.021	85	0.1	0.0043	0.24	0.0096	0.0073
604919	Ord–Dunham confl	16/08/06	catfish	gills	17.7	<0.04	0.0069	<0.02	1	<0.04	<0.04	0.042	<0.7	<0.05	0.27	1270	1.7	0.34	3.8	0.23	0.066
604920	Ord–Dunham confl	16/08/06	catfish	flesh	1.3	<0.003	<0.001	<0.001	0.06	0.0037	0.005	0.0015	<0.1	0.0089	0.013	6.1	0.03	0.0011	0.052	0.0093	0.0053
604921	Ord–Dunham confl	16/08/06	barramundi	gills	7.8	0.082	<0.006	<0.004	0.2	<0.02	<0.02	0.0072	<0.2	<0.02	<0.02	11	0.52	0.13	0.57	0.024	0.046
604922	Ord–Dunham confl	16/08/06	barramundi	flesh	1.1	<0.02	<0.003	0.011	<0.08	<0.02	<0.02	<0.001	<0.9	<0.04	<0.02	2.8	0.1	0.043	0.14	0.0043	<0.01

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604923	Ord–Dunham confl	16/08/06	barramundi	liver	33.8	0.17	<0.03	0.21	0.97	<0.07	<0.02	<0.03	<1	0.12	0.08	62	11	0.9	3.9	0.089	0.23
604924	Ord–Dunham confl	16/08/06	barramundi	visceral fat	82.5	0.2	<0.02	<0.2	2.2	<0.2	0.099	<0.006	2.7	0.33	0.18	140	24	2.5	10	0.21	0.54

Table A4 Pesticide concentrations in fish (ng/g fresh weight) collected at reference sites upstream of ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hept chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507300	L Argyle Ulysses Bay	29/09/05	catfish	flesh	0.6	<0.005	<0.0004	0.0021	0.042	<0.006	0.0057	0.0023	<0.2	0.014	0.011	0.09	0.0068	0.002	0.0059	0.0018	<0.01
507301	L Argyle Revolver Creek	29/09/05	catfish	flesh	1.9	<0.004	<0.001	0.0081	0.088	<0.01	0.018	0.0077	<0.4	<0.02	0.028	0.22	0.022	0.0039	0.017	0.0054	<0.02
507302	L Argyle Revolver Creek	29/09/05	catfish	gills	2.9	<0.009	<0.002	0.0097	0.07	<0.01	<0.02	0.014	<0.3	<0.03	0.023	0.32	<0.009	<0.002	0.01	0.021	<0.03
507303	L Argyle Revolver Creek	29/09/05	catfish	liver	3.0	<0.02	<0.002	0.014	0.11	<0.02	0.023	0.02	<0.6	<0.06	0.039	0.34	<0.02	0.0059	0.019	0.0077	<0.02
507304	L Argyle Remote Is	30/09/05	catfish	flesh	0.9	<0.005	<0.0009	0.0017	0.057	<0.009	0.01	0.0017	<0.3	0.022	0.024	0.14	0.035	0.0032	0.0092	0.0037	<0.009
507307	Pentecost River Ledge	7/10/05	catfish	visceral fat	8.6	<0.03	<0.02	0.11	0.43	<0.05	0.098	0.12	<2	0.21	0.22	7.5	0.44	0.032	0.18	0.21	<0.2
507308	Pentecost River Ledge	7/10/05	catfish	gills	3.7	<0.007	<0.0007	0.016	0.087	<0.01	<0.01	0.016	<0.3	<0.04	0.05	2	0.13	0.0066	0.049	0.031	<0.07
507309	Pentecost River Ledge	7/10/05	catfish	liver	2.2	<0.009	<0.0009	0.017	0.093	<0.01	0.017	0.019	<0.2	<0.02	0.032	0.93	0.058	0.0062	0.025	0.034	<0.07
507310	Pentecost River Ledge	7/10/05	catfish	brain	12.3	<0.1	<0.1	0.075	0.55	<0.1	<0.1	<0.06	<4	<0.2	0.17	2	0.16	0.059	0.22	<0.09	<0.1

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hept chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507311	Pentecost River Ledge	7/10/05	catfish	flesh	1.4	<0.003	<0.0006	0.00062	0.033	<0.003	0.0052	0.00031	0.098	0.0079	0.0077	0.16	0.014	0.0014	0.0041	0.0075	0.0086
507314	Pentecost River Ledge	7/10/05	catfish	flesh	1.4	<0.004	<0.0004	0.0029	0.044	<0.004	<0.008	0.0036	<0.1	<0.01	0.012	0.73	0.026	0.0019	0.0081	0.01	<0.03
507352	Pentecost BBQ Hole	24/02/06	barramundi	Flesh	0.3	0.0016	0.00034	0.0045	0.053	<0.003	0.011	0.001	0.12	0.017	0.015	0.25	0.016	0.00088	0.0052	0.0028	0.0086
507353	Pentecost BBQ Hole	24/02/06	barramundi	liver	4.1	0.018	0.0054	0.094	0.58	0.043	0.11	0.044	1.1	0.14	0.16	2.5	0.18	0.011	0.1	0.076	0.084
604868	Diversion Dam	9/05/06	barramundi	flesh	1.9	0.013	0.00072	0.011	0.1	0.0088	0.014	0.011	0.16	0.022	0.019	0.31	0.014	0.0025	0.013	0.0034	0.024
604869	K'unurra Diversion Dam	9/05/06	barramundi	liver	49.1	<0.2	<0.02	0.094	1.7	<0.2	0.24	<0.1	8.4	0.6	0.33	29	2.3	0.16	0.88	0.073	0.47
604870	K'unurra Diversion Dam	9/05/06	barramundi	visceral fat	76.1	<0.3	<0.04	0.095	1.8	<0.2	<0.2	0.11	<2	<0.2	0.18	40	3.2	0.15	1	0.086	0.61
604871	K'unurra Diversion Dam	9/05/06	barramundi	gills	6.0	0.028	<0.002	0.0091	0.21	0.012	0.023	0.012	0.31	0.037	0.033	3.2	0.16	0.013	0.098	0.0084	0.05
604872	K'unurra Diversion Dam	9/05/06	barramundi	flesh	1.0	0.014	<0.0006	0.0074	0.095	0.0044	0.015	0.0068	0.16	0.024	0.021	0.64	0.031	0.0031	0.023	0.0013	0.011

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hept chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
604874	Pentecost River – Ledge	20/07/06	barramundi	liver	55.4	<0.5	<0.04	0.066	1.5	<0.2	<0.2	0.069	<3	<0.3	0.21	9.5	1.4	<0.06	0.84	0.18	0.47
604875	Pentecost River – Ledge	20/07/06	barramundi	flesh	3.0	0.02	<0.002	<0.006	0.11	<0.006	0.0065	0.0073	<0.1	0.019	0.02	0.65	0.048	0.0037	0.045	0.011	0.024
604876	Pentecost River Ledge	20/07/06	barramundi	visceral fat	94.5	1.9	<0.09	<0.09	2.9	<0.04	<0.3	<0.3	<3	<0.3	0.32	17	2.4	<0.2	1.6	0.33	0.71
604877	Pentecost River Ledge	20/07/06	barramundi	gills	11.0	0.7	<0.003	0.0092	0.34	<0.007	0.0086	0.0097	<0.2	<0.02	0.031	1.8	0.21	0.011	0.17	0.059	0.089

Appendix 2 Pesticide levels in meat and plant samples

Table A5 Pesticide concentration in muscle samples (ng/g fresh weight) collected at reference sites upstream of ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
615151	Ag Research Station	21/09/06	wallaby	flesh – leg	1.4	<0.01	<0.01	<0.03	3	<0.003	0.01	<0.03	<0.07	0.0065	0.026	0.28	0.0044	<0.004	0.0048	0.0094	0.0079
615152	Ag Research Station	21/09/06	wallaby	flesh – tail	17.5	0.067	0.22	0.16	62	0.053	0.29	0.16	1.7	0.18	1.1	2.5	0.052	0.052	0.2	0.22	0.11
615153	Ag Research Station	21/09/06	wallaby	flesh – leg	0.9	<0.03	<0.03	<0.008	1	0.0034	<0.004	<0.007	0.12	0.0095	0.017	0.18	0.0021	<0.002	<0.004	0.0043	0.0047
615154	Ag Research Station	21/09/06	wallaby	flesh – tail	4.8	0.012	<0.03	<0.01	7.5	<0.01	0.038	0.012	<0.4	0.046	0.14	0.61	0.015	0.015	0.05	0.057	0.026
615155	Super market-	1/10/06	beef/ reference	flesh	19.5	<0.2	<0.2	<0.02	0.41	<0.04	<0.06	<0.04	<0.6	<0.06	<0.04	0.85	<0.01	<0.08	<0.1	<0.02	0.1

Table A6 Pesticide concentration in plant material (ng/g fresh weight) collected near the ORIA

Sample number (prefix 200)	Site	Date	Sample description	Sample type	Lipid content %	β-HCH	γ-HCH	aldrin	dieldrin	hepta chlor	hept achlor epox	Oxy chlor dane	*trans*-chlor dane	*cis*-chlor dane	Trans nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507315	Val'tines Xing	31/01/06	bush peanut	plant	17.5	0.036	<0.002	0.054	0.16	<0.02	0.049	0.0092	<0.4	<0.04	0.034	0.15	0.017	0.01	0.022	<0.0007	<0.04
507316	Buttons Gap	31/01/06	flueggia	plant	0.8	0.0049	<0.004	<0.0005	0.012	<0.002	0.0037	<0.0002	0.039	0.0026	0.0028	0.016	0.0038	0.00061	0.0052	<0.0005	<0.002
507317	Buttons Gap	31/01/06	leichhardt pine	plant	1.0	0.0045	0.00025	<0.002	0.022	0.0047	0.0058	0.00098	0.072	0.0055	0.0054	0.036	0.0033	0.0016	0.0068	<0.0005	0.012
507318	Forbes beach	31/01/06	wild passionfruit	plant	1.1	0.0095	<0.0003	0.0098	0.072	0.0041	0.013	0.003	0.16	0.018	0.02	0.12	0.022	<0.0004	0.031	0.00038	0.0039
507319	Forbes beach	31/01/06	flueggia	plant	0.7	0.0031	<0.001	<0.0001	0.01	0.0021	0.0027	0.00011	<0.03	0.0021	0.0021	0.017	0.0039	0.0011	0.0051	<0.0006	<0.001
507320	Ivanhoe xing	31/01/06	cluster fig	plant	1.0	0.0053	<0.0006	<0.004	0.02	<0.002	0.0034	<0.0004	0.13	0.012	0.0071	0.053	0.0093	0.0013	0.0092	<0.00004	0.0046

Table A7 Pesticide concentration in water (ng/L) collected at reference sites

Sample number (prefix)	Site	Date	Sample type	Sample class	β-HCH	γ-HCH	aldrin	dieldrin	Hepta chlor	Hepta chlor epoxide	Oxy chlor dane	trans chlor dane	Cis chlor dane	*trans*-nona chlor	*p,p'*-DDE	*p,p'*-DDD	*o,p'*-DDT	*p,p'*-DDT	mirex	HCB
507305	Lake Argyle Remote Is	30/09/05	Water	Reference	0.31	<0.2	<0.07	0.96	<0.03	<0.04	<0.02	<2	<0.1	<0.07	1.8	<0.03	0.24	0.039	<0.05	4.6
6092801	Lake Argyle Ord mouth	28/09/06	Water	Reference	<0.04	<0.03	<0.06	0.29	<0.07	<0.02	<0.03	<1	<0.06	<0.02	<0.1	<0.06	<0.2	<0.1	<0.05	<0.03
6092802	Lake Argyle middle	28/09/06	Water	Reference	<0.02	<0.04	<0.07	<0.06	<0.04	<0.02	<0.02	<0.7	<0.04	<0.01	<0.2	<0.04	<0.1	<0.1	<0.05	<0.05
6092803	Lake Argyle Remote Is	28/09/06	Water	Reference	<0.09	<0.05	<0.03	<0.03	<0.02	<0.02	<0.02	<0.8	<0.03	<0.01	<0.2	<0.04	<0.08	<0.1	<0.01	<0.04
6092804	Lake Argyle Ulysses Bay	28/09/06	Water	Reference	<0.03	<0.04	<0.06	<0.09	<0.04	<0.02	<0.03	<0.8	<0.04	<0.02	<0.1	<0.04	<0.1	<0.1	<0.05	<0.03
6092805	Lake Argyle north	28/09/06	Water	Reference	<0.03	<0.01	<0.06	<0.1	<0.08	<0.03	<0.01	<1	<0.06	<0.02	<0.2	<0.04	<0.1	<0.09	<0.05	<0.03
6092806	Lake Argyle dam wall	28/09/06	Water	Reference	<0.02	<0.1	<0.2	<0.06	<0.03	<0.02	<0.03	<1	<0.05	<0.01	<0.1	<0.01	<0.09	<0.07	<0.1	<0.04
507312	Pentecost River – The Ledge	7/10/05	Water	Reference	<0.3	<0.2	<0.07	0.41	<0.3	<0.09	<0.03	<4	<0.2	<0.07	<0.5	<0.2	<0.02	<0.02	<0.05	<0.7

Table A8 Pesticide concentration in sediment samples (p*g*/g dry weight) at reference sites

Sample number (prefix 200)	**Site**	**Date**	**Sample type**	**Sample class**	**β-HCH**	**γ-HCH**	**aldrin**	**dieldrin**	**Hepta chlor**	**Hepta chlor epoxide**	**Oxy chlor dane**	**trans chlor dane**	**Cis chlor dane**	***trans*-nona chlor**	***p,p'*-DDE**	***p,p'*-DDD**	***o,p'*-DDT**	***p,p'*-DDT**	**mirex**	**HCB**
507306	Lake Argyle Remote Is	30/09/05	Sediment	Reference	120	<60	<30	190	<2.0	57	84	830	74	64	230	<9	<30	<20	<3	200
507313	Pentecost River – The Ledge	7/10/05	Sediment	Reference	<100	<30	72	240	<2.0	80	75	670	71	60	250	18	<30	<20	<10	180

Appendix 3 Extraneous residue limits

Source: Australian New Zealand Food Standard Code

SCHEDULE 2

Extraneous Residue Limits

ALDRIN AND DIELDRIN SUM OF HHDN AND HEOD	
ASPARAGUS	E0.1
BANANA	E0.05
BRASSICA (COLE OR CABBAGE) VEGETABLES, HEAD CABBAGES, FLOWERHEAD BRASSICAS	E0.1
CARROT	E0.1
CEREAL GRAINS	E0.02
CITRUS FRUITS	E0.05
CRUSTACEANS	E0.1
CUCUMBER	E0.1
DIADROMOUS FISH	E0.1
EDIBLE OFFAL (MAMMALIAN)	E0.2
EGG PLANT	E0.1
EGGS	E0.1
FRESHWATER FISH	E0.1
FRUIT	E0.05
HORSERADISH	E0.1
LETTUCE, HEAD	E0.1
LETTUCE, LEAF	E0.1
MARINE FISH	E0.1
MEAT (MAMMALIAN) (IN THE FAT)	E0.2
MILKS (IN THE FAT)	E0.15
MOLLUSCS (INCLUDING CEPHALOPODS)	E0.1
ONION, BULB	E0.1
PARSNIP	E0.1
PEANUT	E0.05
PEPPERS, SWEET	E0.1
PIMENTO, FRUIT	E0.1
POTATO	E0.1
POULTRY, EDIBLE OFFAL OF	E0.2
POULTRY MEAT (IN THE FAT)	E0.2
RADISH	E0.1
RADISH LEAVES (INCLUDING RADISH TOPS)	E0.1
SUGAR CANE	E*0.01

BHC **(OTHER THAN THE GAMMA ISOMER, LINDANE)** SUM OF ISOMERS OF 1,2,3,4,5,6-HEXACHLOROCYCLOHEXANE, OTHER THAN LINDANE	
CEREAL GRAINS	E0.1
CRUSTACEANS	E0.01
EDIBLE OFFAL (MAMMALIAN)	E0.3
EGGS	E0.1
FISH	E0.01
MEAT (MAMMALIAN) (IN THE FAT)	E0.3
MILKS (IN THE FAT)	E0.1
MOLLUSCS (INCLUDING CEPHALOPODS)	E0.01
PEANUT	E0.1
POULTRY, EDIBLE OFFAL OF	E0.3
POULTRY MEAT (IN THE FAT)	E0.3
SUGAR CANE	E0.005

CHLORDANE SUM OF CIS- AND TRANS-CHLORDANE AND IN THE CASE OF ANIMAL PRODUCTS ALSO INCLUDES 'OXYCHLORDANE'	
CEREAL GRAINS	E0.02
CITRUS FRUITS	E0.02
COTTON SEED OIL, CRUDE	E0.05
COTTON SEED OIL, EDIBLE	E0.02
CRUSTACEANS	E0.05
EDIBLE OFFAL (MAMMALIAN)	E0.02
EGGS	E0.02
FISH	E0.05
FRUITING VEGETABLES, CUCURBITS	E0.05
LINSEED OIL, CRUDE	E0.05
MEAT (MAMMALIAN) (IN THE FAT)	E0.2
MILKS (IN THE FAT)	E0.05
MOLLUSCS (INCLUDING CEPHALOPODS)	E0.05
PINEAPPLE	E0.02
POME FRUITS	E0.02
SOYA BEAN OIL, CRUDE	E0.05
SOYA BEAN OIL, REFINED	E0.02
STONE FRUITS	E0.02
SUGAR BEET	E0.1
VEGETABLES [EXCEPT AS OTHERWISE LISTED UNDER THIS CHEMICAL]	E0.02

DDT SUM OF P,P'-DDT; O,P'-DDT; P,P'-DDE AND P,P'-TDE (DDD)	
CEREAL GRAINS	E0.1
CRUSTACEANS	E1
EDIBLE OFFAL (MAMMALIAN)	E5
EGGS	E0.5
FISH	E1
FRUIT	E1
MEAT (MAMMALIAN) (IN THE FAT)	E5
MILKS (IN THE FAT)	E1.25
MOLLUSCS (INCLUDING CEPHALOPODS)	E1
PEANUT	E0.02
POULTRY, EDIBLE OFFAL OF	E5
POULTRY MEAT (IN THE FAT)	E5
VEGETABLE OILS, EDIBLE	E1
VEGETABLES	E1

HCB HEXACHLOROBENZENE	
CEREAL GRAINS	E0.05
CRUSTACEANS	E0.1
DIADROMOUS FISH	E0.1
EDIBLE OFFAL (MAMMALIAN)	E1
EGGS	E1
FRESHWATER FISH	E0.1
MARINE FISH	E0.1
MEAT (MAMMALIAN) (IN THE FAT)	E1
MILKS (IN THE FAT)	E0.5
MOLLUSCS (INCLUDING CEPHALOPODS)	E0.1

The units are mg/kg (which is the same as µg/g) fresh weight. 1 µg/g = 1000 ng/g. E = extraneous residue limit.

* indicates that the ERL is set close to the limit of determination.

SCHEDULE 2

Extraneous Residue Limits

PEANUT	E0.01
POULTRY, EDIBLE OFFAL OF	E1
POULTRY MEAT (IN THE FAT)	E1
HEPTACHLOR SUM OF HEPTACHLOR AND HEPTACHLOR EPOXIDE	
CARROT	E0.2
CEREAL GRAINS	E0.02
CITRUS FRUITS	E0.01
COTTON SEED	E0.02
CRUSTACEANS	E0.05
EDIBLE OFFAL (MAMMALIAN)	E0.2
EGGS	E0.05
FISH	E0.05
MEAT (MAMMALIAN) (IN THE FAT)	E0.2
MILKS (IN THE FAT)	E0.15
MOLLUSCS (INCLUDING CEPHALOPODS)	E0.05
PEANUT	E0.01
PINEAPPLE	E0.01
POULTRY, EDIBLE OFFAL OF	E0.2
POULTRY MEAT	E0.2
SOYA BEAN	E0.02
SOYA BEAN OIL, CRUDE	E0.5
SOYA BEAN OIL, REFINED	E0.02
SUGAR CANE	E0.02
TOMATO	E0.02
VEGETABLES [EXCEPT AS OTHERWISE LISTED UNDER THIS CHEMICAL]	E0.05

LINDANE LINDANE	
APPLE	E2
CEREAL GRAINS	E0.5
CHERRIES	E0.5
CRANBERRY	E3
CRUSTACEANS	E1
EDIBLE OFFAL (MAMMALIAN)	E2
EGGS	E0.1
FISH	E1
FRUITS [EXCEPT AS OTHERWISE LISTED IN SCHEDULES 1 AND 2]	E0.5
GRAPES	E0.5
MEAT (MAMMALIAN) (IN THE FAT)	E2
MILKS (IN THE FAT)	E0.2
MOLLUSCS (INCLUDING CEPHALOPODS)	E1
OILSEED [EXCEPT PEANUT]	E0.05
PEACH	E2
PEANUT	E0.05
PLUMS (INCLUDING PRUNES)	E0.5
POULTRY, EDIBLE OFFAL OF	E0.7
POULTRY MEAT (IN THE FAT)	E0.7
STRAWBERRY	E3
SUGAR CANE	E*0.002
VEGETABLES	E2

The units are mg/kg (which is the same as μg/g) fresh weight. 1 μg/g = 1000 ng/g. E = extraneous residue limit.
* indicates that the ERL is set close to the limit of determination.

Shortened forms

ADI	acceptable daily intake
AUSLIG	Australian Surveying and Land Information Group
DDT	dichlorodiphenyltrichloroethane
DLI	Department of Land Information
ERL	extraneous residue limit
GCL	Government Chemical Laboratories Western Australia
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane (γ-HCH is lindane)
KDD	Kununurra Diversion Dam
ORIA	Ord River Irrigation Area
ORD	Ord River Dam
ORIC	Ord Irrigation Cooperative
OCs	organochlorine pesticides
OPs	organophosphate pesticides
MRL	maximum residue level
NMI	National Measurement Institute
NRS	National Residue Survey (Australia)
USEPA	United States Environmental Protection Agency

Units

pg (picogram)	1/1 000 000 000 000th of a gram, 10^{-12} g
ng (nanogram)	1/1 000 000 000th of a gram, 10^{-9} g
µg (microgram)	1/1 000 000th of a gram, 10^{-6} g
mg (milligram)	1/1000th of a gram, 10^{-3} g
pg/g	picograms/gram
ng/g	nanograms/gram
µg/g	microgram/gram
mg/g	milligram/gram

Glossary

allowable daily intake This represents the amount of the chemical which it is believed can be ingested on a daily basis without appreciable risk. It is set at 1/100 of the highest dose level which produces no observable toxic effect in the most sensitive test species.

congenor One of two or more substances related to each other by origin, structure or function.

isomer An isomer is any of two or more chemical compounds with the same atomic composition (molecular formula) but with different atomic structures.

lipids Lipids are a group of organic compounds including fats, oils, waxes, sterols, nucleic acids and triglycerides. Lipids are insoluble in water, and account for most of the fat present in animals.

maximum tolerable daily intake Represents the amount of a naturally occurring chemical or widespread environmental contaminant such as DDT which it is believed may be ingested on a daily basis without appreciable risk.

visceral fat Visceral fat, also known as organ fat, is located inside the abdominal cavity, packed in between internal organs, as opposed to subcutaneous fat which is found underneath the skin, and intramuscular fat which is found interspersed in muscle.

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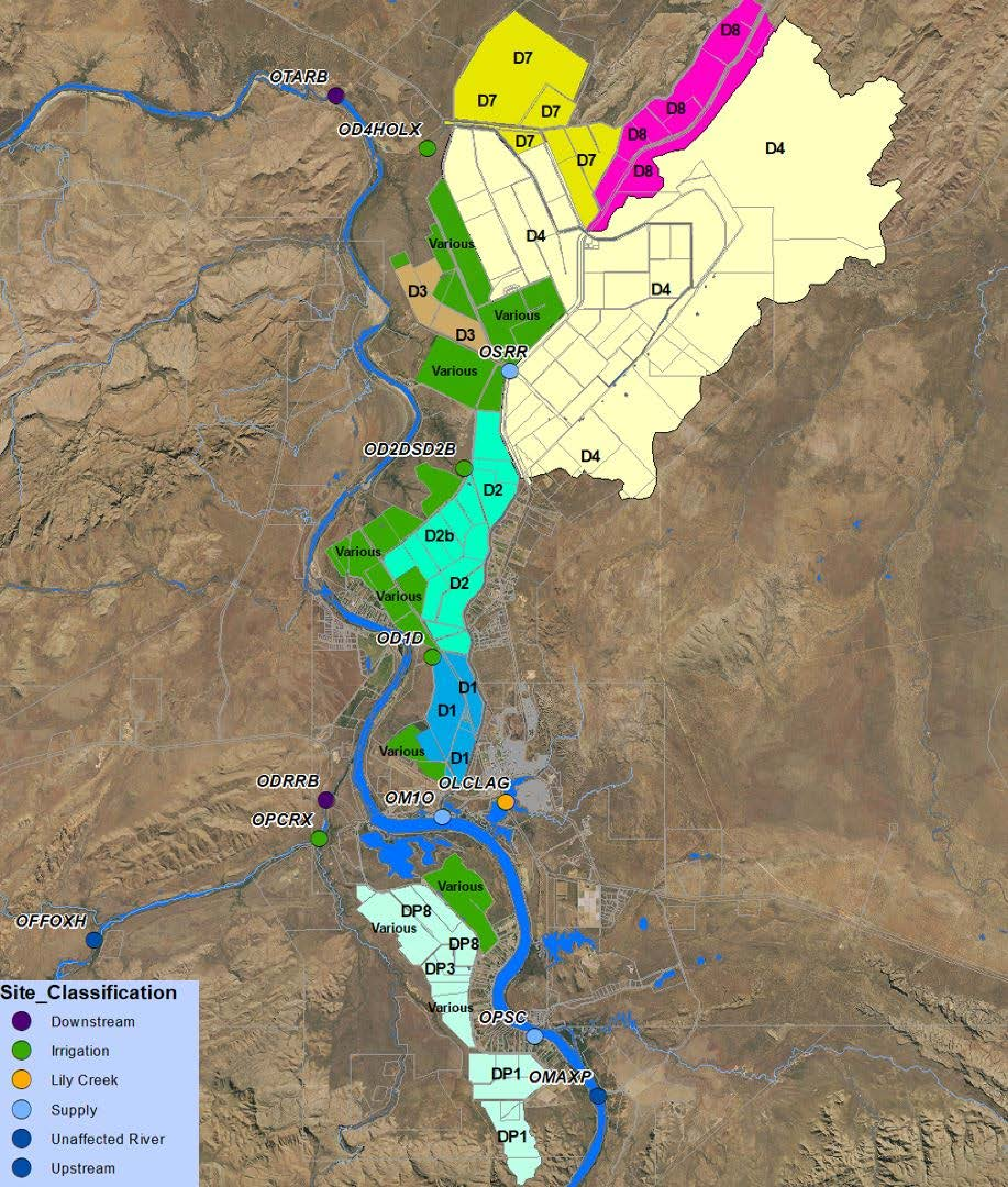
D8
D7
OTARB
D7
D7
D8
D8
OD4HOLX
D7
D7
D4
D8
D4
Various
D3
D4
Various
D3
OSRR
Various
OD2DSD2B
D4
D2
D2b
Various
D2
Various
OD1D
D1
D1
Various
D1
ODRRB
OLCLAG
OM1O
OPCRX
Various
OFFOXH
DP8
Various
DP8
DP3
Various
OPSC
DP1
OMAXP
DP1
Site_Classification
Downstream
Irrigation
Lily Creek
Supply
Unaffected River
Upstream