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An overview of the epidemiology of notifiable infectious diseases in Australia, 1991–2011

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SUMMARY

We reviewed the first 21 years (1991–2011) of Australia's National Notifiable Diseases Surveillance System (NNDSS). All nationally notified diseases (except HIV/AIDS and Creutzfeldt–Jakob disease) were analysed by disease group ($n = 8$), jurisdiction (six states and two territories), Indigenous status, age group and notification year. In total, 2 421 134 cases were analysed. The 10 diseases with highest notification incidence (chlamydial infection, campylobacteriosis, varicella zoster, hepatitis C, influenza, pertussis, salmonellosis, hepatitis B, gonococcal infection, and Ross River virus infection) comprised 88% of all notifications. Annual notification incidence was 591 cases/100 000, highest in the Northern Territory (2598/100 000) and in children aged <5 years (698/100 000). A total of 8·4% of cases were Indigenous Australians. Notification incidence increased by 6·4% per year (12% for sexually transmissible infections and 15% for vaccine-preventable diseases). The number of notifiable diseases also increased from 37 to 65. The number and incidence of notifications increased throughout the study period, partly due to addition of diseases to the NNDSS and increasing availability of sensitive diagnostic tests. The most commonly notified diseases require a range of public health responses addressing high-risk sexual and drug-use behaviours, food safety and immunization. Our results highlight populations with higher notification incidence that might require tailored public health interventions.

Key words: Analysis of data, Australia, epidemiology, public health, surveillance system.

INTRODUCTION

Surveillance is the cornerstone of public health efforts to minimize morbidity and mortality resulting from preventable infectious diseases. Infectious disease surveillance was instrumental in smallpox eradication and in current efforts towards global polio eradication and measles elimination. National surveillance systems allow examination of the epidemiological profile of important infections at a country level and provide oversight to ensure consistent reporting across jurisdictions [1].

In Australia, notification of selected infectious diseases is required by public health legislation in the six states and two territories. Each jurisdiction defines its own notification list and receives data from doctors and/or laboratories. Primary responsibility for public health action lies with the state/territory health departments. Jurisdictions forward de-identified

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notification data for cases meeting national case definitions for diseases on the National Notifiable Diseases List (NNDL) to the National Notifiable Disease Surveillance System (NNDSS), a passive surveillance system operational since 1991.

A summary of national notifiable disease surveillance data from 1917 to 1991 highlighted the lack of consistency, detail, and methodical reporting of nationally notifiable diseases before the introduction of the NNDSS [2]. Annual reports of NNDSS data have been produced since 1991; however, trend analysis of all nationally notifiable diseases has not previously been performed. We present an overview of the epidemiology of all notifiable infectious diseases in Australia [excluding HIV/AIDS and Creutzfeldt–Jakob disease (CJD)] during the first 21 years of the NNDSS, with a view to highlighting diseases and population groups with greatest need of public health intervention to reduce disease incidence.

METHODS

All case notifications of nationally notifiable diseases to the NNDSS from 1 January 1991 to 31 December 2011 were analysed according to their diagnosis date [3]. HIV/AIDS and CJD are under different national surveillance systems and were excluded from this analysis [4]. Notifications were reported by disease and categorized into eight disease groups (as per the NNDL) based on mode of acquisition and/or public health strategies for control and prevention: bloodborne viral hepatitis (BBVH), gastrointestinal, other bacterial, quarantinable, sexually transmissible infections (STIs), vector-borne diseases (VBDs), vaccine-preventable diseases (VPDs), and zoonotic diseases. Diseases included in each group and the year they became notifiable are summarized in Table 1. NNDSS diseases were analysed by pathogen for hepatitis B, hepatitis C, rubella, syphilis, and varicella zoster.

We report the number and annual incidence of notified cases nationally and by jurisdiction. For all-cause and disease-group incidence calculations, all notified cases were included and Australian Bureau of Statistics (ABS) population estimates at 30 June for each study year were used [5]. Data from the Northern Territory (NT) were excluded from both the numerator (number of cases notified) and denominator (population) of incidence calculations for 1994 due to large discrepancies between the study dataset (extracted in 2012) and online (live) NNDSS data that has undergone subsequent data cleaning [6]. For disease-specific incidence calculations, diseases notifiable both nationally and in that jurisdiction were included (Table 1) with the exceptions of hepatitis B and C (Victoria 1991–1997), hepatitis B [South Australian (SA) 1991–1995], tuberculosis (Victoria 1991), and varicella zoster (Victoria 2006–2007) due to discrepancies with online NNDSS data; the denominator comprised the combined populations for included years and jurisdictions. Relative risks (RRs) were calculated for univariate comparison of notification incidence between study sub-periods (1991–1997, 1998–2004, 2005–2011), age groups (<5, 5–19, 20–64, 65–98 years) and jurisdictions for diseases with >400 notifications during the 21-year study period. Three sub-periods were selected to allow more meaningful comparison between disease groups/diseases within a sub-period as well as analysis of change in notification incidence across these sub-periods for a single disease or disease group.

Average changes in annual notification incidence over the study period were investigated by Poisson regression for all diseases combined and by disease group from 1991 to 2011; for individual diseases this calculation was confined to years the disease was nationally notifiable. Tests for statistical significance were not performed as population-based data were used. To allow international comparison, age-standardized incidence rates were calculated using the WHO world standard population distribution [7].

Incidence rates for Aboriginal and Torres Strait Islander ('Indigenous') Australians were calculated for the three jurisdictions reporting Indigenous status for >75% of notified cases [NT, SA, and Western Australia (WA)] using ABS population estimates [8, 9]; cases with unknown Indigenous status were presumed non-Indigenous.

NNDSS data were provided by the Australian Government's Office of Health Protection on behalf of Communicable Diseases Network Australia (CDNA) jurisdictional members in March 2012 as an extract from the national data file.

Ethical considerations

The project was approved by the Monash Human Research Ethics Committee (project no. CF11/2357–201) and CDNA jurisdictional members. Data were analysed using Stata v. 12 (StataCorp., USA). This work did not involve human or animal experimentation.

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Table 1. *Diseases included in the National Notifiable Diseases Surveillance System (NNDSS) by disease group and year introduced, Australia 1991–2011*

	Year*	Variation by jurisdiction
Bloodborne viral hepatitis		
Hepatitis B (newly acquired)	1993	1994 in Qld and WA, 1995 in ACT
Hepatitis B (unspecified)	1991	2005 in NT
Hepatitis C (newly acquired)	1993	1995 in ACT, Tas and WA, 2005 in NT, not notifiable in Qld
Hepatitis C (unspecified)	1995	Included incident cases until hepatitis C newly acquired introduced
Hepatitis D	1999	2002 in WA
Hepatitis (NEC)	1991	2001 in WA. Included reports of hepatitis D and E 1991–1998
Gastrointestinal diseases		
Botulism	1992	1993 in SA, 1998 in NT and NSW, 2001 in WA
Campylobacteriosis	1991†	Not notifiable in NSW
Cryptosporidiosis	2001	
Haemolytic uraemic syndrome	1999	
Hepatitis A	1991†	
Hepatitis E	1999	2001 in WA
Listeriosis	1991	1992 in SA, 1994 in NT
Salmonellosis (non typhoidal)	1991†	
Shiga-/Vero-toxin-producing *E. coli*	1999	2001 in Qld and WA
Shigellosis	1991	2001 in NSW
Typhoid fever	1991†	Includes paratyphoid in NSW, Qld and Vic
Quarantinable diseases		
Cholera	1991†	
Highly pathogenic avian influenza (human)	2004	Reported under influenza in WA
Plague	1991†	
Rabies	1991	1993 in ACT, 1997 in NSW
Severe acute respiratory syndrome	2003	
Smallpox	2004	
Viral haemorrhagic fever	1991	1993 in ACT
Yellow fever	1991†	
Sexually transmissible infections		
Chancroid	1991	No longer nationally notifiable from 2000
Chlamydial infection	1994	1999 in NSW
Donovanosis	1991	1993 in Tas, 2002 in NSW and SA
Gonococcal infection	1991†	
Syphilis	1991	Includes syphilis <2 and >2 years/unknown duration to 2004
Syphilis (<2 years duration)	2004	
Syphilis (>2 years or unknown duration)	2004	Not reported in SA
Syphilis (congenital)	1991†	
Vaccine-preventable diseases		
Diphtheria	1991†	
Haemophilus influenzae type b	1991	1994 in WA
Influenza (laboratory confirmed)	2001	2008 in SA
Measles	1991†	
Mumps	1995	Not reported by Qld in 1995–96, 1999–2000
Pertussis	1991†	
Pneumococcal disease (invasive)	2001	
Poliomyelitis	1991†	
Rubella	1993	1995 in Tas
Rubella (congenital)	1991†	
Tetanus	1991	1994 in Qld
Varicella zoster (chickenpox)	2006	Not notifiable in NSW
Varicella zoster (shingles)	2006	Not notifiable in NSW
Varicella zoster (unspecified)	2006	Not notifiable in NSW

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Table 1 (*cont.*)

	Year*	Variation by jurisdiction
Vector-borne diseases		
Arbovirus infection (Not elsewhere classified)	1991	1991–2000 included Japanese encephalitis, Kunjin, and Murray Valley encephalitis (MVE) notifications
Barmah Forest virus infection	1995	
Dengue virus infection	1991	1993 in ACT, 1995 in WA
Japanese encephalitis virus infection	2001	
Kunjn virus infection	2001	Reported as MVE in ACT
Malaria	1991†	
Murray Valley encephalitis virus infection	2001	
Ross River virus infection	1993	
Zoonoses		
Anthrax	2001	2002 in SA
Australian bat lyssavirus infection	2001	
Brucellosis	1991†	
Hydatid infection	1991	No longer nationally notifiable from 2001
Leptospirosis	1991†	
Lyssavirus (not elsewhere classified)	2001	
Ornithosis	1991	2001 in NSW, Qld did not report 1991, 1997–2001
Q fever	1991†	
Tularaemia	2003	
Other bacterial diseases		
Legionellosis	1991†	
Leprosy	1991†	
Meningococcal disease (invasive)	1991†	Includes conjunctival cases from ACT and NSW
Tuberculosis	1991	

Source: NNDSS online (live) data and 2012 NNDSS annual report [3, 6].
Excludes HIV/AIDS and Creutzfeldt–Jakob disease which are notified to other surveillance systems.
ACT, Australian Capital Territory; NSW, New South Wales; NT, Northern Territory; Qld, Queensland; SA, South Australia; Tas, Tasmania; Vic, Victoria; WA, Western Australia.
* Year became nationally notifiable – listed as 1991 for diseases that were nationally notifiable when NNDSS began in 1991; diseases introduced after 1991 might have cases notified to NNDSS prior to becoming nationally notifiable.
† Diseases which were consistently notifiable across states for the entire study period.

RESULTS

The NNDSS contains 2 421 134 notified cases of 60 diseases from 1991 to 2011. STIs were most common [790 990 (32·7%) notifications] and quarantinable diseases least common (79 notifications, all cholera) (Table 2, Fig. 1). Chlamydial infection, notifiable from 1994, was the most commonly notified disease [621 431 (26%) notifications]. The 10 pathogens with highest notification incidence were *Chlamydia trachomatis, Campylobacter*, varicella zoster virus, hepatitis C virus, influenza virus, *Bordetella pertussis, Salmonella*, hepatitis B virus, *Neisseria gonorrhoeae*, and Ross River virus (RRV) (Tables 3 and 4); these comprised 88% of all notifications despite campylobacteriosis and varicella zoster infection not being notifiable in New South Wales (NSW), the most populous state. Fewer than 20 notifications were received for eight diseases and no notifications were received for seven diseases (Table 3).

Notification numbers increased over the study period, from 43 443 in 1991 (37 notifiable diseases) to 238 164 in 2011 (65 notifiable diseases) (Fig. 1). The national annual notification incidence increased by an average of 6·4% per year (Fig. 2), rising from 386/100 000 in the earliest sub-period (1991–1997) to 853/100 000 in the latest sub-period (2005–2011) (Table 3). Annual notification incidence fell most markedly for rubella (average 30% decrease/year), followed by *Haemophilus influenzae* type B (Hib, 25%), measles (23%), and donovanosis (17%) (Table 3). Rubella and hepatitis A were among the 10 highest incidence diseases in the earliest study sub-period (Table 4). Conversely, influenza (average 33%

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Table 2. *Number, incidence, and demographics of notified cases by disease group and jurisdiction, Australia, 1991–2011*

	Notifications		Age, median years	Male, %	Indigenous*, %	Crude incidence (/100 000 per year)		Age-standardized incidence		Crude incidence, Indigenous cases*†	
	N	(%)				Mean	(range)	Mean	(95% CI)	Mean	(range)
All notifications	2 421 134	(100)	27	51·0	8·4	591	(251–1092)	621	(620–622)	3764	(2211–4910)
Disease group											
Bloodborne viral hepatitis	431 608	(17·8)	34	61·1	3·4	106	(43–150)	104	(103–104)	195	(70–278)
Gastrointestinal diseases	518 808	(21·4)	24	52·8	4·5	127	(88–147)	136	(135–136)	490	(309–819)
Other bacterial diseases	36 960	(1·5)	37	55·5	5·1	9·0	(6·4–11·3)	8·7	(8·6–8·8)	27	(9–59)
Quarantinable diseases	79	(0·0)	42	50·7	2·5	0·02	(0–0·03)	0·0	(0·0–0·0)	—	—
Sexually transmissible infections	790 990	(32·7)	23	45·7	17·8	193	(50–428)	210	(210–211)	2758	(1312–3525)
Vaccine-preventable diseases	487 176	(20·1)	25	47·5	3·8	119	(17–470)	126	(126–126)	267	(22–1395)
Vector-borne diseases	137 817	(5·7)	40	51·3	2·0	34	(16–53)	31·9	(31·7–32·0)	26	(7–58)
Zoonoses	17 696	(0·7)	40	79·3	2·4	4·4	(2·4–6·6)	4·1	(4·1–4·2)	—	—
Jurisdiction											
Australian Capital Territory	38 083	(1·6)	26	51·5	0·5	560	(129–1098)	555	(549–561)		
New South Wales	584 382	(24·1)	29	53·7	1·8	430	(114–812)	449	(448–450)		
Northern Territory	110 930	(4·6)	23	47·9	58·1	2598	(1824–3653)	2512	(2497–2523)	5121	(3609–7204)
Queensland	644 556	(26·6)	26	49·1	9·7	850	(491–1504)	880	(877–882)		
South Australia	218 624	(9·0)	27	49·3	5·7	694	(291–1653)	740	(736–743)	2085	(972–4417)
Tasmania	48 633	(2·0)	24	47·6	1·1	483	(245–991)	526	(523–531)		
Victoria	501 335	(20·7)	28	52·3	0·5	494	(184–995)	507	(506–509)		
Western Australia	274 591	(11·3)	25	50·6	18·1	684	(251–1262)	713	(711–716)	3353	(1535–4340)

CI, Confidence interval.

* Assumes all cases without Indigenous status reported were non-Indigenous.

† Only calculated for jurisdictions with Indigenous status reported for >75% of notified cases (Northern Territory, South Australia, Western Australia); –, <50 Indigenous cases notified.

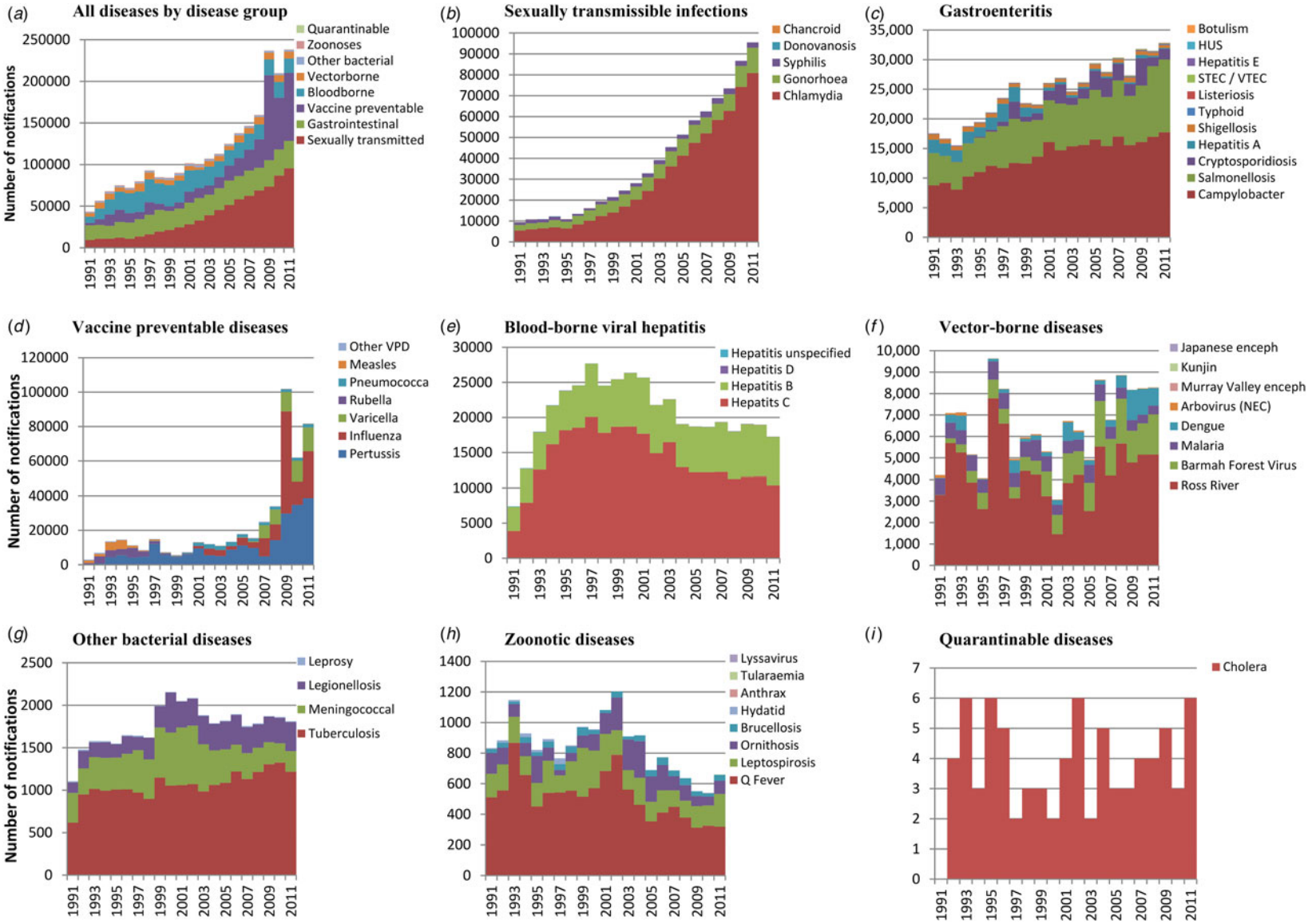

Fig. 1. Number of notifications by disease group and year, Australia 1991–2011. HUS, Haemolytic uraemic syndrome; NEC, not elsewhere classified; STEC/VTEC, Shiga/Vero-toxin-producing *Escherichia coli*; VPD, vaccine-preventable disease.

Table 3. *Infectious disease notification incidence by sub-period and age group, Australia 1991–2011*

	Overall		Average change annual inc.	Sub-period						Age group							
				1991–1997		1998–2004		2005–2011		<5 years		5–19 years		20–64 years		65–98 years	
	Cases notified	Inc.		Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR
All diseases	2 421 134	591·2	6·4%	385·9	0·5	504·5	0·6	853·0	Ref.	698·4	1·1	564·6	0·9	653·9	Ref.	262·6	0·4
Bloodborne viral hepatitis	431 608	105·6	−1·1%	108·6	1·2	122·7	1·4	87·4	Ref.	5·9	0·04	28·5	0·2	158·6	Ref.	28·6	0·2
Hepatitis B	134 797	35·8	−1·5%	41·2	1·3	36·0	1·1	32·5		2·4	0·0	14·9	0·3	51·6		11·8	0·2
Hepatitis C	296 022	73·9	−5·3%	100·2	1·8	86·9	1·6	54·8		3·3	0·0	15·6	0·1	113·0		17·4	0·2
Hepatitis D	573	0·1	3·1%	–	–	0·1	0·8	0·2		0·006	0·0	0·04	0·2	0·2		0·02	0·1
Hepatitis (NEC)	216	0·06															
Gastrointestinal diseases	518 808	126·7	2·0%	105·0	0·7	129·8	0·9	142·0	Ref.	440·4	4·2	109·4	1·1	104·2	Ref.	88·2	0·8
Botulism	16	0·005															
Campylobacteriosis	286 865	105·4	2·0%	85·9	0·7	112·4	1·0	115·2		255·3	2·6	86·7	0·9	97·2		89·4	0·9
Cryptosporidiosis	33 157	11·9	0·0%	–	–	9·9	0·8	12·9		79·0	12·2	12·9	2·0	6·5		1·8	0·3
Haemolytic uraemic syndrome	260	0·08															
Hepatitis A virus	23 506	5·7	−12·9%	11·9	8·7	4·8	3·5	1·4		4·9	0·8	7·0	1·1	6·2		1·5	0·2
Hepatitis E virus	346	0·1															
Listeriosis	1295	0·3	0·4%	0·3	1·0	0·3	1·1	0·3		0·4	1·8	0·01	0·1	0·2		1·3	5·9
Salmonellosis	157 428	38·4	3·0%	30·5	0·7	37·4	0·8	45·9		195·7	7·7	32·4	1·3	25·4		24·3	1·0
Shiga/Vero-toxin-producing *E. coli*	1035	0·4	5·7%	–	–	0·3	0·6	0·5		0·9	3·1	0·4	1·5	0·3		0·6	2·1
Shigellosis	13 297	3·8	−5·5%	6·2	2·1	3·1	1·1	2·9		17·3	5·7	3·0	1·0	3·0		1·2	0·4
Typhoid fever	1603	0·4	1·8%	0·4	0·9	0·3	0·7	0·5		0·4	1·0	0·5	1·1	0·4		0·09	0·2
Quarantinable diseases	79	0·02															
Cholera	79	0·02															
Sexually transmissible infections†	790 990	192·9	11·8%	64·4	0·2	156·3	0·5	333·8	Ref.	6·1	0·03	228·7	1·0	239·1	Ref.	11·2	0·05
Chancroid	8	0·005															
Chlamydial infection	621 431	185·1	12·5%	64·4	0·2	119·8	0·4	280·3		3·3	0·01	234·3	1·0	226·7		2·9	0·01
Donovoanosis	426	0·09	−17·5%	0·3	46·3	0·09	15·4	0·006		0·03	0·3	0·10	0·9	0·11		0·02	0·2
Gonococcal infection	130 008	31·5	5·6%	18·4	0·4	32·4	0·8	41·8		1·8	0·05	33·2	0·8	40·4		1·4	0·03
Syphilis (incl. congenital $n = 54$)	39 117	9·4	3·4%	6·8	0·6	9·3	0·8	11·7		0·9	0·07	5·2	0·4	12·2		7·1	0·6
Vaccine-preventable diseases	487 176	119·0	14·7%	57·5	0·2	51·8	0·2	241·6	Ref.	229·3	2·5	178·1	2·0	90·7	Ref.	95·9	1·1
Diphtheria	358	0·09															
Haemophilus influenzae type b	2081	0·5	−24·7%	1·4	15·7	0·1	1·5	0·09		5·6	75·2	0·3	3·5	0·07		0·2	2·6
Influenza (laboratory confirmed)	137 940	60·6	32·6%	–	–	13·4	0·2	87·8		143·0	2·8	90·5	1·8	50·9		35·1	0·7
Measles	16 780	3·9	−22·9%	11·6	29·8	0·7	1·8	0·4		17·0	18·3	10·4	11·3	0·9		0·2	0·2
Mumps	3363	1·0	0·7%	1·0	0·8	0·7	0·6	1·2		1·3	1·3	1·3	1·3	1·0		0·2	0·2
Pertussis	220 541	53·9	13·4%	25·6	0·3	33·4	0·3	96·3		86·6	2·1	87·3	2·1	41·8		39·3	0·9
Pneumococcal disease (invasive)	21 813	8·8	−4·5%			11·2	1·5	7·6		31·5	5·3	3·0	0·5	6·0		19·9	3·3

Table 3 (*cont.*)

	Overall		Average change annual inc.	Sub-period						Age group							
				1991–1997		1998–2004		2005–2011		<5 years		5–19 years		20–64 years		65–98 years	
	Cases notified	Inc.		Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR	Inc.	RR
Poliomyelitis	1	0·000															
Rubella (incl. congenital $n = 4$)	24 388	5·3	−30·4%	19·5	99·5	1·5	7·7	0·2		6·5	1·6	11·6	2·9	4·0		0·3	0·07
Tetanus	120	0·03															
Varicella zoster	59 791	77·9	4·1%	–	–	–	–	77·9		91·6	1·5	92·0	1·5	62·1		123·2	2·0
Vector-borne diseases	137 817	33·7	0·5%	36·1	1·0	28·5	0·8	36·3	Ref.	3·2	0·07	13·3	0·3	46·6	Ref.	21·1	0·5
Arbovirus infection (NEC)	869	0·2	−9·1%	0·3	3·7	0·3	2·9	0·09		0·02	0·06	0·08	0·3	0·3		0·2	0·6
Barmah Forest virus infection	21 815	6·1	6·0%	4·3	0·5	4·7	0·6	8·1		0·2	0·03	1·8	0·2	8·4		5·1	0·6
Dengue virus infection	8691	2·1	8·1%	1·2	0·4	1·9	0·6	3·2		0·3	0·09	1·1	0·4	2·9		1·1	0·4
Japanese encephalitis	11	0·001															
Kunjin virus infection	60	0·02															
Malaria	13 733	3·3	−3·3%	4·0	1·5	3·4	1·3	2·7		1·8	0·5	3·5	0·9	4·0		0·8	0·2
Murray Valley encephalitis virus	79	0·01															
Ross River virus infection	92 559	22·3	−1·0%	28·7	1·3	18·1	0·8	22·2		0·7	0·02	7·0	0·2	31·5		14·5	0·5
Zoonoses	17 696	4·4	−3·2%	5·1	1·6	5·1	1·7	3·1	Ref.	0·3	0·04	1·8	0·3	6·0	Ref.	2·7	0·4
Anthrax	4	0·001															
Australian bat lyssavirus	1	0·0															
Brucellosis	724	0·2	0·3%	0·2	1·0	0·2	1·0	0·2		0·01	0·04	0·08	0·3	0·3		0·07	0·3
Hydatid infection	136	0·07															
Leptospirosis	3544	0·9	−2·1%	0·9	1·3	1·1	1·7	0·7		0·02	0·02	0·4	0·3	1·2		0·3	0·3
Ornithosis	2480	0·8	−4·5%	0·9	1·9	1·0	2·0	0·5		0·06	0·06	0·09	0·10	1·0		1·3	1·3
Q fever	10 805	2·6	−4·1%	3·3	1·9	3·1	1·8	1·7		0·2	0·04	1·2	0·3	3·7		1·2	0·3
Tularaemia	2	0·001															
Other bacterial diseases	36 960	9·0	0·1%	8·7	1·0	10·1	1·2	8·8	Ref.	13·2	1·5	4·9	0·6	8·8	Ref.	14·8	1·7
Legionellosis	5658	1·4	2·3%	1·0	0·6	1·7	1·1	1·5		0·03	0·02	0·06	0·04	1·3		4·7	3·6
Leprosy	200	0·05															
Meningococcal disease (invasive)	8766	2·1	−2·7%	2·2	1·6	3·0	2·2	1·4		11·5	11·0	3·1	3·0	1·0		0·8	0·8
Tuberculosis	22 336	5·5	0·4%	5·4	1·0	5·4	0·9	5·7		1·7	0·3	1·7	0·3	6·4		9·3	1·4

Inc., Incidence per 100 000 person-years; Avg change inc., % average percentage change in annual incidence per year of the study period (while disease was nationally notifiable; Table 1); RR, relative risk; Ref., reference group for RR calculations; NEC, not elsewhere classified; –, not notifiable for that sub-period.

Annual change in notification incidence, sub-period and age-group analysis for diseases with >400 cases notified.

† Chlamydial and gonococcal infections and syphilis include non-sexually acquired infections (especially in children) such as perinatal and eye infections.

Diseases with zero notifications: highly pathogenic avian influenza in humans (HPAIH), plague, rabies, severe acute respiratory syndrome (SARS), smallpox, viral haemorrhagic fevers, yellow fever.

Table 4. *Pathogens with highest notification incidence, Australia 1991–2011, by sub-period and age group*

		Sub-period			Age group			
Rank	Overall	1991–1997	1998–2004	2005–2011	<5 years	5–19 years	20–64 years	65–98 years
1	*Chlamydia*	Hepatitis C virus	*Chlamydia*	*Chlamydia*	*Campylobacter*	*Chlamydia*	*Chlamydia*	Varicella zoster
2	*Campylobacter*	*Campylobacter*	*Campylobacter*	*Campylobacter*	*Salmonella*	Varicella zoster	Hepatitis C virus	*Campylobacter*
3	Varicella zoster	*Chlamydia*	Hepatitis C virus	*B. pertussis*	Influenza	Influenza	*Campylobacter*	*B. pertussis*
4	Hepatitis C virus	Hepatitis B virus	*Salmonella*	Influenza	Varicella zoster	*B. pertussis*	Varicella zoster	Influenza
5	Influenza	*Salmonella*	Hepatitis B virus	Varicella zoster	*B. pertussis*	*Campylobacter*	Hepatitis B virus	*Salmonella*
6	*B. pertussis*	Ross River virus	*B. pertussis*	Hepatitis C virus	***Cryptosporidium***	*N. gonorrhoeae*	Influenza	***S. pneumoniae***
7	*Salmonella*	*B. pertussis*	*N. gonorrhoeae*	*Salmonella*	***S. pneumoniae***	*Salmonella*	*B. pertussis*	Hepatitis C virus
8	Hepatitis B virus	**Rubella**	Ross River virus	*N. gonorrhoeae*	***Shigella***	Hepatitis C virus	*N. gonorrhoeae*	Ross River virus
9	*N. gonorrhoeae*	*N. gonorrhoeae*	Influenza	Hepatitis B virus	**Measles**	Hepatitis B virus	Ross River virus	Hepatitis B virus
10	Ross River virus	**Hepatitis A**	***S. pneumoniae***	Ross River virus	***N. meningitidis***	***Cryptosporidium***	*Salmonella*	***M. tuberculosis***

Incidence calculated for years each disease was nationally notifiable and jurisdictional data available.
Bold text indicates pathogens not in the overall top 10.

increase/year, notifiable from 2001), pertussis (13%), and chlamydial infection (13%, notifiable from 1994) increased the most across the study period. Twenty-one diseases were consistently notifiable across jurisdictions for the entire study period (Table 1); annual incidence of these increased by 4·1% per year.

The median age of notified cases was 27 [interquartile range (IQR) 19–40] years, younger for STIs and in the NT (both with median age 23 years) (Table 2). Median age at onset was ⩽7 years for congenital rubella, congenital syphilis, botulism, Hib, cryptosporidiosis, chickenpox and haemolytic uraemic syndrome; and ⩾62 years for legionellosis, listeriosis and tetanus. Notification incidence (/100 000 per year) was highest for young children aged <5 years (698) and adults aged 20–64 years (654) and lowest for older adults aged 65–98 years (263) (Table 3). Cryptosporidiosis, invasive pneumococcal disease, shigellosis, measles and invasive meningococcal disease were among the 10 highest-incidence diseases for young children; cryptosporidiosis for older children and adolescents (aged 5–19 years); and pneumococcal disease and tuberculosis for older adults (Table 4). Compared to adults (aged 20–64 years), notification RR was highest for Hib (75), measles (18), cryptosporidiosis (12) and invasive meningococcal disease (11) for young children; measles (11) for older children and adolescents; and listeriosis (6) for older adults (Table 3). Fifty-one percent of notified cases were male, ranging from 46% for STIs to 79% for zoonoses (Table 2).

Overall, 202 584 (8·4%) cases were identified as Indigenous – ranging from 0·5% in the Australian Capital Territory (ACT) and Victoria to 58% in the NT (Table 2) – 36% of cases identified as non-Indigenous and for 56% Indigenous status was not reported. STIs comprised 70% of Indigenous case notifications. In the three jurisdictions with Indigenous status completed for >75% of cases, notification rates for all diseases were six times higher and STIs 14 times higher in Indigenous Australians compared to the total population.

Queensland had the greatest number of notifications (644 556 notifications, 27%), despite ranking third in population behind NSW and Victoria. The NT had the highest annual notification incidence (2598/100 000) (Fig. 2); age-standardized notification rates remained four times higher in the NT than the national average (2512 *vs.* 621/100 000 per year). Notification rates were highest in the NT for all disease groups except quarantinable and zoonotic diseases; however, the NT made the best progress in

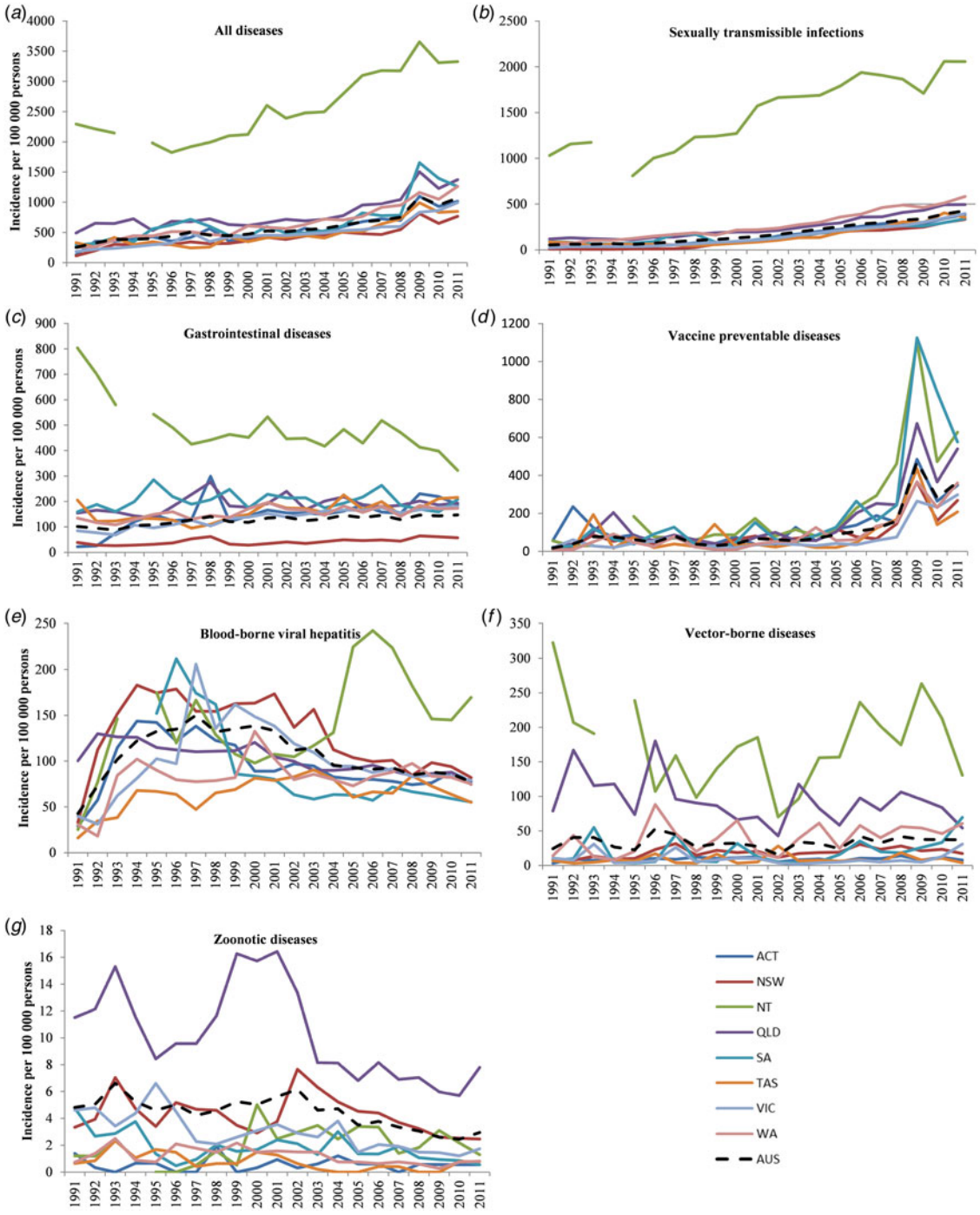

Fig. 2. Annual notification rate by jurisdiction and year for all diseases groups, Australia 1991–2011. NT notifications from 1994 not included in incidence calculations.

reducing (or limiting increase of) notifications overall (Supplementary Appendix Fig. A1). Compared to notification incidence in NSW, RR was $\geqslant$15 for shigellosis, gonococcal infection, and syphilis in the NT; brucellosis in Queensland; and Shiga- or Verotoxin-producing *Escherichia coli* (STEC/VTEC) in SA (Supplementary Appendix Table A1).

STIs

STIs comprised 33% of all notifications, increasing fivefold from 64/100 000 per year in 1991–1997 to 334/100 000 per year in 2005–2011 (Table 3). Chlamydial infections (notifiable from 1994) accounted for 79% of STI notifications, gonococcal

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disease 16% (32/100 000 per year), and syphilis 5% (9/100 000 per year) (Fig. 1*b*). Annual incidence of STIs was highest in those aged 20–29 years (239/100 000) and was eightfold higher in the NT than the national average (1527 *vs.* 193/100 000) (Fig. 2*b*).

Gastrointestinal diseases

Gastrointestinal diseases comprised 21% of notifications, with campylobacteriosis accounting for 55% despite not being notifiable in NSW (Fig. 1*c*). The national incidence of notified gastrointestinal diseases increased by 2% per year. Gastrointestinal disease notifications in the NT were nearly four times the national incidence (481 *vs.* 127/100 000 per year, Fig. 2*c*). NSW had the lowest notification incidence (Supplementary Appendix Fig. A1); however, national notification incidence of gastrointestinal diseases excluding campylobacteriosis (55/100 000 per year) was similar to NSW (43/100 000 per year).

VPDs

Just under half a million VPD cases were notified (Table 2), of which 45% were pertussis, 28% influenza (notifiable from 2001), and 12% varicella zoster (notifiable from 2006) (Fig. 1*d*). VPD notifications increased 15% per year, from 3016 in 1991 to a peak of 101 942 cases in 2009 during the H1N1 influenza pandemic. Median age at disease onset increased from 14 years in 1991–1997 to 30 years in 2005–2011. National incidence of VPD notifications was 119/100 000 per year, highest in the NT (239/100 000) and lowest in Victoria (77/100 000) (Fig. 2*d*).

BBVH

BBVH comprised 18% of notifications nationally and 30% of notifications in NSW (Supplementary Appendix Fig. A1). Annual incidence of notified BBVH cases was higher in the NT and NSW (144 and 128 notifications/100 000, respectively) than other jurisdictions (64–101/100 000, Fig. 2*e*). Hepatitis C, notifiable from 1995, accounted for 69% and hepatitis B 31% (Fig. 1*e*). BBVH notification incidence increased threefold from 43/100 000 per year persons in 1991 to 150/100 000 per year in 1997 before dropping to 77/100 000 per year in 2011, reflecting changes in hepatitis C notifications.

VBDs

There were 137 817 VBD notifications (5·7% of notifications), 67% being RRV infections (notifiable from 1993), 16% Barmah Forest virus infections (notifiable from 1995), 10% malaria, and 6% dengue (Fig. 1*f*). VBD notification incidence was 34/100 000 per year for Australia, highest in the NT (175/100 000) and Queensland (92/100 000) and lowest in Tasmania (9/100 000) (Fig. 2*f*).

Other bacterial diseases

There were 36 960 notifications of other bacterial diseases, of which 60% were tuberculosis, 24% invasive meningococcal disease, and 15% legionellosis. Other bacterial disease notification incidence was 9/100 000 per year, highest in the NT (27/100 000) and lowest in Tasmania (5/100 000) (Fig. 2). Tuberculosis notification incidence was 6/100 000 per year for Australia (range 21/100 000 in the NT to 2/100 000 in Tasmania) and was stable over the study period (Supplementary Appendix Fig. A1). Fifty-five percent of notified cases were male; highest for *Legionella* (67%) and leprosy (62%).

Zoonotic diseases

There were 17 696 zoonotic disease notifications (0·7% of all notifications). Q fever was most common (61%), followed by leptospirosis (20%) and ornithosis (14%). Males predominated, especially for anthrax (100% of four cases notified), leptospirosis (90%), brucellosis (84%), and Q fever (80%). Queensland notified 43% of all zoonotic cases, 83% of brucellosis and 56% of leptospirosis cases. Zoonotic disease notification incidence was 4·4/100 000 per year; highest in Queensland (10·0/100 000) and lowest in the ACT (0·6/100 000) (Fig. 2*h*). Zoonotic disease notifications fell by an average 3% annually (Supplementary Appendix Fig. A1).

DISCUSSION

Intelligence obtained from national communicable disease surveillance regarding infectious disease epidemiology guides national policy development, resource allocation, disease control programmes and quarantine activities, as well as allowing identification of and coordinated responses to national or multijurisdictional outbreaks [3]. This paper provides the first trend analysis of all nationally notifiable diseases in

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Australia (except HIV/AIDS and CJD) since the inception of the NNDSS in 1991. Both the number and incidence of notifications increased steadily over the 21 years, partly due to the addition of diseases to the system. Incidence rates were highest in the NT and in Indigenous and young Australians. The ten diseases with highest notification incidence accounted for nearly 90% of notifications and required a range of public health strategies for disease prevention and control; including safe sex, contact tracing, harm-reduction for people who inject drugs, food safety, and immunization [10–14]. This highlights the complex challenges facing state, territory, and federal health departments in preventing and controlling infectious diseases in Australia.

Indigenous people comprised 8% of notified cases but only 3% of the Australian population [15]. Significant under-reporting of Indigenous status among notified cases means likely underestimation of this proportion. Indigenous Australians have poorer health outcomes: life expectancy is 9·7 and 11·5 years lower for Indigenous females and males, respectively [16], and disease burden measured in years of life lost was 2·6 times that of non-Indigenous Australians for all causes and 3·8 times for infections in 2010 [17]. Childhood vaccination coverage is lower for Indigenous children [18], potentially explaining some difference in VPD notification rates. In a previously published study, the notification RR for Indigenous compared to non-Indigenous Australians from 2000 to 2009 was 24 for chlamydial infection and 174 for gonococcal infection [19], and higher positivity rates for Indigenous patients tested for *Chlamydia* confirm greater STI burden rather than ascertainment bias [20].

Higher notification rates in the NT reinforce previous findings that the health adjusted life expectancy for the NT population was 5 years less than the Australian average in 2003 (67·7 *vs.* 72·9 years) [21]. The NT is the least populous Australian jurisdiction (estimated resident population 231 000 in 2011) [5]. The NT population is younger and has a high proportion of Indigenous persons (30% in NT *vs.* 3% nationally) than other jurisdictions [15, 22]; factors reflected in NT notifications. However, age-standardized notification rates were higher in the NT than elsewhere and notification rates in Indigenous people were higher in the NT than SA and WA. As NT data from 1994 were excluded from both the numerator (number of cases notified) and denominator (population) of incidence calculations, this would not have substantially impacted our RR calculations comparing notification incidence between the NT and other jurisdictions. It is likely that climactic and environmental diseases also impact disease incidence in the NT, while variability in health-seeking, diagnostic and notification practices might further contribute to the interjurisdictional differences.

Importantly, our results highlight some major public health achievements. The marked reduction in notification incidence for rubella, measles and Hib demonstrate the impact of Australia's National Immunization Programme. In 2014 Australia was recognized by the WHO to have eliminated measles [23]. Similarly, the reduction in donovanosis cases results from sustained public health programmes such as the National Donovanosis Eradication Project [24].

The annual number of notifications increased more than fivefold over the 21-year study period. The reasons for this are multifactorial, including addition of notifiable diseases to national and jurisdictional notification lists, population growth, introduction of screening programmes (e.g. for chlamydial infection), and improved diagnostics as well as true changes in disease incidence. There were 37 nationally notifiable diseases in 1991 and 65 in 2011. The number of nationally notifiable diseases has also increased internationally; from 56 to 87 (1992–2011) in the United States and from 41 to 58 (1991–2011) in Canada [25, 26]. The number of nationally notifiable diseases varied between European countries, ranging from 26 in France to 82 in Hungary in 2005 [27]. Some differences are due to increased number of disease categories associated with a single pathogen (e.g. syphilis has eight categories in the US system and three in the Australian NNDSS), but also reflect inclusion of diseases that are endemic in selected countries (particularly VBDs).

While many diseases are common between national surveillance systems, some differences are seen. In Australia, 10 diseases accounted for 88% of NNDSS notifications. National surveillance systems in the United States and Canada as well as the European Surveillance System (TESSy) receive notifications for eight of these diseases; varicella is not notifiable in to the Canadian or European surveillance systems and RRV is not notifiable to any [25–28]. In New Zealand, chlamydial infection, influenza, varicella and RRV are not nationally notifiable [29]. Conversely, some common infectious diseases are not notifiable in Australia and their inclusion on the Australian

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NNDL may increase the burden on notifiers and public health departments. For example, rotavirus and norovirus diseases have high notification rates in Germany [30, 31]. National notification rates for all diseases or by disease group are generally not published and the variable inclusion of high-incidence diseases limit direct comparisons, but different notification rates for individual diseases could indicate differential disease burden between countries.

A major limitation of notification data is that they underestimate the number of infections, particularly for diseases that cause mild or no clinical symptoms. Despite uniform national case definitions [32], disease notification rates are influenced by jurisdictional and local diagnostic, screening, case follow-up, and notification practices. For example, disproportionately high STEC notification rates in SA have been linked to differences in diagnostic practices with a very high number of STEC toxin gene tests performed in SA [33]. Additionally, over the 21-year study period, sensitive diagnostic tests (particularly PCR) have become widely available and marked changes to testing practices among doctors and laboratories have been documented [34–37]. These factors potentially account for much of the observed change for several diseases, including chlamydial infection, influenza and pertussis which had the greatest increase in notification incidence over the study period [34, 36, 37]. As notification fractions vary between diseases, jurisdictions, population subgroups and over time, notification rates represent the frequency of disease diagnosis but not necessarily disease incidence. Similarly, as it is impossible to determine disease severity, notification incidence alone cannot determine the population burden of infectious diseases. A European study of seven infectious diseases found foodborne diseases (campylobacteriosis and salmonellosis) had the highest notified incidence, tuberculosis the highest mortality, and HIV infection and tuberculosis the greatest disability-adjusted life years burden [38].

The NNDSS dataset provides comprehensive coverage of national infectious disease notifications over two decades. Previously, annual Australian and international reports have been produced but this paper is unique in reporting the entire dataset of nationally notifiable diseases (excluding HIV/AIDS and CJD) for a 21-year period across all Australian jurisdictions. While we provide an overview of diseases reported, we have not reported system performance or data completeness and quality. However, this analysis highlights the breadth of diseases notified in Australia and complexity of public health responses required to reduce associated morbidity and mortality. Understanding the increasing number of notifiable diseases and notified cases is crucial for informing surveillance and public health workforce planning at a jurisdictional and national level.

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SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper visit http://dx.doi.org/10.1017/S0950268816001072.

DECLARATION OF INTEREST

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