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An atlas of common *Salmonella* serotypes from routinely notified human cases in the Northern Territory of Australia, 2005–2024

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Surveillance summary

Abstract

Salmonella infections cost Australian society an estimated 140 million Australian Dollars (AUD) per year *circa* 2019. Salmonellosis is caused by *Salmonella enterica*, with over 2,500 serotypes of *S. enterica* identified. Knowledge of the epidemiology of *Salmonella* serotypes may facilitate traceback from strains detected in human cases to identify the cause of local and multijurisdictional outbreaks and to implement control measures. We analysed cases of human salmonellosis notified in the Northern Territory (NT), Australia, between 1 January 2005 and 31 December 2024. We calculated the incidence of salmonellosis for all locally acquired infections according to the NT location where the infection was most likely acquired. We mapped the geographical distribution of the 25 most frequently notified *Salmonella* serotypes to Statistical Areas Level 2. There were 8,706 salmonellosis cases acquired in the NT: *Salmonella* Saintpaul (1,047 notifications) was the most frequently notified serotype, followed by *S*. Virchow (948 notifications); *S*. Typhimurium (822 notifications); *S*. Ball (578 notifications); and *S*. Lansing (460 notifications). While *S*. Typhimurium was ubiquitous in the NT, *S*. Saintpaul, *S*. Virchow and *S*. Hvittingfoss showed distinct geographic patterns. Our atlas makes key epidemiological information about common NT *Salmonella* serotypes readily available, which may be useful for developing hypotheses during outbreak investigations; for facilitating traceback of suspected food vehicles; and for implementing control strategies more rapidly.

Keywords: *Salmonella*; salmonellosis; *Salmonella* Saintpaul; *Salmonella* Virchow; *Salmonella* Hvittingfoss; *Salmonella* Ball; *Salmonella* Muenchen; foodborne disease; OzFoodNet; geographic information system (GIS) mapping

Introduction

Salmonella enterica subspecies *enterica* is a gram-negative bacillus of the genus *Salmonella*.[1] There have been over 2,500 serotypes (serovars) of *S. enterica* identified.[2] The diseases caused by serotypes *Salmonella* Typhi and *S*. Paratyphi are known as typhoid and paratyphoid fever, respectively.[3] Salmonellosis refers to the diseases caused by the other (i.e. nontyphoidal) *Salmonella* serotypes, which more commonly present as gastroenteritis.[3]

Salmonella bacteria are found in the gastrointestinal tracts of animals including birds, reptiles, amphibians and mammals.[3] A person typically becomes ill 6–72 hours after ingesting the bacteria, which may be through direct or indirect contact with a contaminated environment, or through the ingestion of contaminated water or food, where the latter is typically raw or undercooked meat or eggs, or contaminated raw fruits or vegetables.[3]

Salmonellosis causes a considerable burden on Australian society in the form of lost productivity, costs associated with pain and suffering, direct healthcare costs and premature mortality. The annual cost of salmonellosis in Australia was estimated at approximately 140 million Australian Dollars (AUD) per year *circa* 2019.[4] Within Australia, salmonellosis is a notifiable condition both in the Northern Territory (NT)[5] and nationally;[6] it is a disease under surveillance by the OzFoodNet network, a network of epidemiologists in each Australian jurisdiction who conduct surveillance on enteric diseases.[7] There has been an OzFoodNet site in the NT since 2003. The NT typically observes rates of salmonellosis four to five times higher than the rest of Australia,[8] with approximately half of notified cases in children aged < 5 years old. It is likely that most of these infections are acquired from the environment,[9,10] which is an important source of sporadic infection in the NT.

Salmonella Virchow, *S*. Lansing, *S*. Saintpaul, *S.* Ball, *S*. Hvittingfoss, *S*. Reading, *S*. Muenchen, *S*. Weltevreden, and *Salmonella* subspecies I ser 16:l,v:- are all considered environmental serotypes in the NT.[11–16] The NT OzFoodNet site has published regular reports which include brief annual summaries of the epidemiology of salmonellosis in the NT,[11–28] as well as other epidemiological studies[29–31] and case reports.[32,33]

When specific *Salmonella* serotypes are detected in human cases during outbreaks in Australia, knowledge and documentation of the historical epidemiology may be useful in hypothesis generation while investigating cases or outbreaks, and may facilitate traceback of foods to a particular location in order to identify the cause of an outbreak and implement control measures. Fresh produce grown in the NT has been previously implicated in salmonellosis outbreaks in other parts of Australia, including outbreaks of *S*. Saintpaul[34] and *S*. Hvittingfoss[35] (commonly isolated serotypes in the NT) both associated with rockmelons (cantaloupes) grown in the NT. There have also been local outbreaks associated with food produced in the NT such as wild hunted turtle,[36] wild hunted kangaroo,[37] and cordial contaminated with environmental *Salmonella*.[38] The OzFoodNet NT site has also published the results of numerous salmonellosis outbreaks that have occurred in the NT since 2003 (Appendix A, Table A.1).

The Northern Territory Notifiable Disease System (NTNDS) is a surveillance system which records case information of notifiable conditions in the NT.

This study used routinely collected surveillance data from the NTNDS to describe the geographical distribution of common *Salmonella* serovars in the NT during 2005–2024. We mapped the most commonly notified *Salmonella* serotypes in the NT to serve as a tool for rapid and accurate hypothesis generation and traceback during foodborne disease outbreaks across Australia.

Methods

Methods of surveillance and data analysis are published elsewhere.[46] In brief, data were extracted from the NTNDS on all salmonellosis notifications in the NT with a diagnosis date (earliest of onset date, specimen collection date or notification date) between 1 January 2005 and 31 December 2024.

We used Stata 17.0 (StataCorp) to calculate the incidence (over 20 years) of salmonellosis according to the NT location (e.g. suburb or locality) where the infection was most likely acquired. Place acquired was defined as the NTNDS variable ‘place infected’, which describes the known location of infection as determined by previously completed routine case follow-up. In the NT, follow-up is generally restricted to cases aged > 5 years and performed by trained staff at the NT Centre for Disease Control. Where ‘place infected’ was missing, place of residence was used as a proxy. All interstate or international residents with no defined ‘place infected’ in the NT were excluded, as were those notifications where ‘place infected’ was an overseas or interstate location.

We used Quantum GIS (QGIS) 3.38 to map the geographical distribution of the 25 most frequently notified *Salmonella* serotypes to Statistical Areas Level 2 (SA2s)[47] according to place acquired. These maps are presented in Appendix A for this article, as Maps A.1 to A.25.

Ethics

We obtained ethical approval from the Human Research Ethics Committee (HREC) of the NT Department of Health and Menzies School of Health Research (2025-5121), and the HREC of the Australian National University (H/2025/0127).

Results

There were 9,628 notifications of salmonellosis in the twenty-year study period; 449 notifications (4.7%) likely acquired their infection overseas and a further 473 notifications (4.9%) were either overseas or interstate residents with no defined place infected in the NT and were thus excluded. Of the 8,706 notifications whose infection was acquired in the NT, 53% were aged < 5 years of age. *Salmonella* Saintpaul (1,047 notifications) was the most frequently notified serotype, followed by *S*. Virchow (948 notifications); *S*. Typhimurium (822 notifications); *S*. Ball (578 notifications); and *S*. Lansing (460 notifications; Table 1). Together these five serotypes accounted for 44.3% of all NT acquired salmonellosis notifications during the study period.

The geographical distribution of the most frequently notified locally acquired *Salmonella* serotypes can be found in Maps A.1–A.25. *Salmonella* Typhimurium was ubiquitous in the NT, while *S*. Saintpaul, *S*. Virchow and *S*. Hvittingfoss showed distinct geographic patterns in the northern parts of the NT. *S*. Hvittingfoss cases were highly clustered in the SA2 of Katherine.

Table 1: Commonly notified locally acquired *Salmonella* serotypes in the Northern Territory of Australia, 2005–2024 (n = 8,706)

Serotype	Notifications	Percentage of all notifications (%)	Map, in supplementary material
S. Saintpaul	1,047	12.0	Map A.1
S. Virchow	948	10.9	Map A.2
S. Typhimurium	822	9.4	Map A.3
S. Ball	578	6.6	Map A.4
S. Lansing	460	5.3	Map A.5
S. subspecies I ser 16:l,v:-	300	3.4	Map A.6
S. Chester	239	2.7	Map A.7
S. Weltevreden	223	2.6	Map A.8
S. Anatum	196	2.3	Map A.9
S. Hvittingfoss	185	2.1	Map A.10
S. Muenchen	175	2.0	Map A.11
S. Aberdeen	169	1.9	Map A.12
S. Reading	159	1.8	Map A.13
S. Litchfield	153	1.8	Map A.14
S. Infantis	134	1.5	Map A.15
S. Paratyphi B bv Java	132	1.5	Map A.16
S. Havana	123	1.4	Map A.17
S. Mgulani	104	1.2	Map A.18
S. Senftenberg	91	1.0	Map A.19
S. Chailey	90	1.0	Map A.20
S. Newport	90	1.0	Map A.21
S. Poona	88	1.0	Map A.22
S. Zanzibar	87	1.0	Map A.23
S. Kinondoni	74	0.8	Map A.24
S. Enteritidis	51	0.6	Map A.25
All other *Salmonella* serotypes	1,988	22.8	–
Total	**8,706**	**100**	**–**

Discussion

Salmonellosis is common in the NT, with a large proportion of cases aged < 5 years who probably acquire their infection from a contaminated environment.[9,10,29] This atlas of common *Salmonella* serotypes in the NT shows the geographic distribution of human cases as a proxy for the environmental distribution in the NT. It may be used as a tool in the investigation of salmonellosis outbreaks in Australia to formulate hypotheses, particularly during multijurisdictional outbreaks where the serotype is one that is common in the NT or where food production and distribution patterns may suggest a food produced in the NT. It is important, though, to understand the national epidemiology of *Salmonella* serotypes and their distribution across other jurisdictions in Australia while formulating hypotheses.

An example of how this atlas could have been utilised is during a multijurisdictional outbreak of *S*. Hvittingfoss which occurred in Australia in 2016 and was associated with a single rockmelon grower in the Katherine region of NT.[48,49] There were 144 cases of *S*. Hvittingfoss in total, notified across every jurisdiction in Australia except the NT as all affected product was sold interstate. Initial epidemiological investigations suggested rockmelons and food-traceback activities were conducted in multiple states and territories concurrently. If the investigators had access to the geographical distribution map of *S*. Hvittingfoss in the NT (Appendix A, Map A.10), they would have quickly identified that the Katherine region is a hotspot for *S*. Hvittingfoss. This evidence could have led to quicker hypothesis generation, faster traceback and faster removal of the risk to public health.

There are some limitations to consider when using this atlas. Firstly, the maps are an estimated location of exposure to salmonellosis only and assume that the exposure has occurred in the same SA2 location that the person resides in. Secondly, the maps do not account for food exposures where foods have been imported into the NT from interstate or overseas; this is shown by the map of *S*. Typhimurium where human cases occur across the NT. In Australia, chicken and eggs have been shown to be the predominant sources of human infection with *S*. Typhimurium;[50,51] accordingly, NT cases or outbreaks involving this serotype are not likely environmental in origin. Conversely, other serotypes which are common in the NT showed distinct geographical patterns which likely reflect their presence in the environment at different locations.

Thirdly, we have included all cases of notified salmonellosis, not just those aged < 5 years. The sustained high rates of salmonellosis in the NT across all age groups shows that *Salmonella* are ubiquitous in the NT environment, but it is more likely that some adults have acquired their infection from food, rather than the environment where they live. Fourth, we are unable to distinguish outbreak cases from sporadic cases due to the nature of the surveillance data; however, outbreak-related cases are likely to be a small proportion compared to sporadic cases due to the small number of salmonellosis outbreaks reported in the NT (Appendix A, Table A.1); it is likely that health seeking behaviour and case notification is higher in outbreak cases than in sporadic cases, especially as investigators may facilitate case-finding and sample submission.

Finally, this atlas is formulated on surveillance data from notified human cases of salmonellosis. This atlas does not use data on *Salmonella* that is detected through veterinary sampling, environmental sampling or through food testing, which would increase our understanding of environmental distribution of *Salmonella*. Future surveillance and research of salmonellosis in the NT should occur with a focus on data integration through a One Health approach. Furthermore, it is estimated that for every laboratory notification of salmonellosis there are another seven cases in the community that are not detected.[52] Another limitation is that the data presented in this paper and maps is limited to the 20 years analysed. Future epidemiology may not always correspond to this historical data, so geographical trends in serovar incidence should be continually and routinely analysed over time.

Conclusion

This atlas of common *Salmonella* serotypes notified in the NT provides useful epidemiological data to public health units, outbreak investigators, food authorities and food safety agencies in Australia. It makes key information about the geographical distribution of these common serotypes readily available to support hypotheses during outbreak investigations, facilitating the traceback of suspected food vehicles, the judicious allocation of resources to targeted areas, and the implementation of control strategies more rapidly. This atlas should not be used in isolation; it should augment knowledge acquired from previous published outbreak investigations and should be used in conjunction with knowledge about food supply chains and with other sources of data and interpretive advice. The Australia Centre for Disease Control should consider routinely mapping diseases in a national interoperable disease surveillance database, especially those with an environmental or zoonotic transmission route. Geographic distribution of serovars should be routinely and systematically analysed over time to identify trends.

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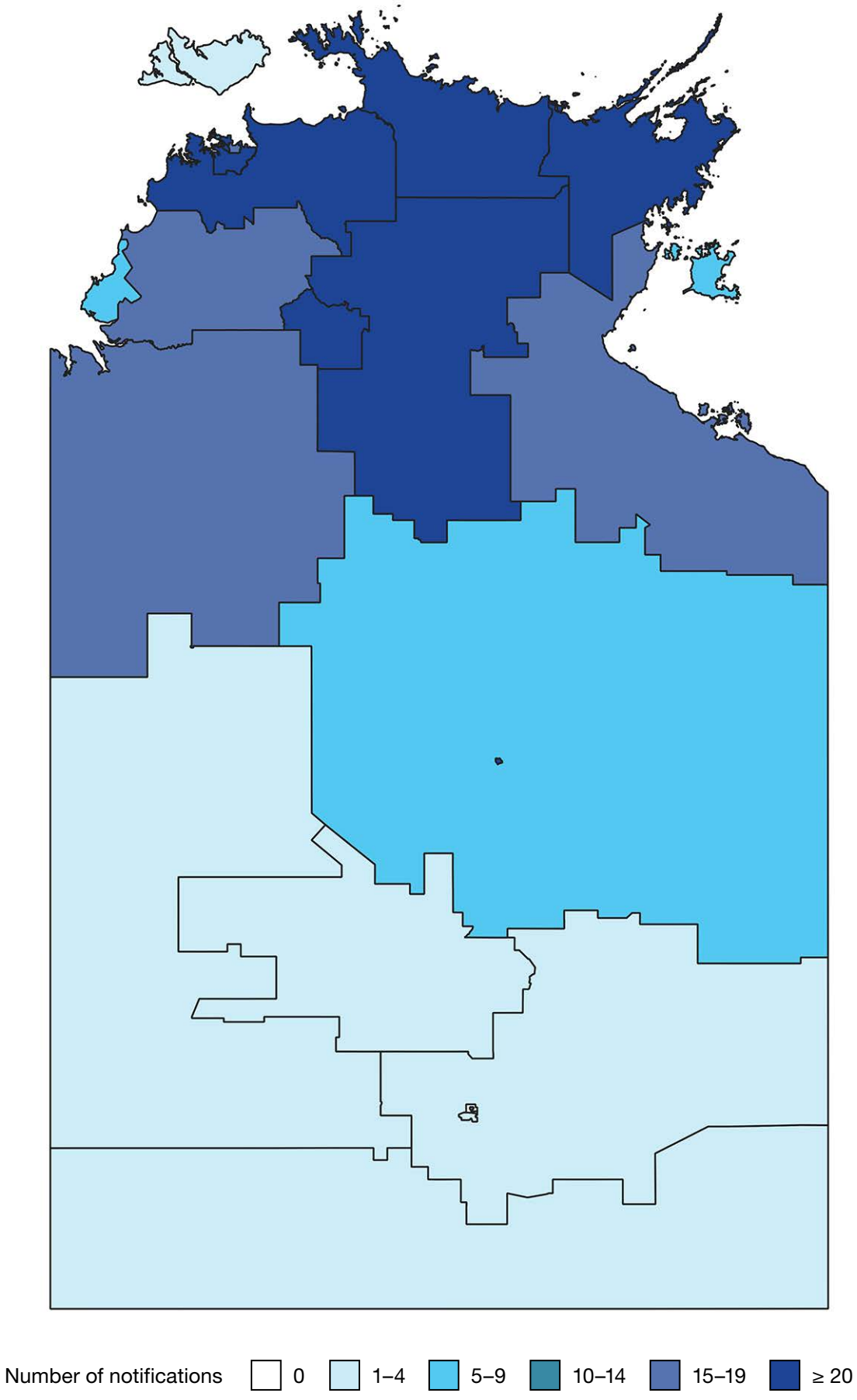
Appendix A

Table A.1: Published salmonellosis outbreaks, Northern Territory (NT), Australia, from the NT OzFoodNet site since 2003 by aetiology, likely source and year

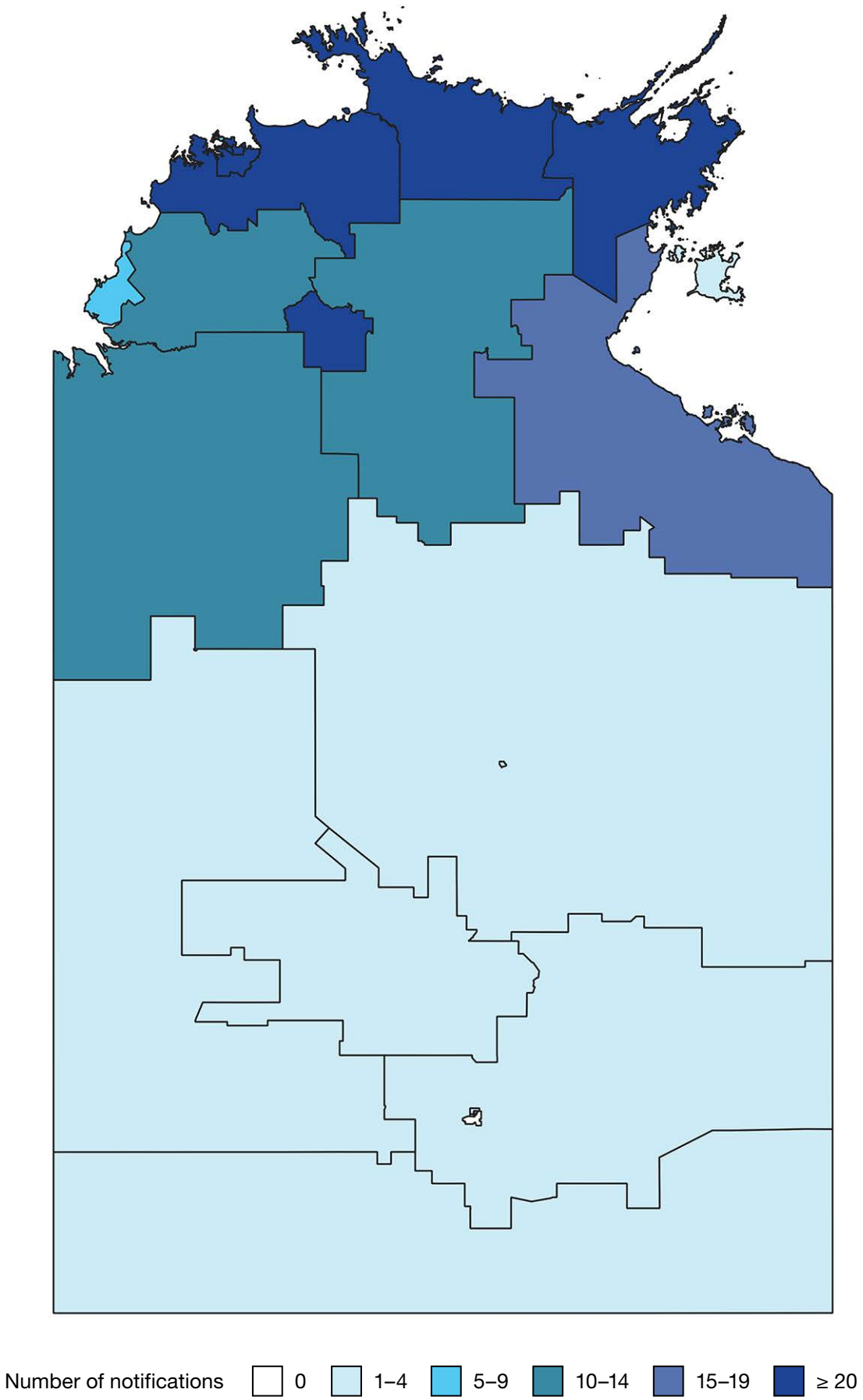
Year	Aetiology[a]	Likely source	Reference
2003	*Salmonella* (untyped)	Quail	39
2003	*S.* Typhimurium PT135	Undercooked meat rolls and sandwiches	40
2007	*S.* Oslo	Unknown	41
2008	*S.* Typhimurium PT9	Unknown (likely cross contamination from eggs)	42
2009	*S.* Litchfield	Barramundi fillets	43
2014	*S.* Saintpaul	Cordial	38
2015	*S.* Typhimurium	Duck prosciutto	44
2016	*S.* Saintpaul	Bean sprouts	45
2017	*S.* Muenchen	Wild hunted turtle	36
2024	*S.* Muenchen	Wild hunted kangaroo	37

a PT: phage-type.

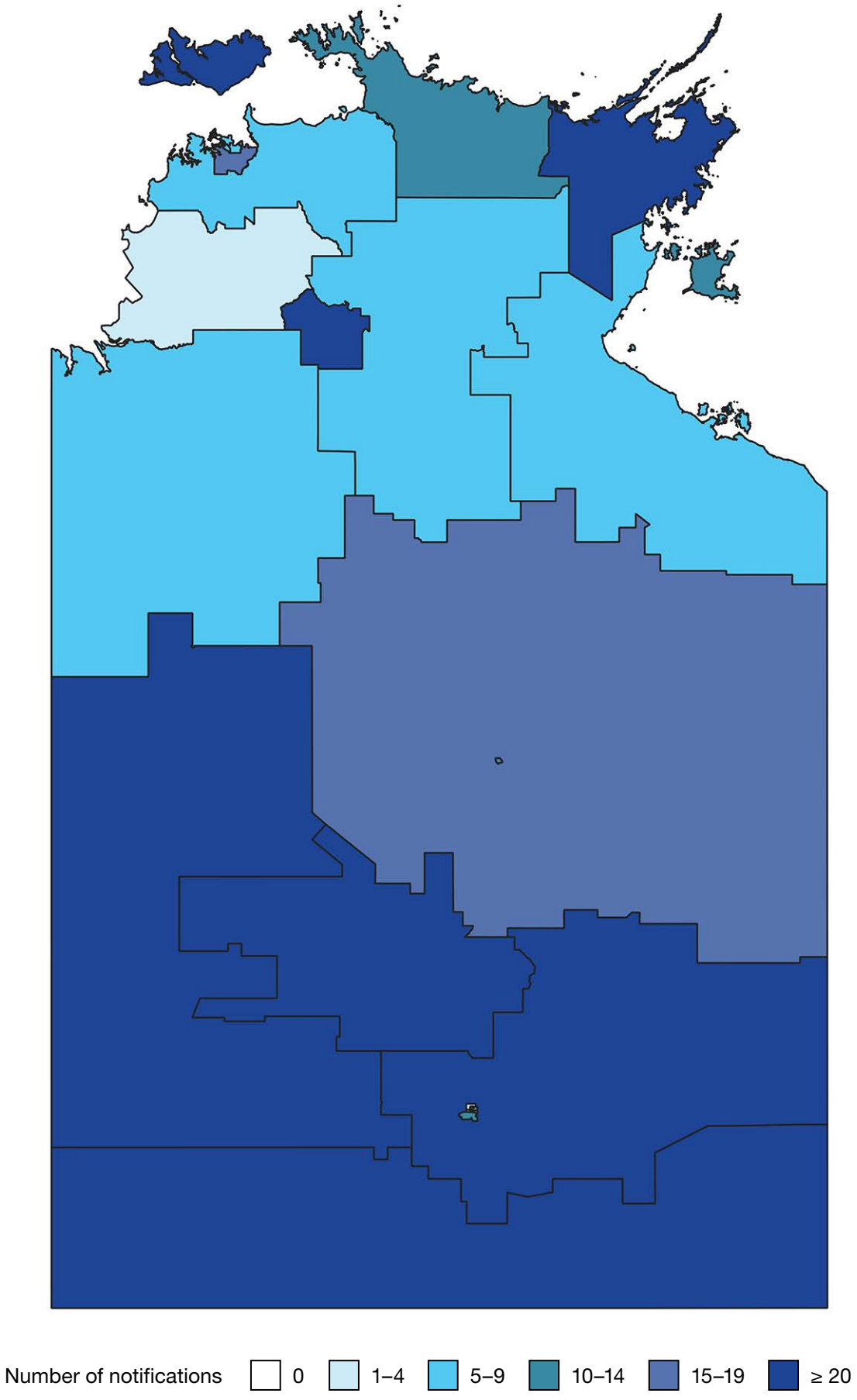
Map A.1: *Salmonella* Saintpaul notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



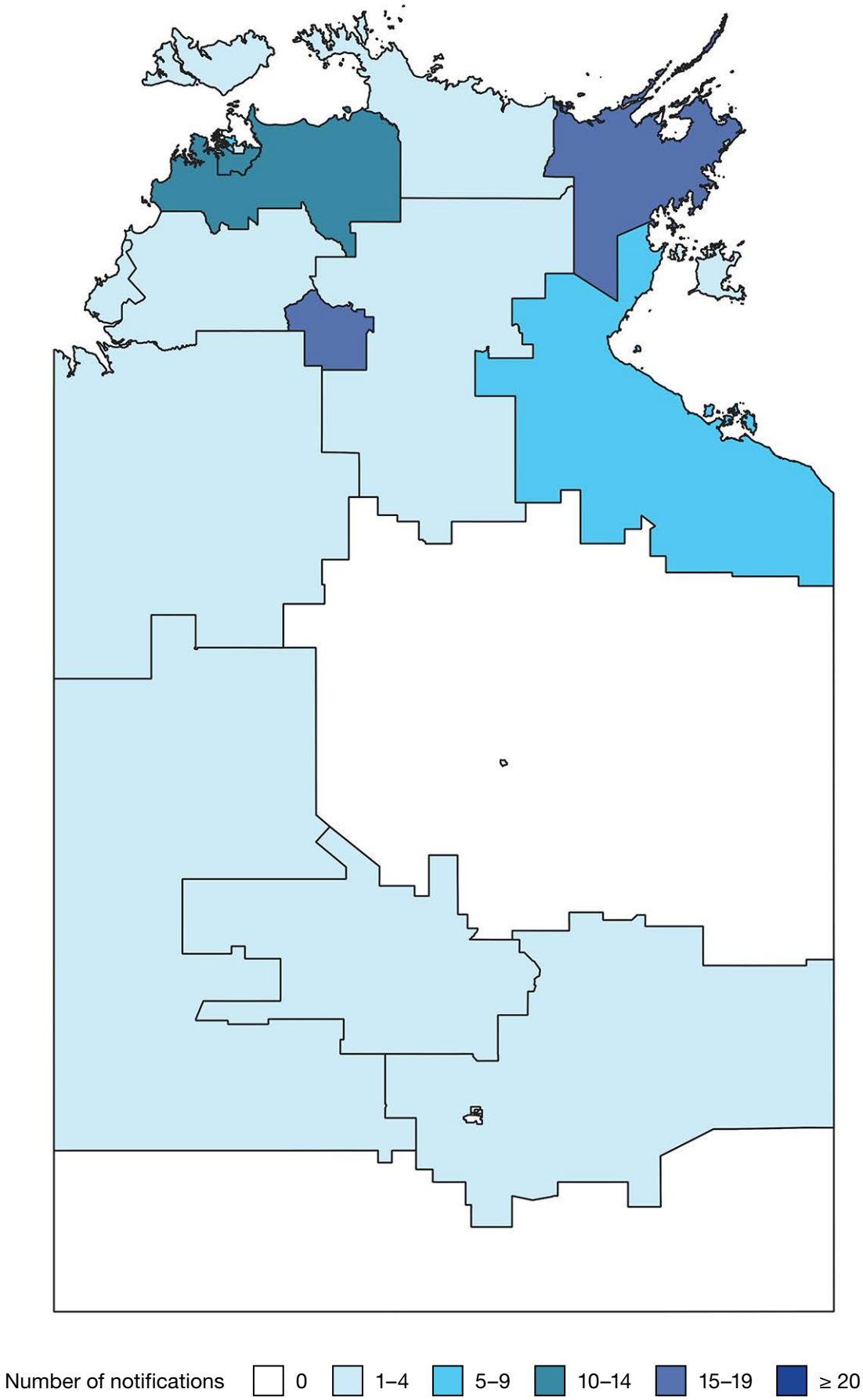
Map A.2: *Salmonella* Virchow notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



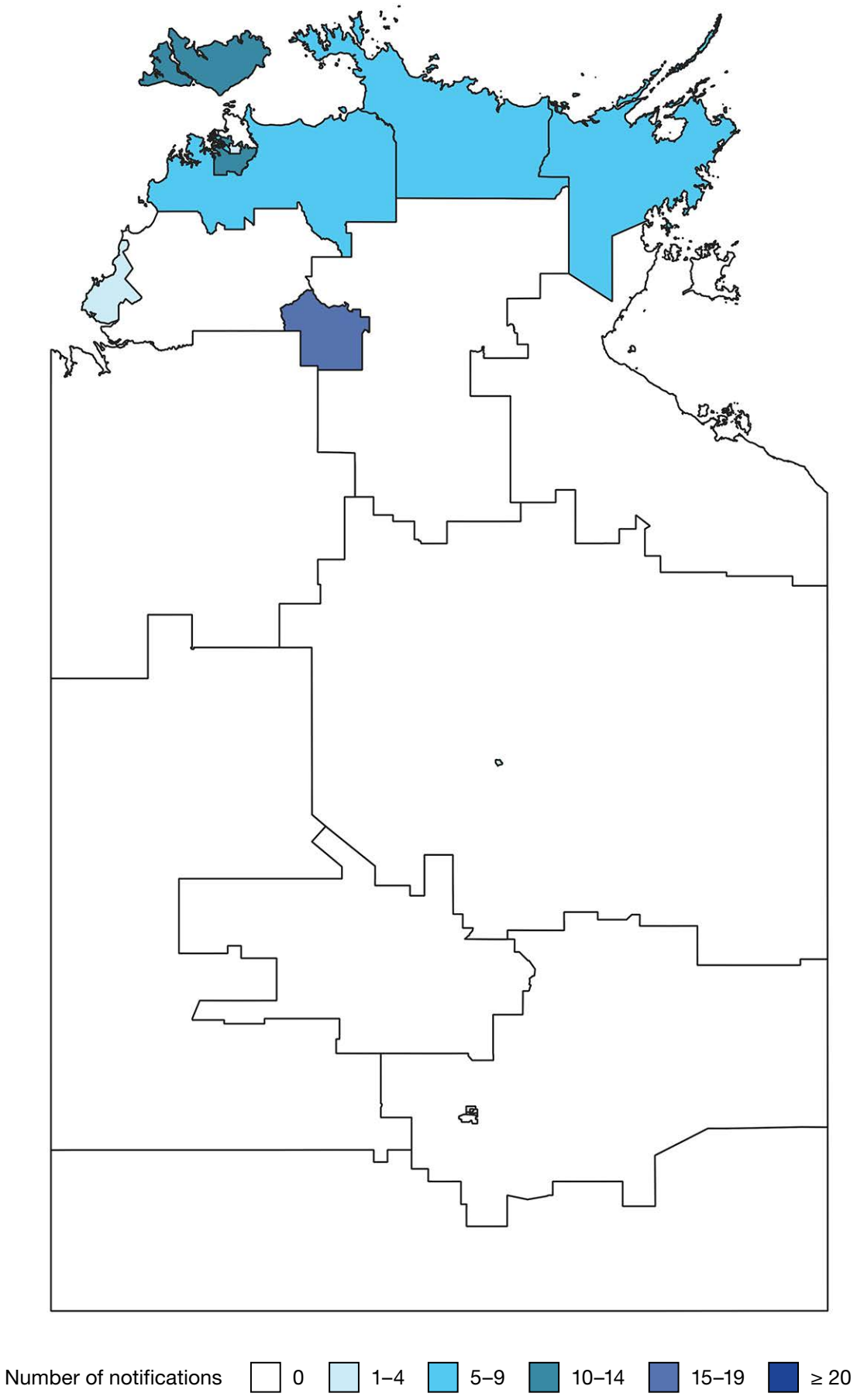
Map A.3: *Salmonella* Typhimurium notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



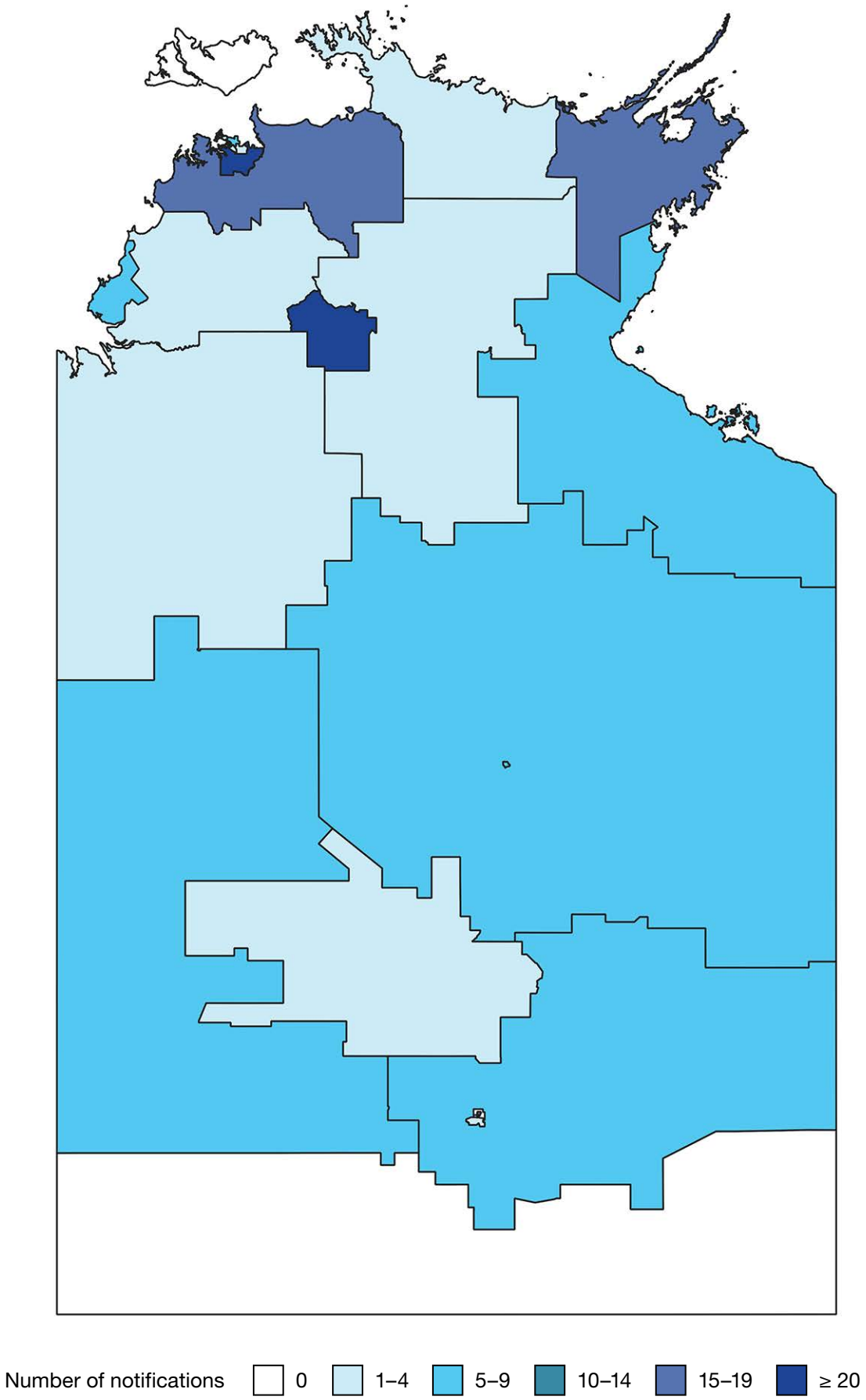
Map A.4: *Salmonella* Ball notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



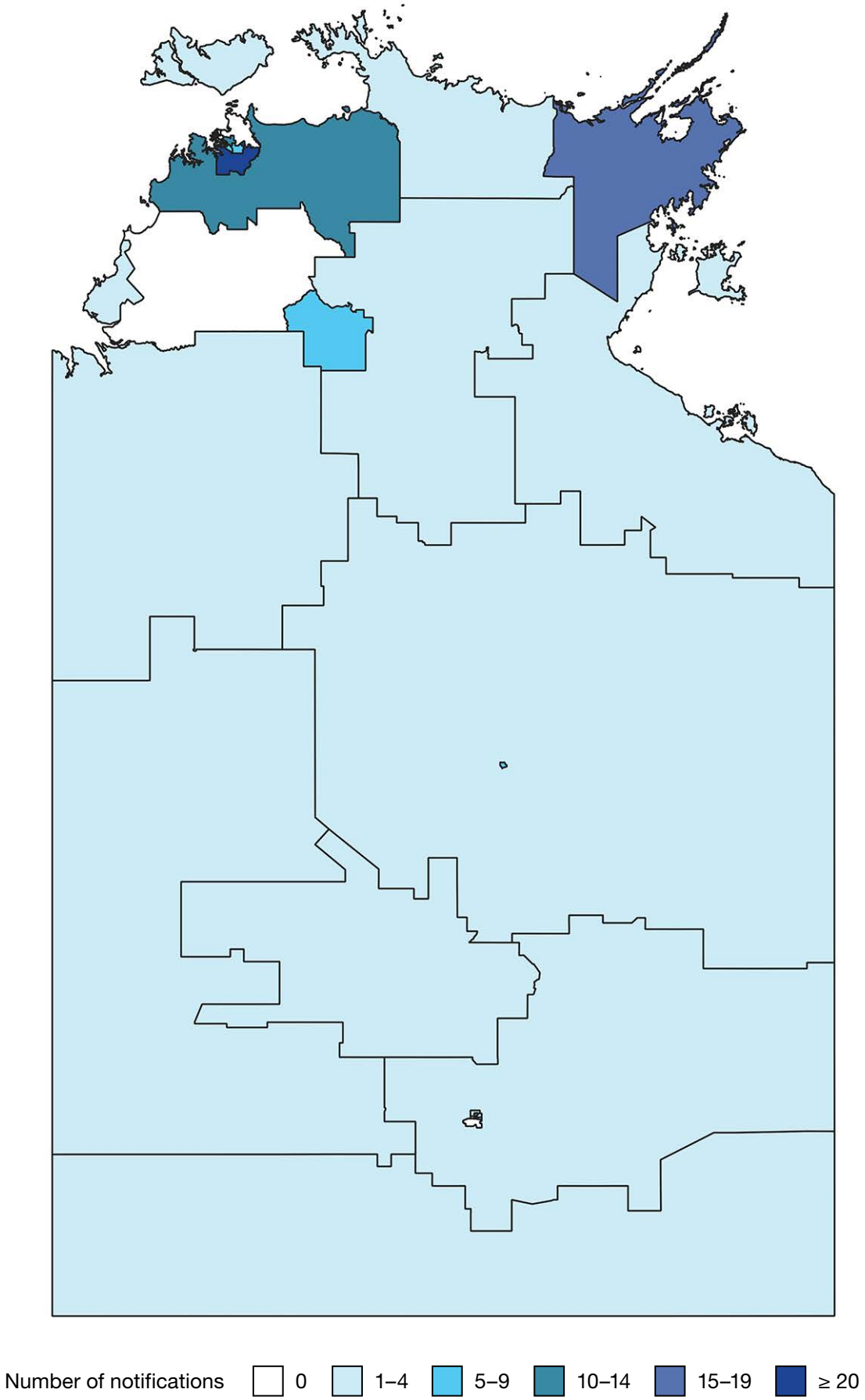
Map A.5: *Salmonella* Lansing notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



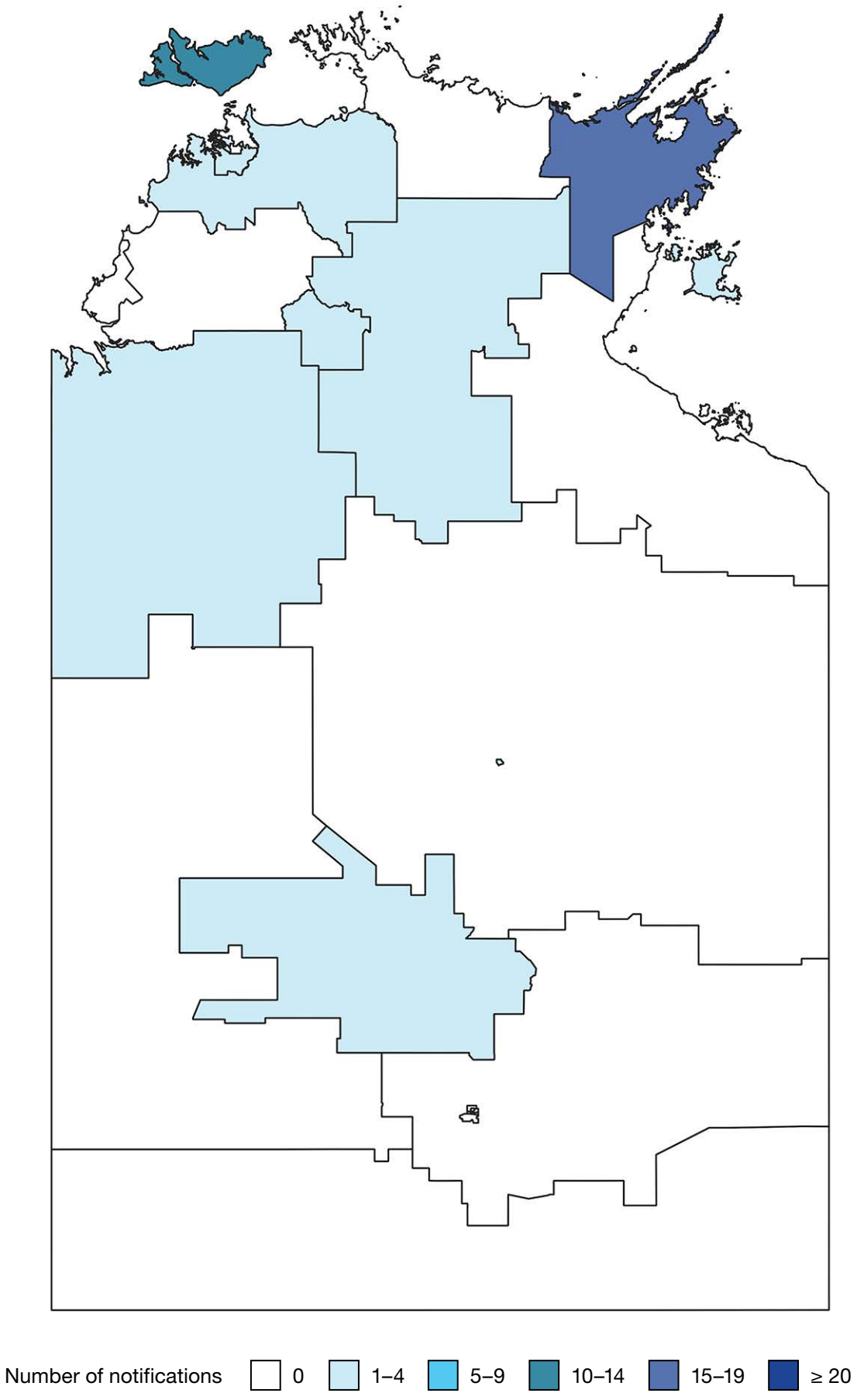
Map A.6: *Salmonella* subspecies 1 ser 16:l:v;- notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



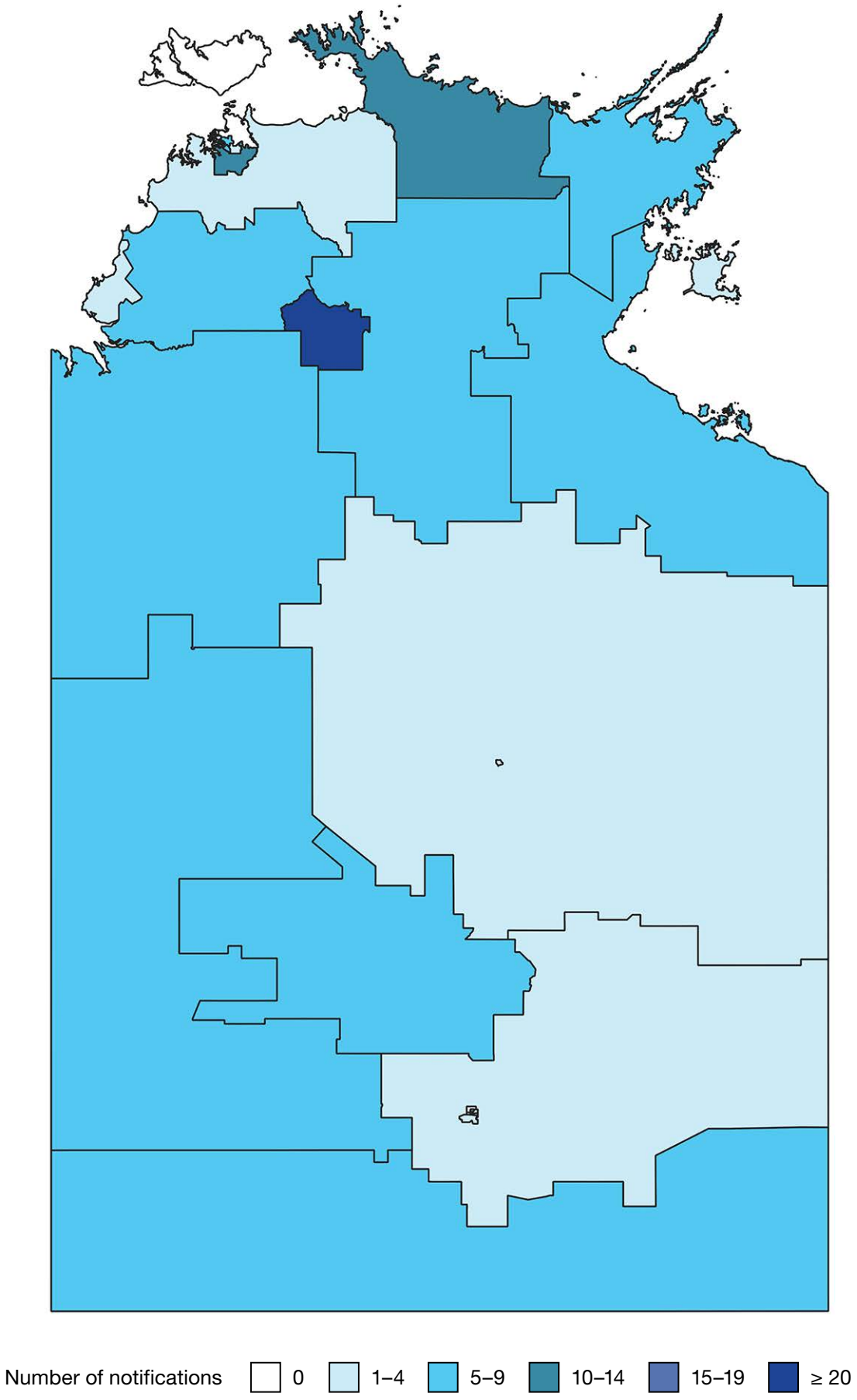
Map A.7: *Salmonella* Chester notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



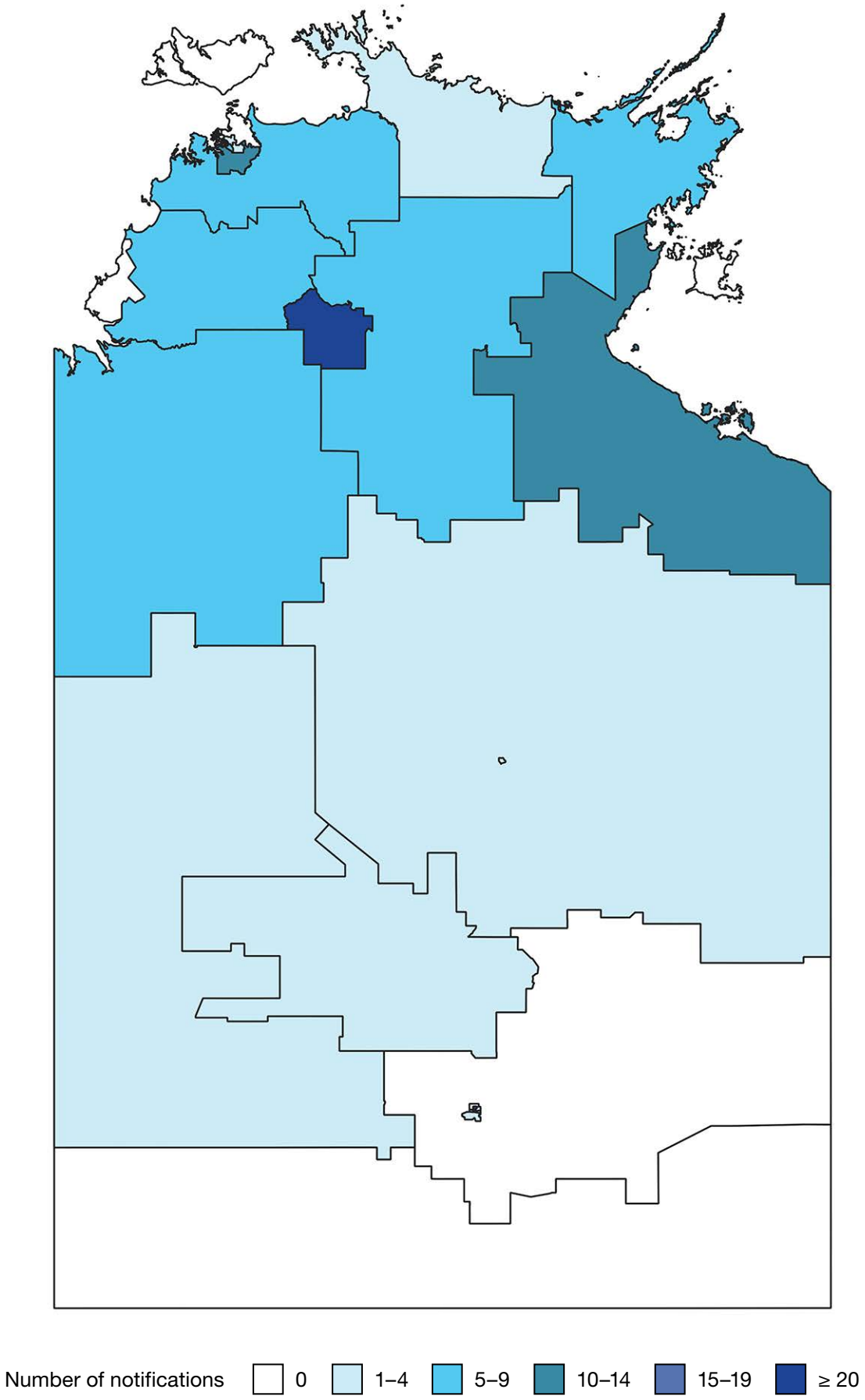
Map A.8: *Salmonella* Weltevreden notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



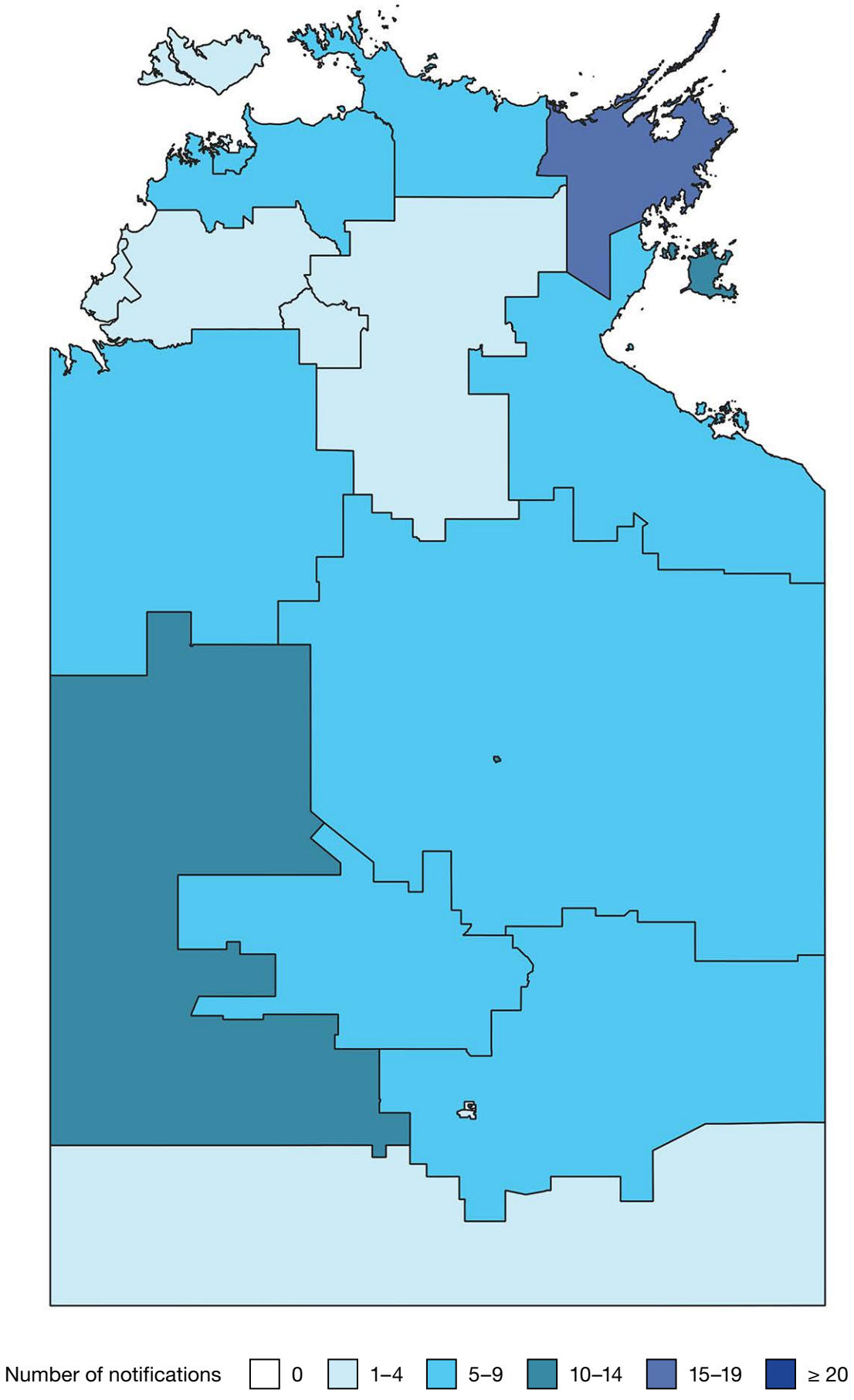
Map A.9: *Salmonella* Anatum notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



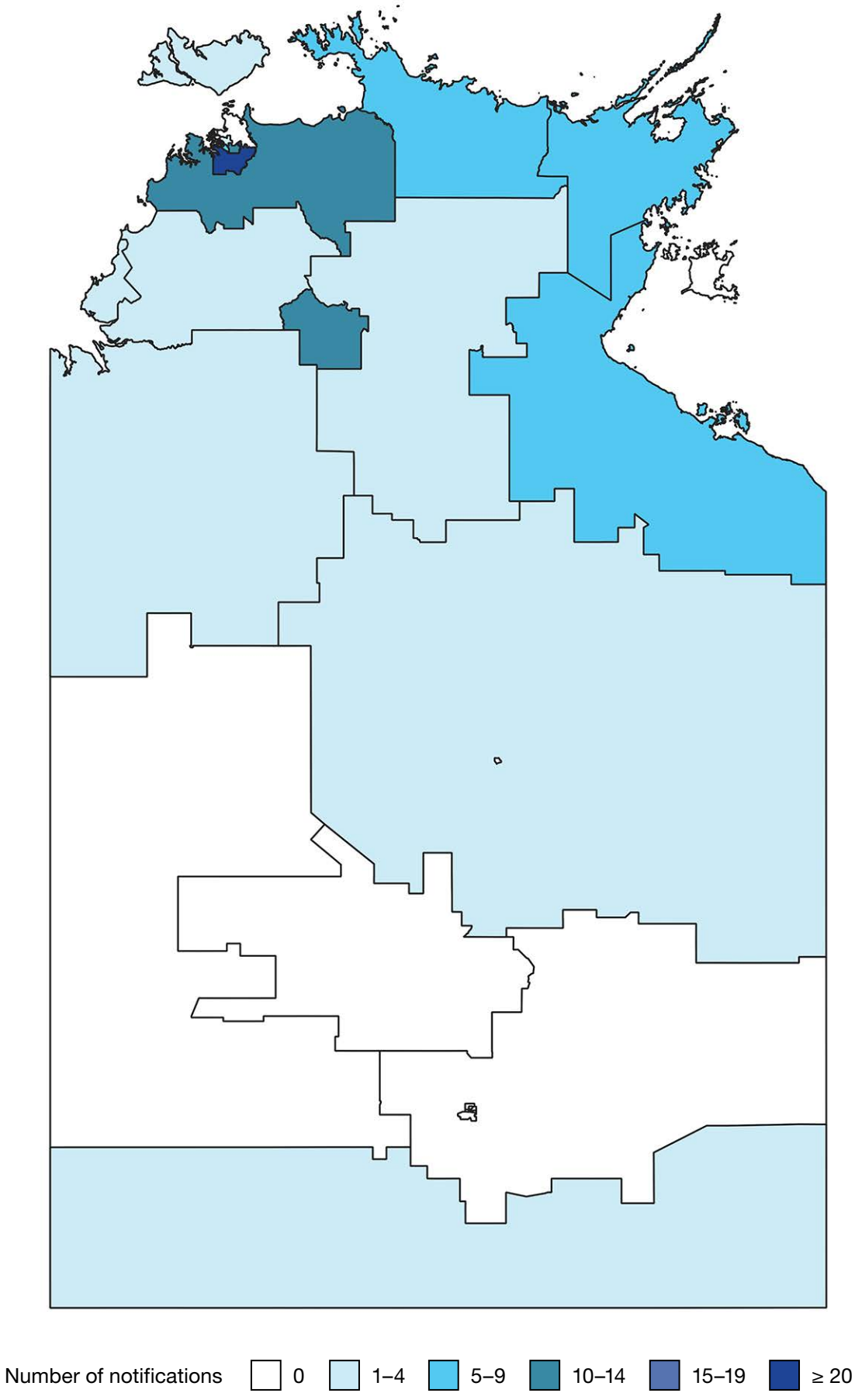
Map A.10: *Salmonella* Hvittingfoss notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



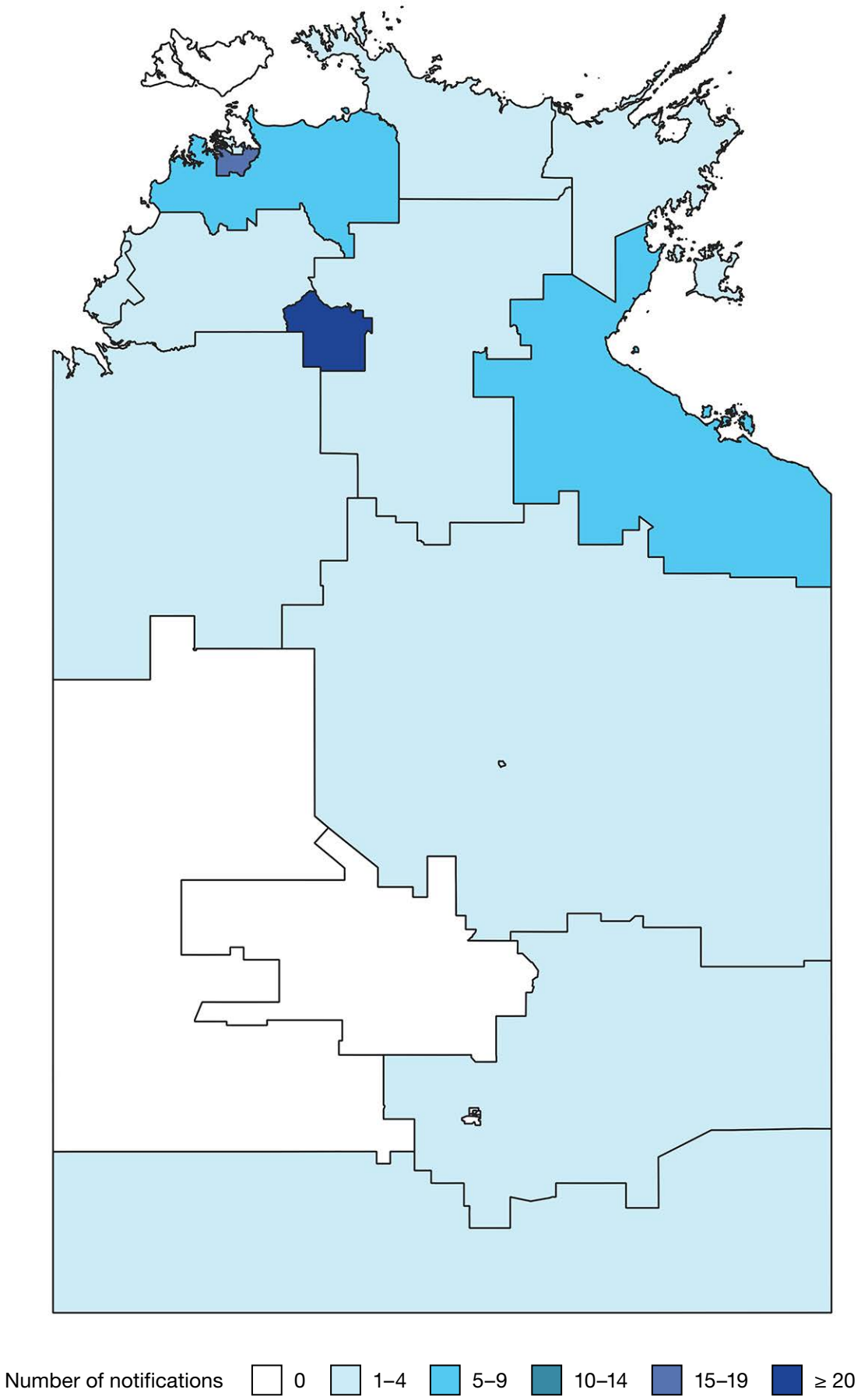
Map A.11: *Salmonella* Muenchen notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



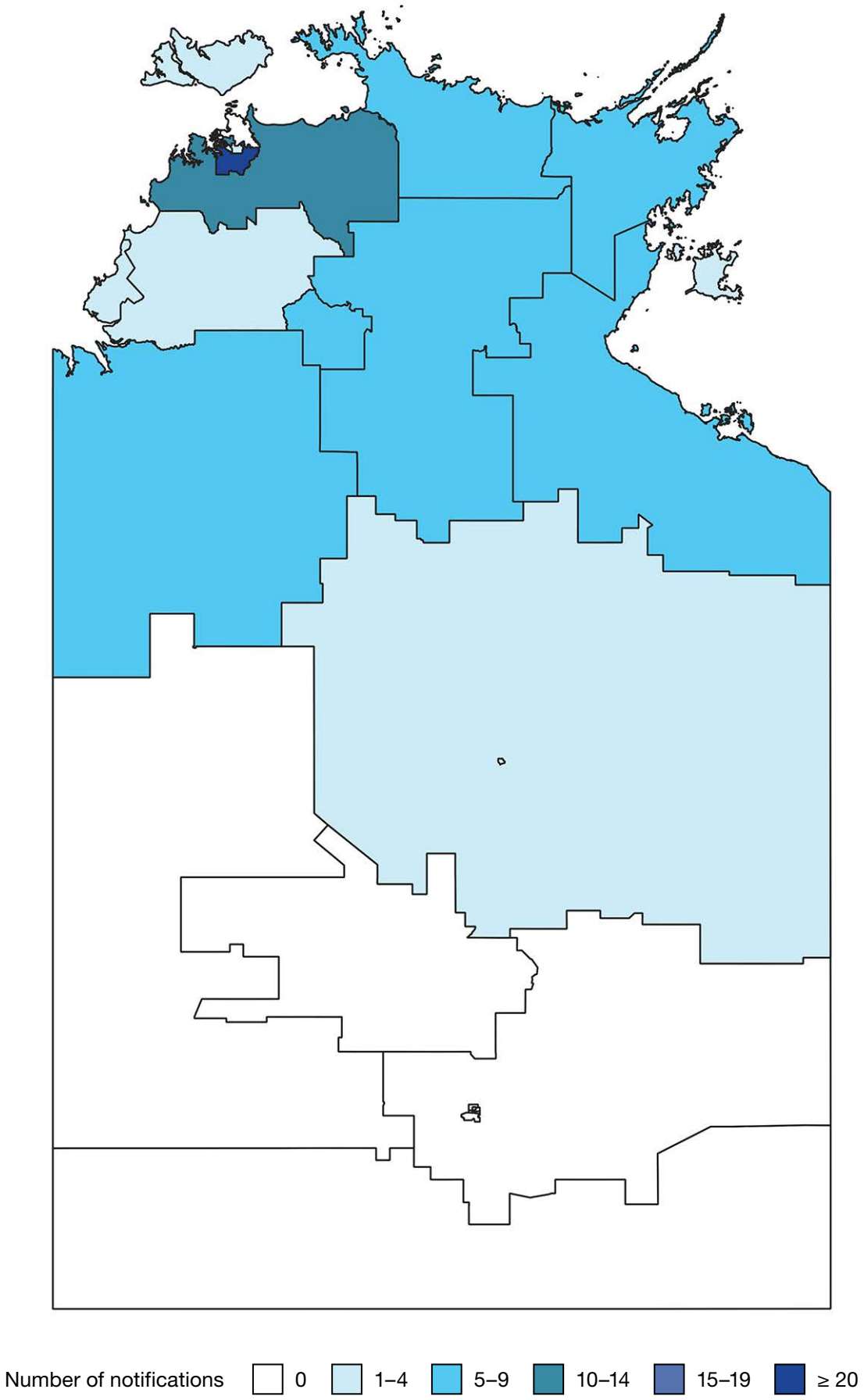
Map A.12: *Salmonella* Aberdeen notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



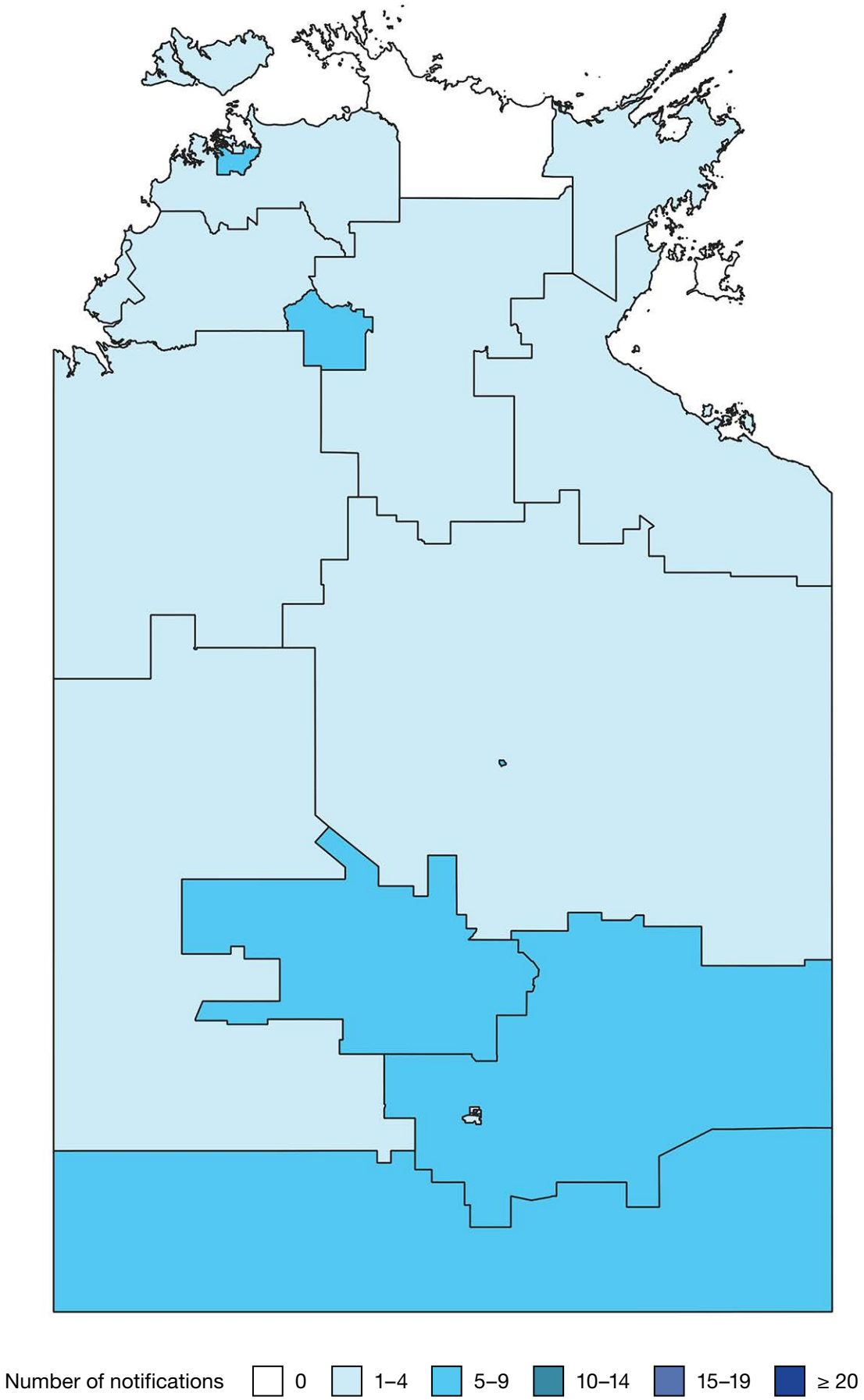
Map A.13: *Salmonella* Reading notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



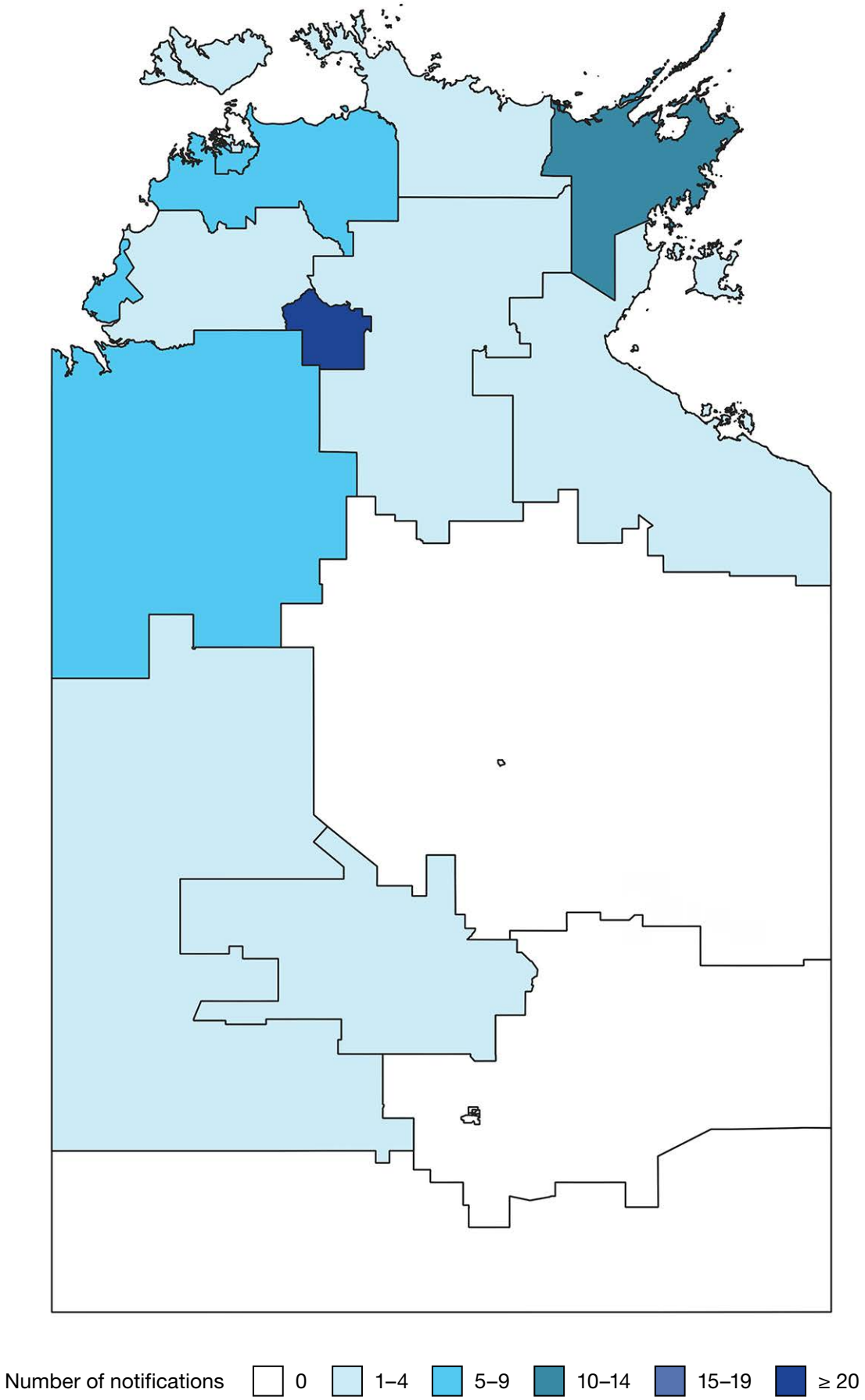
Map A.14: *Salmonella* Litchfield notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



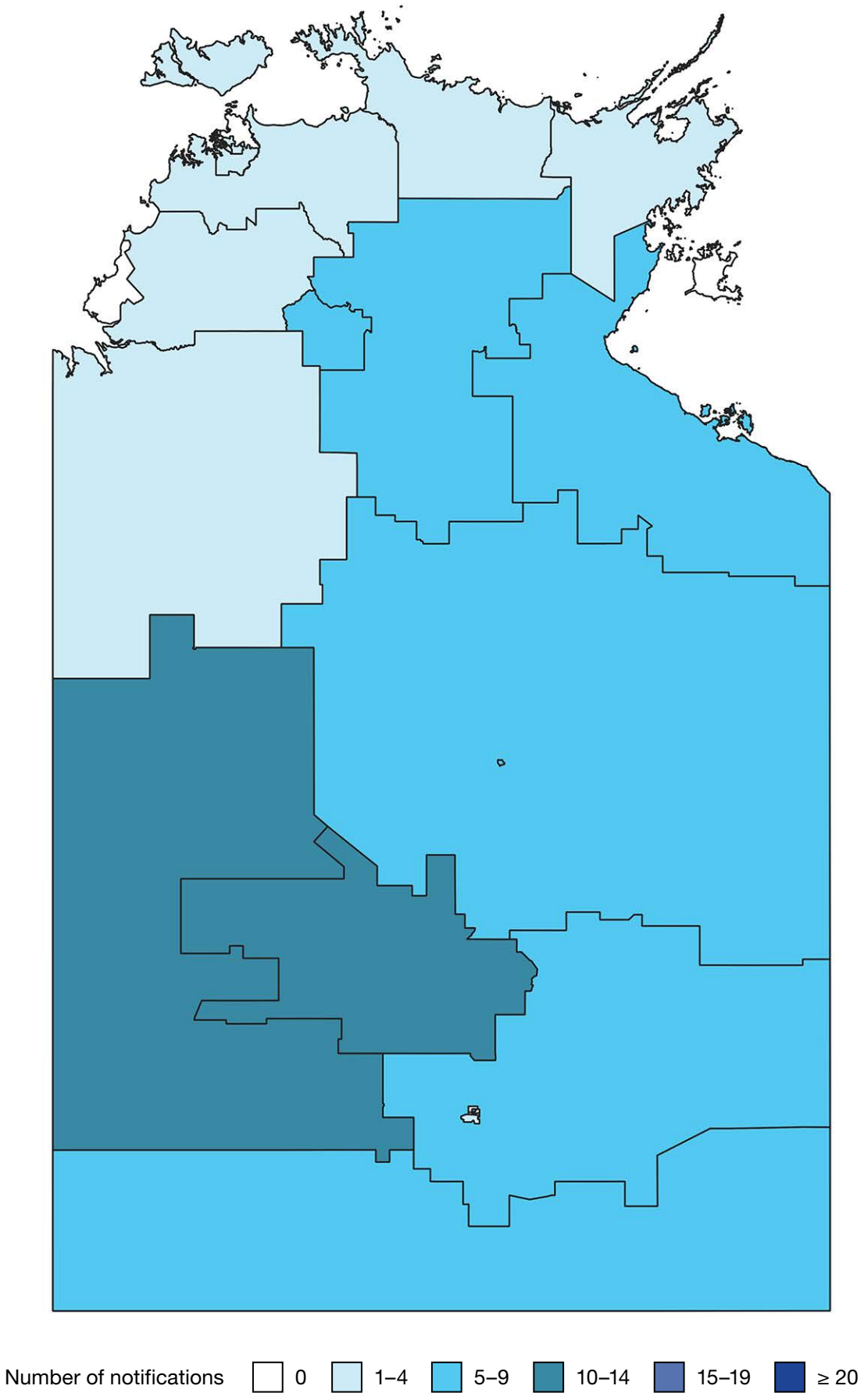
Map A.15: *Salmonella* Infantis notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



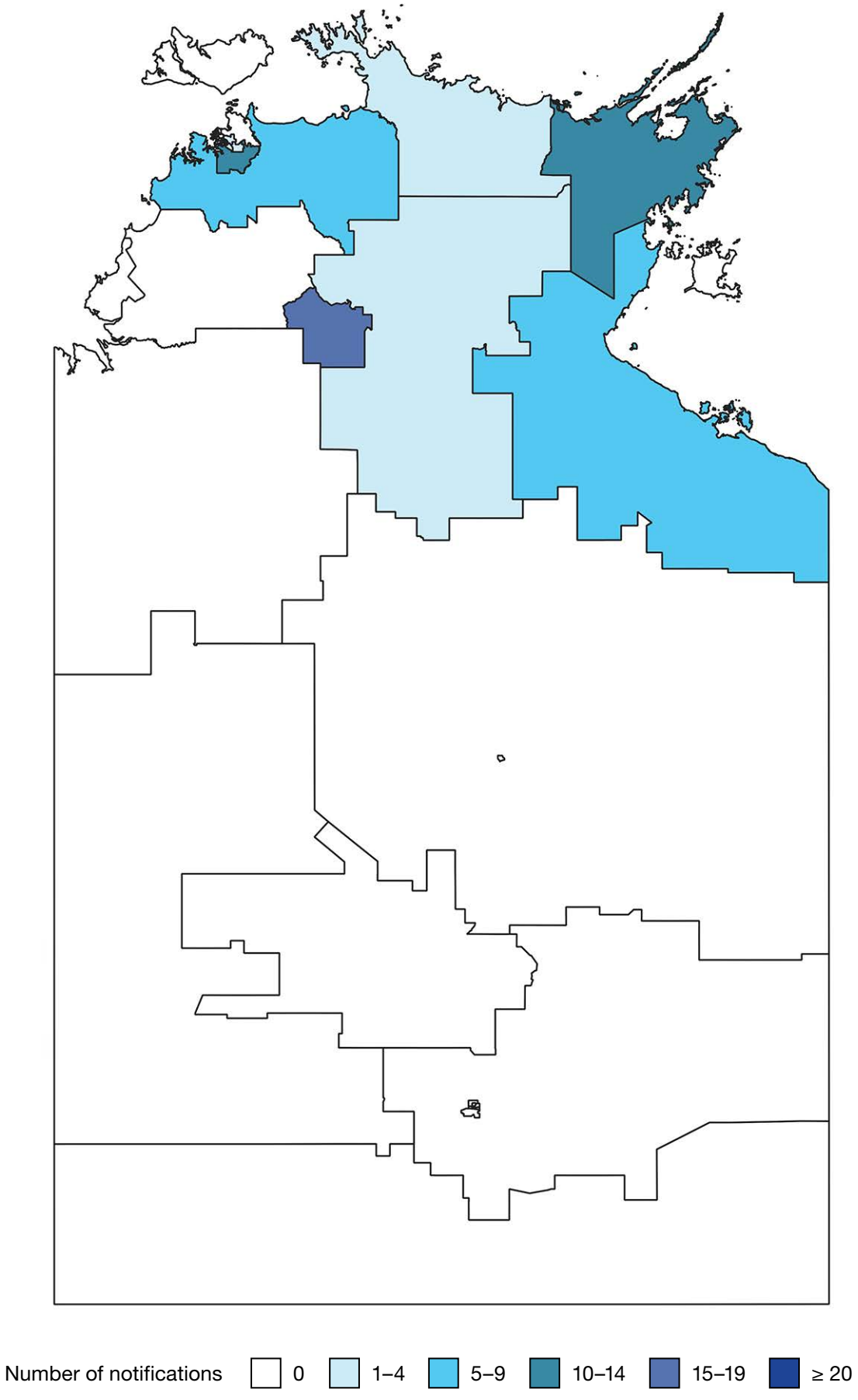
Map A.16: *Salmonella* Paratyphi B bv Java notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



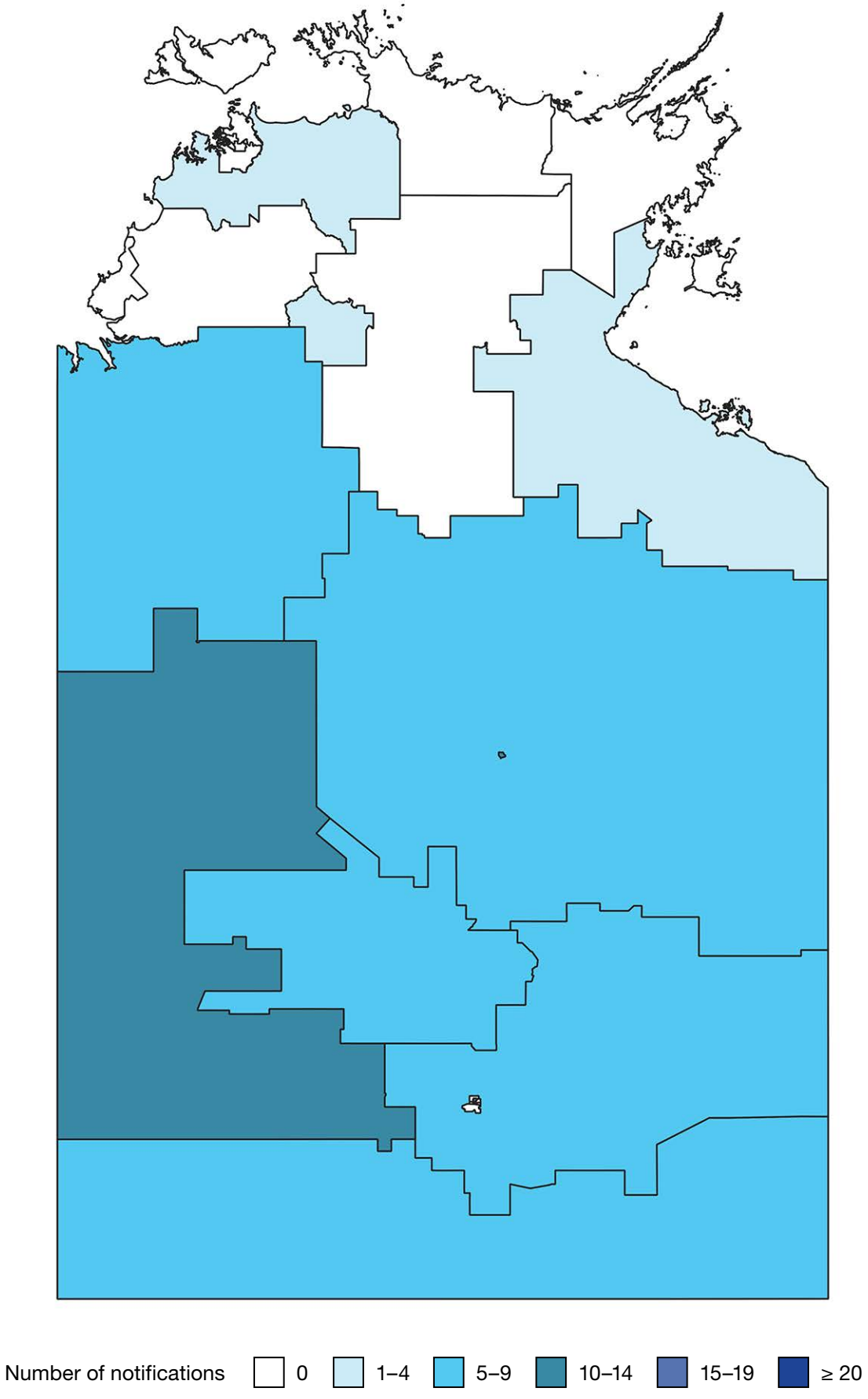
Map A.17: *Salmonella* Havana notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



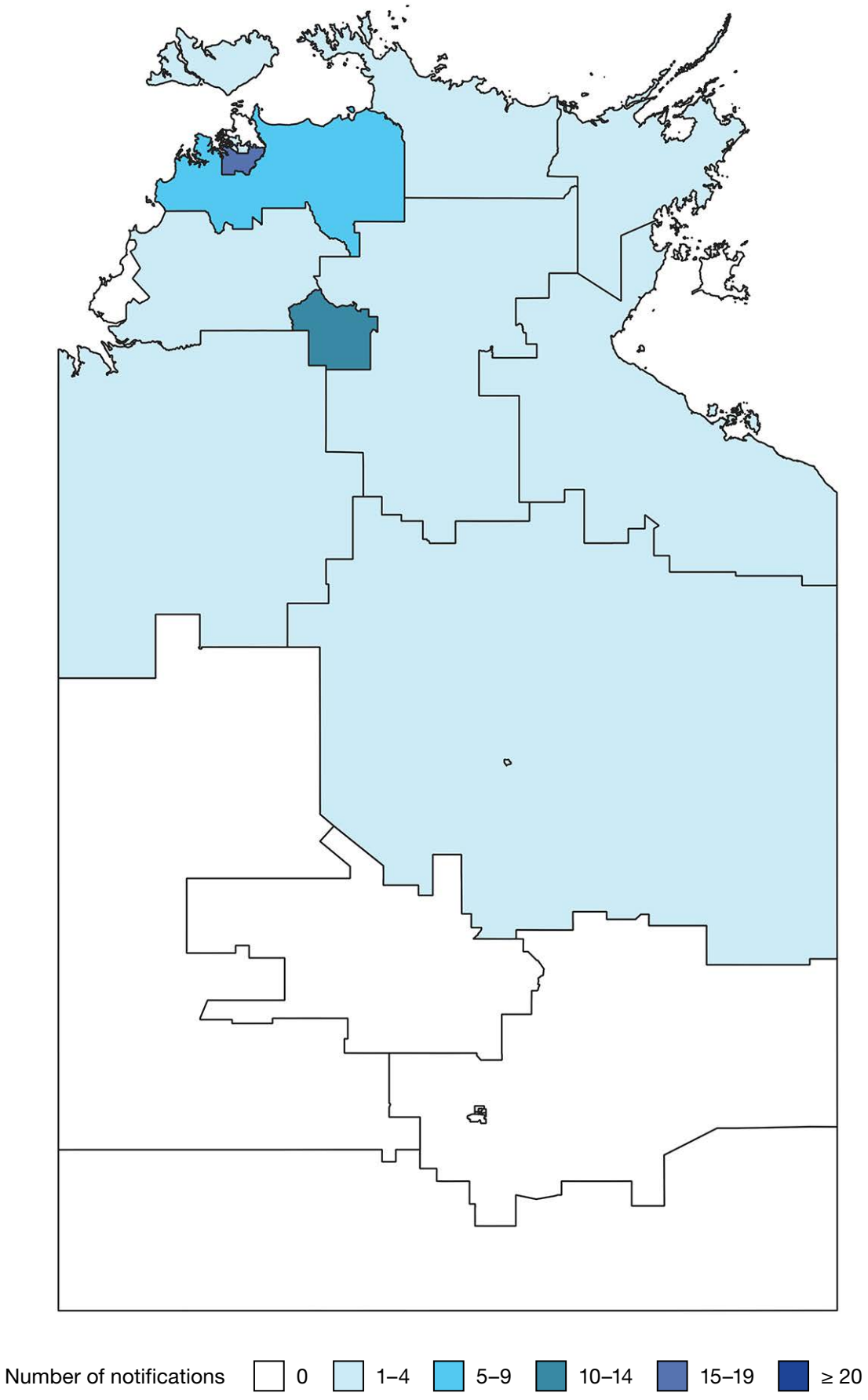
Map A.18: *Salmonella* Mgulani notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



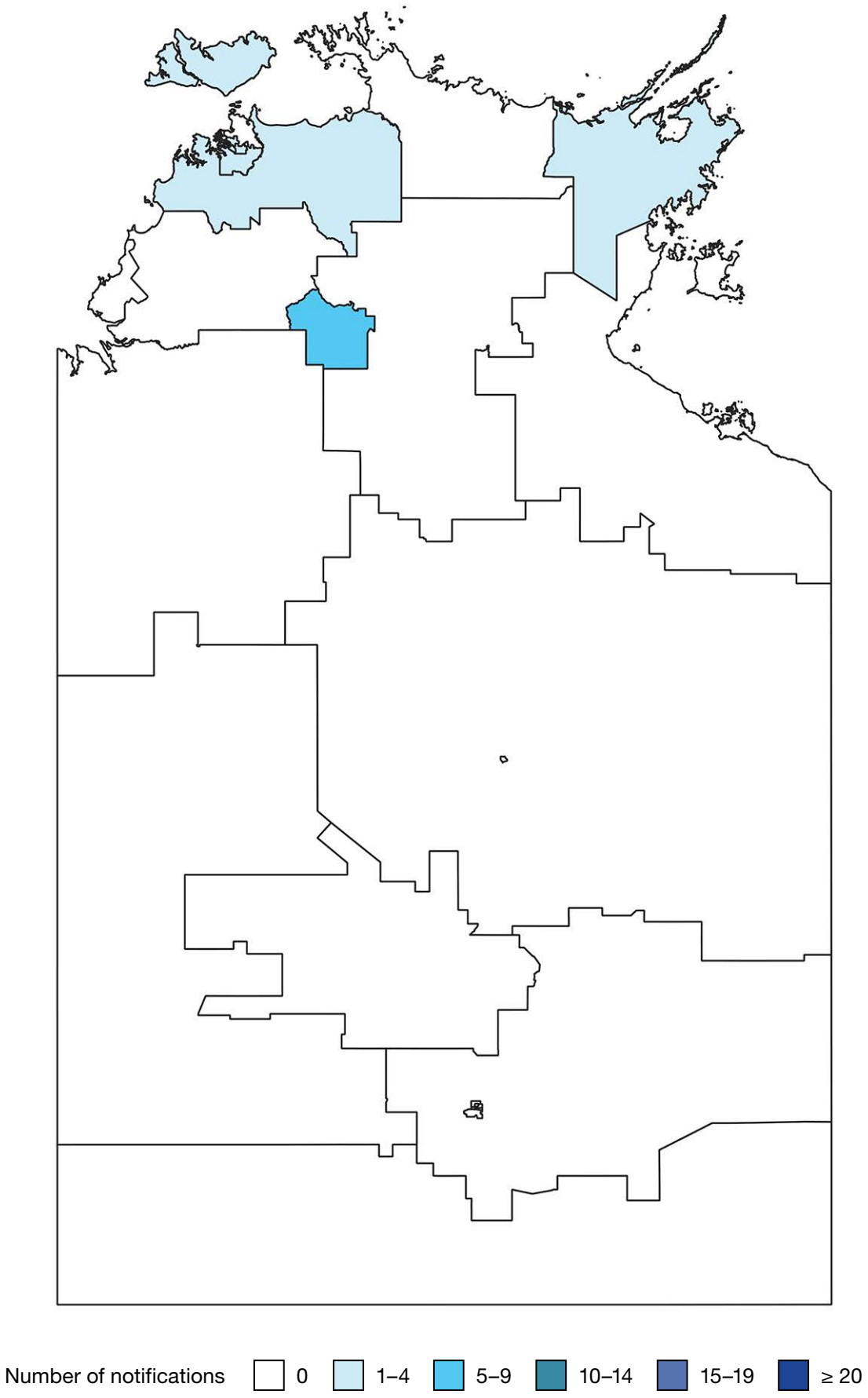
Map A.19: *Salmonella* Senftenberg notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



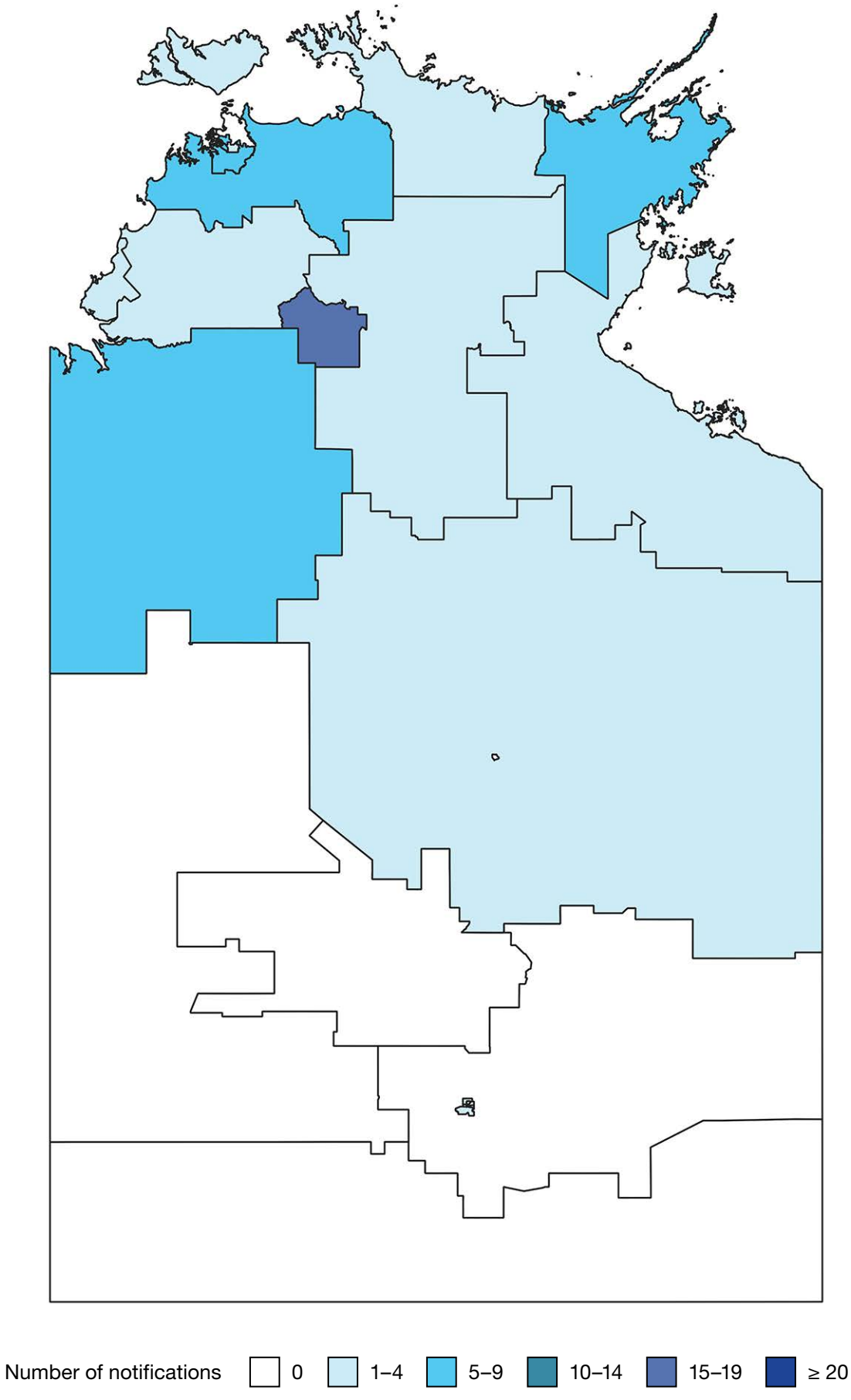
Map A.20: *Salmonella* Chailey notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



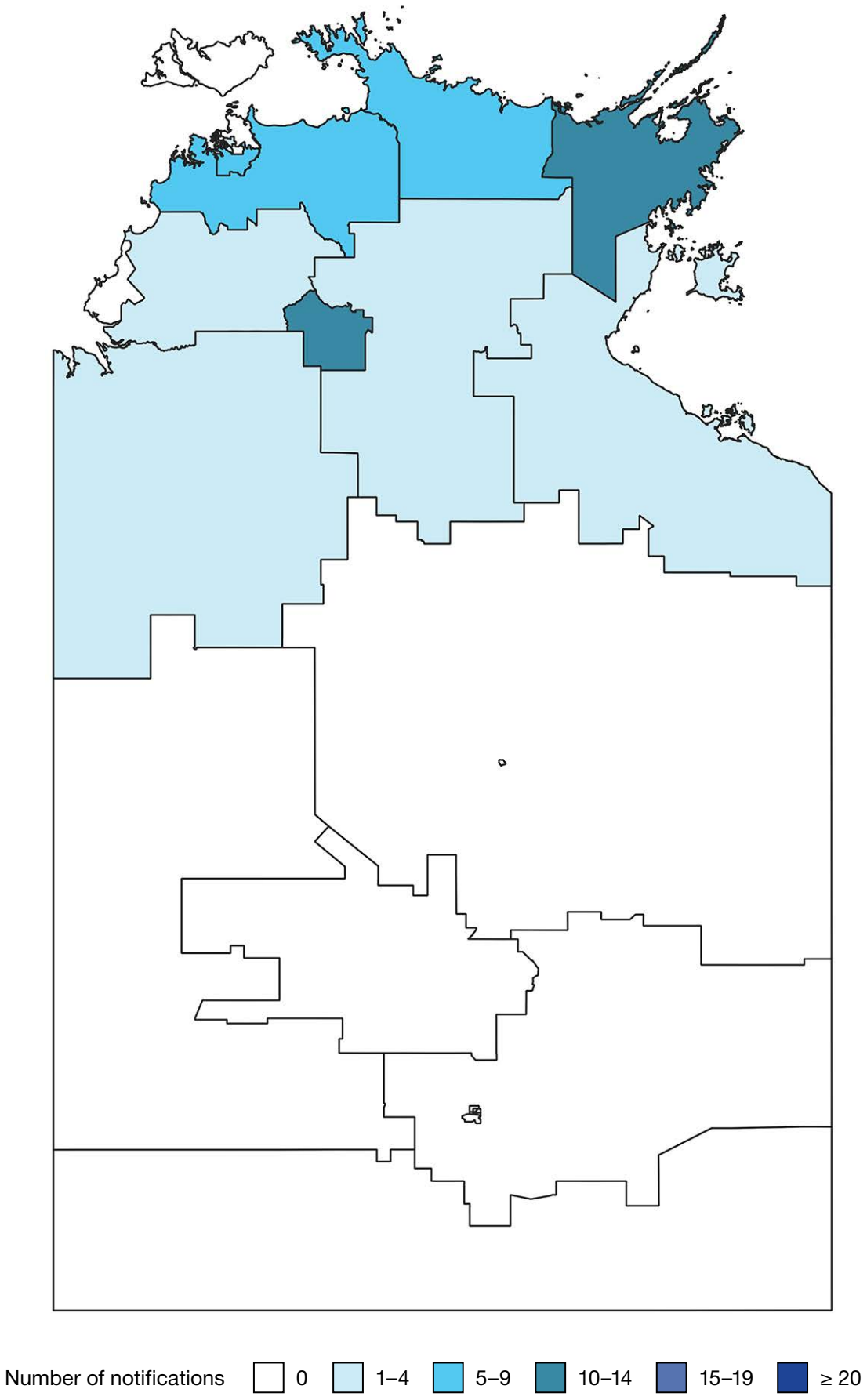
Map A.21: *Salmonella* Newport notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



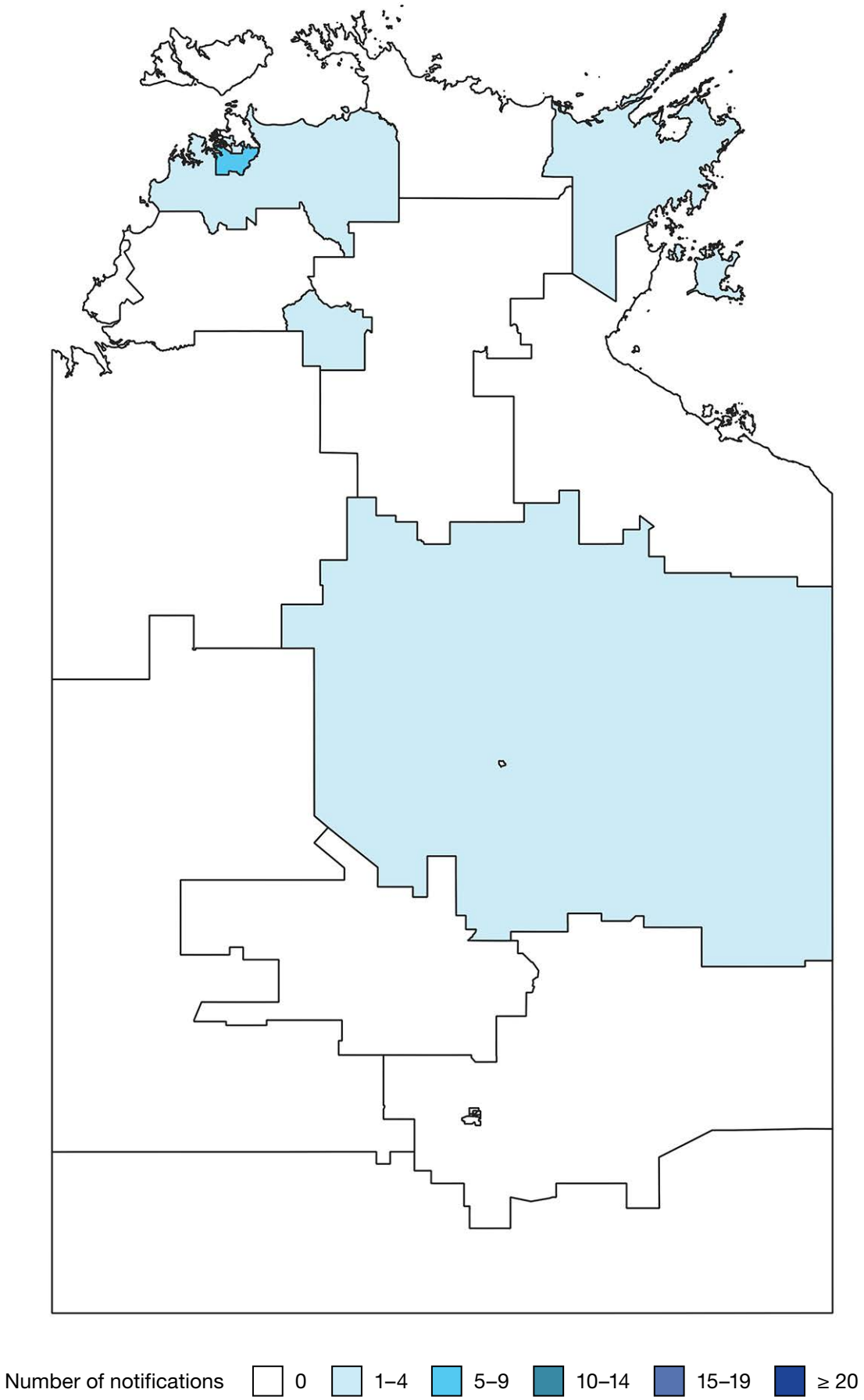
Map A.22: *Salmonella* Poona notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



Map A.23: *Salmonella* Zanzibar notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



Map A.24: *Salmonella* Kinondoni notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024



Map A.25: *Salmonella* Enteritidis notifications in the Northern Territory, Australia by Statistical Areas Level 2, 2005–2024