

Injury trends from envenoming in Australia, 2000-2013

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Abstract

Background: This study provides the first contemporary epidemiological insight into venomous injuries based on demographics and geography in Australia in the timeframe 2000-2013.

Methods: Analysis of national hospitalisation and mortality data to examine the incidence of injury and death due to envenoming in Australia. Rates were calculated using the intercensal population for all Australian age groups.

Results: Over the study period, deaths were due to an anaphylactic event (0.16 per 100 000), snake envenoming (0.13 per 100 000) or box jellyfish envenoming (0.01 per 100 000). Only 44% of cases involving anaphylaxis reached medical care prior to death, compared to 74% of those envenomed by snakes. Over half of all deaths (52%) occurred at home, and 64% of these occurred within a major city or inner regional area, with 48% of anaphylaxis deaths work related. Hospital admission rates of 199 per 100 000 persons over the 11 years were caused by contact with wasps or bees (31%), spiders (30%) and snakes (15%) with a predominate age range of 30-44 years.

Conclusions: The greatest burden of injury due to envenoming was caused by arthropods and snakes. Causes of death led by anaphylaxis subsequent to an arthropod bite or sting, followed by death from snake envenoming. Over half the incidence resulting in death occurred at home, in areas where health care is accessible. Operational data routinely collected is informative, with variations of injury incidence between States and Territories indicating a need for a more localised approach to management of this injury.

Introduction

Accidental injuries are a major public health problem in developed countries^{1,2}, with poisoning and envenoming a subset of this category. Australia has an international reputation for being the epicentre of all things venomous, whether these are venomous snakes and arthropods on land, or lethal jellyfish, stingrays, stonefish and octopuses in our oceans. Injuries and deaths caused by venomous snakes and jellyfish are often sensationalised in the media, yet there is a paucity of high resolution data regarding fundamental national public health questions, such as where venomous injuries occur, the reasons for their occurrence, and determinants of their outcomes.

Injuries have multifaceted requirements within Australia's health plans and strategies³⁻⁵ including aspects of population health, access to pharmaceutical and medical services, acute and primary health care and health workforce capacity. A key strategic outcome identified in these plans includes the need to build a consumer-focused health care system^{4, 5}. That is, individuals within different population groups will require different types of support from the health system with varying risks including age, gender, cultural background, geographical location and remoteness. Evidence is necessary to support decision making for planning, resource allocation, co-ordination and integration of effort across health areas, and to lead the identification of training needs to provide an informed and capable workforce.

While envenoming incidents are considered a minor injury⁶⁻¹⁰, minor injuries make up a large portion of the overall cost of injuries⁵, and some may be both potentially life

threatening and challenging to manage^{11, 12}, further reinforcing the advisability of understand national needs.

Clinical envenoming by snakes¹¹⁻¹³, marine and jellyfish stings^{14, 15} or from arthropods¹⁶⁻¹⁸ has been studied extensively in recent times and the findings used to underpin present management guidelines. However contemporary national research on the burden of envenoming across Australia is lacking with only one national report to date¹⁰. Such information is essential for evidence-based planning and resource allocation. Here we report core data on national incidence and mortality resulting from venomous bites and stings between 2000 and 2013, and highlight how improved data collection can yield even greater resolution and deeper insights into the burden of envenoming in Australia.

Methods

Australian hospital separations provided by the Australian Institute of Health and Welfare [AIHW] and National Coronial Information System [NCIS] mortality data were examined to describe the incidence, trends and the characteristics of venomous bite and sting injuries resulting in hospital inpatient treatment and/or death.

AIHW data for all public hospital separations in Australia from August 2001 to May 2013 enabled identification of acute hospital admissions. Separations by care type code 1.0: (Acute admitted care) were used for analysis with other admission types (for example 2.0: Rehabilitation care, 8.0: other admitted care) and transfer separations were excluded from the database. The scope of the venomous injuries was defined by the International Statistical Classification of Diseases and Related Health Problems 10th Revision, Australian Modification [ICD-10-AM] codes¹⁹. Data

extracts were requested for external cause codes (levels 1-10): X20-X29, W56, W57, W59, W60; and diagnosis codes (levels 1-10): T61-63, S61, S91, T78.2, T78.3, T78.4, L02, L03, L50, L97, and Z04¹⁹. Data were tabulated into T63 or external cause codes X20-X29, as detailed in Table 1. Code 59.1 (Bitten or crushed by snake, unknown if venomous or non-venomous) with no association with X or T codes per Table 1 were excluded (n=6,149).

Deaths were identified from January 2000 to December 2013 using external cause and diagnostic codes, keyword and mechanism searches. Cause of death assignment was based on closed coronial findings and autopsy reports. AIHW 2006-2011 Cause of Death Unit Record Files [COD URF] were reviewed for all cases with an external cause code or principle diagnosis associated with an envenomation event. COD URF data were cross checked against the NCIS searches between 2006-2011 to identify correlations or gaps between the databases and ensure any limitations were valid. Medical literature and media reports were reviewed to broaden searches. Cases identified from a minimum of two sources were included in the study. Cases were excluded if deaths occurred among non-residents, were caused by ingestion of a poisonous substance, where the identified causes of death were definitively not linked to envenoming, or if cases remained open within the NCIS (n=19).

ArcGIS Desktop 10.2.1 (ESRI)²⁰ was used to extract and process data. An Australian basemap²¹ was overlaid with Australian Bureau of Statistics (ABS) remoteness structures²². Incidence (hospital separations) and mortality rates due to bites and stings were calculated per 100,000 population using a 2007 intercensal Australian age group profile with 5-year age increments, gender and state specific populations²³. Rates were presented for the entire study period. Remoteness

populations were calculated²⁴ using 2007 state population. Confidence intervals were calculated using published methods¹⁰. Where case counts were greater or equal to 100, symmetrical 95% confidence intervals were used.

This project was approved by the University of Melbourne Human Research Ethics Committee (1441602), the NCIS (M0308) and Western Australian Coronial ethics (EC08-14) and the AIHW (560824/1).

Results

Hospitalisations

From August 2001 to May 2013, there were 41,521 hospital admissions with a principle ICD-10 diagnosis of T63 or X20-X29 (199 persons admissions per 100,000 people). Gender distribution was skewed towards males (Table 2), with gender-specific rates of males and females 127 and 72 per 100,000 persons, respectively. ICD-10-AM external cause codes X21, X23 and X25 (contact with arthropods) represented 76% of all admissions (139 per 100 000 people). Admissions due to contact with venomous snakes (X20.0) accounted for 15% of all admissions (29 per 100,000 people), with a further 9% due to contact with marine animals (X26) (18 per 100,000 people).

A diagnosis of “venom of other arthropods” (T63.4) was recorded for 44% of admissions (73 per 100,000 people). A diagnosis of “snake venom” (T63.0) was the third leading cause admission, accounting for 16% (Table 2) (26.3 per 100,000 people). A diagnosis of allergy or anaphylaxis (T78.2, T78.3, T78.4) related to the allergenic effect following contact with venomous animals (T63.0-T63.9) was noted in 26% (n=8,997) of patients (43 per 100,000 persons).

In terms of absolute numbers, the largest proportion of admissions occurred among Australians aged 30-34 years, representing 34% of all admissions (233 admissions per 100,000 people). This was followed closely by the 5-9 and 75-79 year age groups (223 and 228 admissions per 100,000 people, respectively). (Figure 1)

Figure 2 illustrates hospitalisation incidence per State according to cases by organism and rates per remoteness category. Rates of admissions by remoteness vary considerably between state and territories. The highest rates of admissions within a remote or very remote area were reported in WA and the NT, whereas more than half the reported cases in Victoria and Tasmania were hospitalised within a major city or inner regional area (see also supplementary table 1). Contact with venomous snakes (X20) and marine animals was highest in NT, Qld, Tasmania and NSW, and contact with marine animals (X26) highest in Qld and NT. Arthropod envenoming (spiders [X21], bees, wasp, hornets [X23] and contact with other specified arthropods [X25]) was common and was reported in all states and territories.

Mortality

There were 82 deaths identified within the NCIS. Cases were removed from the analysis where the coronial findings and death certificate did not confirm envenoming as cause of death. Data records from NCIS and COD URF were correlated from 2006-2011. Cases were reviewed +/- 6 months outside of these years to identify lags in reporting. Thirty five NCIS cases and 34 COD URF cases were identified, with a total of 36 within this period. Keyword searches and coronial record review identified two cases not recorded within the COD URF due to no codes allocated to the case, and one case in COD URF was corroborated with media reports, but not recorded within the NCIS.

During the period from 2000 to 2013, 64 deaths after a bite or sting from a venomous organism were identified. This corresponded to a crude rate of 0.30 per 100,000 persons. The majority of deaths occurred between the months of October and April (n=58). Deaths due to insects, arthropods or unknown causes occurred at a rate of 0.16 per 100,000 persons, with bees (n=25), wasps (n=2), ants (n=2), ticks (n=3) or unknown organisms (n=2) being recorded as the cause. Deaths due to snakebite envenoming occurred at a rate of 0.13 per 100,000 persons, and involved 27 cases. No deaths were recorded during the study period from Tasmania or the ACT.

Deaths due to anaphylaxis post-envenoming from an arthropod occurred in 0.16 per 100,000 people (n=33). South Australia (n=8) and Western Australia (n=9) had the highest number of deaths due to anaphylaxis. The mean age was 46.2 years ($\pm$ SD 14.3), with 91% (n=31) of cases being male. The majority of anaphylaxis deaths (87%) occurred at home, with 62% of these occurring within a major city or inner regional area (Figure 3). Only one death from anaphylaxis was due to work as a bee keeper. Sixteen out of 33 cases occurred during paid work, with 6 of these occurring in SA. Snake bite was the only other cause of envenoming deaths (n=2) that occurred whilst in the workplace.

There were a total of 30 deaths due to envenoming *per se*, that is, not due to anaphylaxis (0.14 per 100,000 people). Twenty seven were attributed to snakebite and 66% occurred within a major city or inner regional area (Figure 3). Queensland (n=13) had the highest number and rate (2.0 per 100,000 people). The mean age was 47.8 years ($\pm$ SD 22.6) and 70% (n=21) of cases involved males.

Two-thirds of cases that involved fatal bites took place at the person's home, and 74% of all cases were hospitalised prior to death. Brown snakes (*Pseudonaja* spp.) were recorded as the cause of 63% (n=17) of all snakebite deaths.

There were only three jellyfish-related deaths.

Discussion

We have provided the first national analysis of the morbidity and mortality following envenoming in recent times, drawing together data using a Geographic Information System (GIS) based software collated with three routinely collected health data sets (AIHW hospital and COD URF, NCIS) to demonstrate the capacity of this information to provide demographic and geographic metrics.

Overall, the leading causes of envenoming-related admissions in Australia was from contact with arthropods, followed by contact with snakes, with most deaths caused by either the effects of snakebite or anaphylaxis following a bee sting. Admission rates due to arthropod envenoming were highest in populated areas of SA and WA, which reflected the higher number of deaths in these states. However, the deaths were not related to industries requiring handling of bees. Anaphylaxis from ubiquitous environmental causes provides a platform of challenges for management²⁵. Given the number of deaths occurring at home, in males, where health care is accessible, further investigation to determine which interventions can further mitigate these incidents is required.

Snakebite envenoming, although pre-eminent in the public consciousness, constituted just 15% of admissions, third after envenoming by hornets, wasps and bees, and spider bite. Hospital admissions with a diagnosis of venom from snakes (T63.0) resulted in more than twice the deaths per admission observed following admissions diagnosed as venom from other arthropods (T63.4). Snakebite is often thought of as an outdoor medical emergency, but our data showed the majority of snakebite fatalities occur around a person's residence within a major city or inner

regional area. This is perhaps not so surprising given that several medically important species of snakes are abundant in the most densely settled southern and eastern coastal corridors of Australia from South West WA to Victoria and north along the eastern seaboard. Higher death rates in outer regional areas may not be representative due to the small numbers.

Our use of these injury datasets demonstrates feasibility of utilising this information to identify geographic, organism and demographic evidence that could inform priority setting for policy makers, health professionals and public consumers. Ongoing surveillance can not only inform a national agenda, but a further decentralised review per Primary Health Network would better focus the needs of this injury in accordance with the National Health Plan. This in turn would ensure that while envenoming is a relatively uncommon injury, the right data is used to ensure coordinated implementation of informed decisions within each Primary Health Network foci. For example, workforce training priorities such as clinical education could be focused initially upon higher burden areas with the potential for online education. Localised and targeted public health initiatives will have a greater impact and information could also be used to lead a conversation in regard to the best policy for anaphylaxis management, venom immunotherapy and antivenom distribution for patient centred care. To achieve this, access to finer geospatial and clinical data will be required to further expand upon determinants and trends not available within the current hospital data provided.

When discussing data it is important that all groups, from policy makers to health professionals use common language and denominators in order to align priorities. Policy development in Australia uses the concept of remoteness as an important analytic dimension. The Remoteness Structure of Australia seeks to provide a

classification for statistics by dividing Australia into areas that share common characteristics. The use of common subjective terms such as rural and urban need to be re-evaluated and potentially replaced by vocabulary that conforms to a structure enabling data to be analysed and compared in accordance with national policy metrics.

Several limitations to our study warrant mention. First, we relied on the accuracy of ICD-10 coding to identify relevant hospital admissions. Coding can be affected by variations in the quality of coding and the numbers reported. There are no national standards for auditing the comparability of local, state or national coded diagnosis and external cause data, so it is not possible to make quantitative assessments of data quality on a national basis²⁶⁻²⁸. Secondly, AIHW records are de-identified, and while cases were chosen based on their coding for acute admitted care, multiple sequential admissions for the same injury could not be ascertained. Therefore these numbers may overestimate the overall burden. Thirdly, other researchers have identified changes to the ICD-10-AM third edition as having influenced the rates of cases attributed to X20–X29 external cause codes, leading to a suspicion that cases previously coded to X20 had been coded as W59.1¹⁰. The data provided by AIHW contained a number of examples where W59.1 was used without an X or T code (n=6,149), and thus the burden of venomous snakebite may be underrepresented. Lastly, the NCIS is an administrative data set with limitations that may include cases that remain open (and unavailable for research use). Therefore the number of cases presented under-represent the true burden²⁹. However, a keyword search within the NCIS did identify cases not coded with venom related ICD-10 codes. In addition to the cross checking of NCIS with COD URF, we are satisfied this is as complete as possible without reporting open cases.

Conclusion

This study aimed to provide contemporary epidemiological insight into venomous injuries based on demographics and geography in Australia. It was shown that operational data routinely collected are informative. The greatest burden of injury due to envenoming was caused by arthropods and snakes, with most deaths resulting from arthropod-related anaphylaxis or snake envenoming. Variations of injury incidence between States and Territories indicate a need for a more localised approach for the management of this injury. However, greater resolution of detail for hospital data is required in order to identify localised needs, such as per Primary Health Network. Our study shows that most deaths after envenoming occur in settings where access to health services is available. Since distance to hospital appears not to be a major determinant, further research is needed to investigate other factors that contribute to these outcomes is required. It is also important to improve our capacity to spatially analyse the burden of injury and mortality after envenoming, particularly with regard to environmental, social, ethnic and occupational factors. This approach can potentially lead to enhanced understanding of the determinants of poor outcomes after envenoming, and better inform Federal and State health administrations, health networks, health professionals and the broader community. This will lead to targeted allocation of resources, education strategies and help drive secondary prevention priorities.

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Table 1: External cause and diagnosis codes related to venomous animals

Code	Description
X20	Contact with venomous snakes and lizards
X21	Contact with venomous spiders
X22	Contact with scorpions
X23	Contact with hornets, wasps, and bees
X24	Contact with centipedes and venomous millipedes (tropical)
X25	Contact with other specified venomous arthropods
X26	Contact with venomous marine animals and plants
X27	Contact with other specified venomous animals
X28	Contact with other specified venomous plants
X29	Contact with unspecified venomous animal or plant
T63	Toxic effect of contact with venomous animals

Table 2: Bites and stings by external cause code X20-X29 and diagnosis code T63:
Australia August 2001-May 2013.

External cause code	Total	Percent	M:F ratio
Contact with venomous snakes or lizards (X20)	6,123	15.45%	2.1
Contact with spiders (X21)	11,994	30.27%	1.3
Contact with scorpions (X22)	61	0.15%	1.3
Contact with hornets, wasps, bees (X23)	12,351	31.17%	2.5
Contact with centipedes and venomous millipedes (X24)	119	0.30%	0.9
Contact with other specified venomous arthropods (X25)	4,533	11.44%	1.2
Contact with venomous marine animals and plants (X26)	3707	9.36%	2.4
Contact with other specified venomous animals (X27)	151	0.38%	1.8
Contact with other specified venomous plants (X28)	44	0.11%	2.4
Contact with unspecified venomous animal or plant (X29)	536	1.35%	1.3
Total	39,619		
Diagnosis code			
Snake venom (T63.0)	5,483	15.64%	2.2
Venom of other reptiles (T63.1)	28	0.08%	3.0
Venom of scorpion (T63.2)	55	0.16%	1.1
Venom of spider (T63.3)	10,794	30.80%	1.3
Venom of other arthropods (T63.4)	15,269	43.56%	2.0
Toxic effect of contact with fish (T63.5)	424	1.21%	4.4
Toxic effect of contact with other marine animals (T63.6)	2,188	6.24%	1.7
Toxic effect of contact with other venomous animals (T63.8)	263	0.75%	1.2
Toxic effect of contact with unspecified venomous animal (T63.9)	546	1.56%	1.4
Total	35,050		

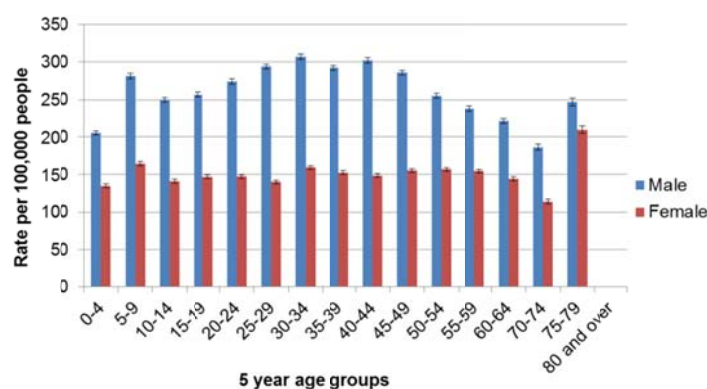


Figure 1: Age-specific rate of admissions: Males and Females, Australia from August 2001 to May 2013 (95% CI)

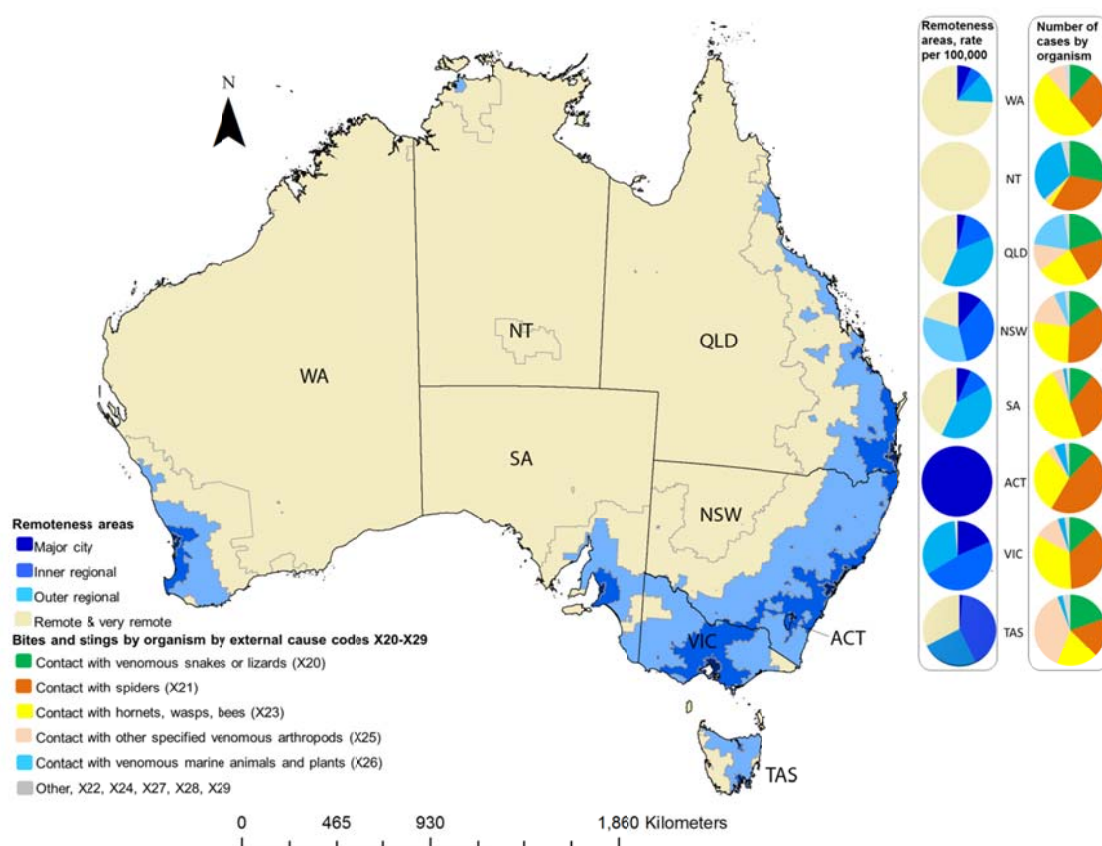


Figure 2: Map of Australia by remoteness area, and bite and sting hospitalisations by remoteness area and organism: Australia, August 2000-May 2013. See also supplementary table 1

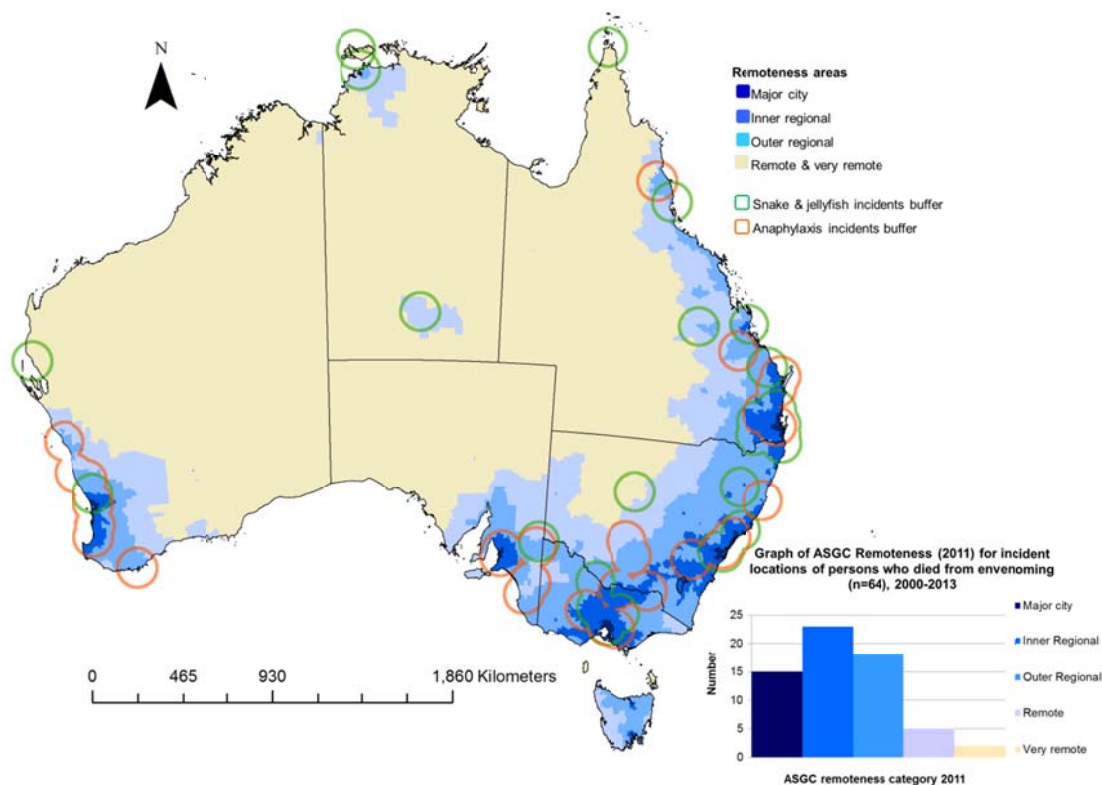


Figure 3: Multiple envenomation events, within a 100km radius, that resulted in mortality from January 2000-December 2013. Orange depicts anaphylactic shock from a bee, wasp, tick or ant, green depicts snake or jellyfish envenoming. Albers projection against ABS ASGC 2007 remoteness structure of major city, inner regional, outer regional, remote and very remote locations