

Appendix: Survey data summary

Notes:

- A full list of all sources consulted for this survey is available in the Supplementary Material associated with this paper.
- Language names follow the Gambay First Languages Map (<https://gambay.com.au/>). Location and topographic details are accessible via the Gambay Map zoom function. Names from Glottolog and other well-known names are in parentheses in the table.
- The names of language families follow Glottolog.⁴ For families other than Pama-Nyungan (PN), only the family name is given, or “Isolate” for family-level isolates. For Pama-Nyungan languages, first-order

⁴ With the exception of varieties of Kriol, which are shown as “Creole”.

subgroups are also given. For especially large first-order subgroups, second-order subgroup names are also given in parentheses.

- The columns representing spatial systems in the table are checked if at least one attested term in the language is anchored in the relevant phenomenon. For example, the “river” column is checked if at least one term is attested that invokes a watercourse (upriver, downriver, cross-river, along-river, or riverbank distinction). The column is checked whether the relevant term or terms uniquely invoke that phenomenon (e.g. a dedicated “upriver” term), or is colexified with another anchoring phenomenon (e.g. a term that lexifies both “upriver” and topographic elevation). See Section 2 for further discussion. The spatial system columns are as follows:
 - Cardinal (the language displays at least one attested term encoding an abstract cardinal direction, whether all four are attested or only three, two, or one; note that such terms may form part of a single system with other terms anchored in topography, see Section 2.1)
 - Sun
 - Wind
 - Climate (climate or weather)
 - Coast
 - River
 - Tide
 - Cultural (spiritually or culturally significant places)
 - Elev. only (it is confirmed that the language has no geocentric terms other than elevation)
 - Elev. attest (topographic elevation is only geocentric system attested)
 - Elevation (topographic elevation attested)

These final three columns all relate to topographic elevation. The “Elev. only” column is checked if it is confirmed that the language does not employ any geocentric terms other than for topographic elevation (this applies to only one language in the sample, Murrinhpatha). The “Elevation” column is checked if the language is attested as employing terms referring to topographic elevation, regardless of whether they solely encode topographic elevation, or colexify topographic elevation with vertical elevation or another topographic phenomenon. The total of this column and the absence of a check in the column for any particular language should not be taken as significant. It is likely that the lack of attestation of topographic elevation in many or even all such languages results from a gap in the often limited data for the relevant languages. All but one language with no check in this column do have terms for vertical elevation (‘up’ vs. ‘down’), but we have not been able to confirm from the available data that these terms also apply to topographic elevation – however there is no evidence that they do not. The limited data simply does not contain examples that clearly indicate topographic rather than vertical elevation. The exception is Darkinyung, where even terms for vertical ‘up’ and ‘down’ are not attested in the source. This is likely to be the result of the limited nature of the salvage data assembled in the source, rather than evidence of the absence of vertical elevational terms from the language. Aside from Darkinyung, all languages in the sample are attested as having terms for vertical elevation, so this is not shown in the table. The “Elev. attest.” column shows the subset of languages displaying topographic elevation where that is the only attested geocentric system in the language. The “Elev. only” and “Elev. attest.” columns differ in that the former shows languages where it is confirmed no geocentric system other than topographic elevation is encoded, whereas the latter shows languages where no geocentric system other than topographic elevation is attested, but the absence of attestation of other systems may simply be a gap in the data.

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|---|-----|--|-------------|-------------|-------------|---------|-------------|-------------|-----------|----------|---------------|------------------|-----------|---|
| Total languages attested with each system ($n = 116$) | | | 78 (67%) | 24 (21%) | 32 (28%) | 3 (3%) | 37 (32%) | 57 (49%) | 1 (1%) | 3 (3%) | 1 (1%) | 4 (4%) | 91 (79%) | |
| Adnyamathanha | adt | PN Arandic-Thura-Yura | x | x | x | | | x | | | | | | McEntee and McKenzie 1992; Nash 2013; Schebeck 1973, 1974 |
| Alyawarr | aly | PN Arandic-Thura-Yura | x | | x | | | | | | | | x | J. Green 1992; J. Green et al. 2019; Moore et al. 2004; Yallop 1977 |
| Angkamuthi (Uradhi) | | PN Paman (North-ern Pama) | | | | | | | | | | x | | Crowley 1983 |
| Anguthimri (Mpakwithi dialect) | awg | PN Paman (North-ern Pama) | x | | | | | | | | | | | Crowley 1981 |
| Anmatyerr | amx | PN Arandic-Thura-Yura | x | | | | | | | | | | x | J. Green 2010 |
| Arabana | ard | PN Karnic | x | x | | | | | | | | | x | Hercus 1994 |
| Awabakal | awk | PN Southeastern (NSW) | x | x | | | x | | | | | | x | Anonymous 2008; Lissarrague 2006 |
| Banyjima (Panytyima) | pnw | PN South-West (Pilbara) | x | | | | | x | | | | | | Dench 1991; Sharp and Thieberger 1992 |
| Bardi | bcj | Nyulnyulan | | | x | | | x | x | | | | x | Bowern 2012, 2016, pers. comm. |
| Bayungu | bxj | PN South-West (Pilbara) | x | | | | | | | | | | | Austin 1992b; Deak 2008; Walgar 2006 |
| Bilinarra | nbj | PN Desert Nyungic (Ngumpin-Yapa) | x | | | | | x | | | | | x | Meakins 2013, pers. comm.; Meakins and Nordlinger 2014 |
| Bundjalung (Middle Clarence Bandjalang) | bdy | PN Southeastern (NSW) | x | | | | x | x | | | | | x | Crowley 1978; Smythe 1978 |
| Bunganditj/Boandik | xbg | PN Southeastern (Victorian) | x | | | | | | | | | | x | Blake 2003a |
| Bunuba | bck | Bunaban | x | | | | | x | | | | | x | Knight 2004; Rumsey 2000 |
| Dalabon (Ngalkbun) | ngk | Gunwinyguan | x | | | | | x | | | | | x | Cutfield 2011; Ponsonnet 2013, pers. comm.; Ross 2011 |
| Darkinyung (Hawkesbury) | xda | PN Southeastern (NSW) | | | | | | | | | | x | | Jones 2008; Wafer & Lissarrague 2008 |
| Dhanggati (Dyangadi) | dyn | PN Macleay-New England | x | | | | | x | | | | | x | Lissarrague 2007, 2021 |
| Dharug (Eora, Dharruk, Sydney) | xdk | PN Southeastern (NSW) | | | x | | | | | | | | | Nash 2013, pers. comm.; Steele 2005; Troy 1994, 2019 |
| Dhuwal (Djapu) | dwu | PN Yuulngu | | | x | | x | x | | | | | x | Heath 1980c; Morphy 1983 |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|---|-----|--|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|---|
| Dieri (Diyari) | dif | PN Karnic | x | | | | | | | | | | x | Austin 2013a, 2013b, 2021 |
| Djabugay | dyy | PN Yimidhirr- Yalanji-Yidinic | x | | | | x | | | | | | x | Patz 1991; Quinn et al. 1992 |
| Djinan̄ (Djinang) | dji | PN Yuulngu | | x | x | | x | x | | | | | x | Waters 1984, 1989, 2011 |
| Dyirbal | dbl | PN Dyirbalic | x | | | | | x | | | | | x | Dixon 1972, 2003 |
| Eastern Arrernte (Mparntwe dialect) | aer | PN Arandic-Thura- Yura | x | | x | | | x | | | | | x | J. Green 2005; Henderson & Dobson 1994; Wilkins 1989, 1997, 1999, 2000, 2006 |
| Gagadju (Gaagudju) | gbu | Isolate | | | | | | | | | | | x | Harvey 2002; Spencer 1914 |
| Gangalidda (Yukulta, Ganggalida) | gcd | Tangkic | | x | | | x | | | | | | x | Keen 1983; Nancarrow 2014, pers. comm. |
| Garrawa (Garra) | wrk | Garrwan | x | | | | | x | | | | | x | Furby & Furby 1976; Mushin 2012 |
| Gathang (Worimi) | kda | PN Southeastern (NSW) | x | | | | x | x | | | | | x | Lissarrague 2010 |
| Gooniyandi | gni | Bunaban | x | | | | | x | | | | | x | McGregor 1990 |
| Gooreng Gooreng (Gur- eng Gureng) | xgg | PN Southeastern (North Coast) | | | x | | x | | | | | | x | Brasch 1975; Helon 1994 |
| Gumbaynggirr (Kumbainggar) | kgs | PN Southeastern (North Coast) | x | | | | x | x | | | | | x | Eades 1979; Morelli 2008, 2015; Muurrbay Aboriginal Language and Culture Coop. 2001; Smythe 1948– 1950 |
| Gunditjmarra (Warrnam- bool, “Dartmoor” doculect) | gjm | PN Southeastern (Victorian) | | x | x | x | | | | | | | | Blake 2003b |
| Gun-nartpa (Burarra) | bvr | Maningrida | | x | x | | x | | | | | | x | Carew 2016, pers. comm.; Glasgow 1984; Glasgow & Glasgow 2011; R. Green 1987 |
| Gurindji | gue | PN Desert Nyungic (Ngumpin-Yapa) | x | | | | | x | | | | | x | Dunn et al. 2021; Meakins & McConvell 2021; Meakins 2011; Meakins & Algy 2016; Meakins et al. 2013, 2016 |
| Guugu Yimidhirr | kky | PN Yimidhirr- Yalanji-Yidinic | x | | | | x | | | | | | x | de León 1995; Haviland 1979, 1993, 1998; Levinson 2003 |
| Iwaidja | ibd | Iwaidjan | x | x | x | | x | | | | | | x | Edmonds-Wathen 2011, 2012; Pym & Larrimore 2011 |
| Jaminjung | dja | Mirndi | | | | | | x | | | | | x | Hoffmann 2011, 2019; Schultze- Berndt 2000, 2006, 2008 |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|---|-----|--|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|--|
| Jaru | ddj | PN Desert Nyungic (Ngumpin-Yapa) | x | x | | | | x | | | | | x | Dahmen & Blythe n.d.; Tsunoda 1981; Wrigley 1992 |
| Kala Lagaw Ya (Western Torres Strait) | mwp | PN Kala Lagaw Ya | | | x | | x | | | | | | x | Bani 2001; Ford & Ober 1991; Stirling 2011 |
| Kalkatungu (Kalkadoon) | ktg | PN Kalkatungic | x | x | x | | | x | | | | | x | Blake 1979a; Enoch 2013 |
| Kamu | xmu | Eastern Daly | | | | | | | | | | x | x | Harvey 1990; Palmer et al. 2021 |
| Kaurua | zku | PN Arandic-Thura-Yura | x | | | | | | | | | | | Amery & Simpson 2013; Fitzpatrick 1989; Simpson & Hercus 2004 |
| Kayardild | gyd | Tangkic | x | | | | x | | | | | | x | Evans 1992, 1995, pers. comm.; Ross 2011; Round pers. comm. |
| Kaytetye | gbb | PN Arandic-Thura-Yura | x | | | | | | | | | | x | Koch 1984; Turpin 2000; Turpin & Ross 2012; Wafer 1982 |
| Kugu Uwanh (Kuku Uwanh, Kugu Nganhcara) | uwa | PN Paman (Wik) | x | | | | | | | | | | | Smith & Johnson 2000 |
| Kuku Yalanji | gvn | PN Yimidhirr-Yalanji-Yidinic | | | | | x | x | | | | | x | Hershberger & Hershberger 1986; Oates 1992a; Patz, 2002 |
| Kuuk Thayorre (Kuuk Thaayorre) | thd | PN Paman (South-west Pama) | | x | | | x | x | | | | | x | Boroditsky & Gaby 2010; Gaby 2012; Gaby et al. 2017 |
| Kuuku Ya'u | kuy | PN Paman (North-eastern Pama) | | | x | | x | | | | | | x | Thompson 1988; Hill 2002, 2011, 2017 |
| Lardil | lbz | Tangkic | | x | x | | x | | | | | | x | Klokeid 1976; McKnight 1999; Nancarrow pers. comm.; Nash 2013; Ngakulmungan Kangka |
| Limilngan | lmc | Limilngan-Wulna | x | | | | | | | | | | x | Leman 1996; Tindale 1974 |
| Malak Malak | mpb | Northern Daly | | x | x | | | x | | | | | x | Harvey 2001 |
| Malgana | vml | PN South-West (Kartu-Nhanda) | x | | | | | | | | | | | Hoffmann 2013, 2017, 2019; Lindsay et al. 2017; Palmer et al. 2021 |
| Mangarrayi | mpc | Mangarrayi-Maran | x | x | | | | x | | x | | | x | Gargett 2011 |
| Margany | zmc | PN Greater Maric | x | | | | | | | | | | | Merlan 1989 |
| Marrithiyel (Marithiel) | zmj | Western Daly | | | | | x | | | | | | | Breen 1981 |
| Martu Wangka (Manyjilyjarra dialect) | mpj | PN Desert Nyungic (Wati) | x | | | | | | | | | | | I. Green 1989; Tryon 1974 |
| | | | | | | | | | | | | | | Hill et al. 2016; Marsh 1976; Sharp & Thieberger 1992 |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|-------------------------------------|-----|--|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|--|
| Martuthunira | vma | PN South-West (Pilbara) | | | | | x | x | | | | | x | Dench 1987, 1995; Sharp & Thieberger 1992 |
| Matngele | zml | Eastern Daly | | x | x | | | x | | | | | x | Harvey n.d.a; Hoffmann 2017; Palmer et al. 2021; Zandvoort 1999 |
| Mawng | | Iwaidjan | | | | | x | | | | | | x | Capell & Hinch 1970; Hewett et al. 2013; Singer 2006, 2016; Singer et al. 2015 |
| Mbabaram | vmb | PN Paman (Finas- leigh Pama) | x | | | | | x | | | | | x | Dixon 1966, 1991 |
| Murrinhpatha | mwf | Southern Daly | | | | | | | | | x | | x | Blythe et al. 2016; Bohnemeyer et al., this collection; Gaby et al. 2016; Gaby & Singer 2014 |
| Muruwari | zmu | PN Southeastern (NSW) | | | | | | x | | | | | x | Oates 1988, 1992b |
| Na-kara | nck | Maningrida | | x | x | | x | x | | | | | x | Eather 1990; Eather et al. 2005 |
| Narungga | nnr | PN Arandic-Thura- Yura | x | | x | | | | | | | | | Eira et al. 2010 |
| Ndjébbana (Djeebbana) | djj | Maningrida | x | | x | | x | x | | | | | x | McKay 2000 |
| Ngaanyatjarra | ntj | PN Desert Nyungic (Wati) | x | x | | | | | | | | | | Douglas 1964, 1988, 2010; Glass 1983, 1997, 2017; Glass & Hackett 1970; Nash 1997 |
| Ngadju (Ngadjunmaya) | nju | PN South-West (Mirning) | x | | | | | | | | | | x | Hanson 2013; Nash 1997; von Brandenstein 1980 |
| Ngandi | nid | Gunwinyguan | x | | | | x | x | | | | | x | Heath 1978 |
| Ngarla | nrk | PN South-West (Pilbara) | x | | | | | | | | | | x | Brown & Geytenbeek 1989; Sharp & Thieberger 1992; Westerlund 2015 |
| Ngarluma | nrl | PN South-West (Pilbara) | | | | | | x | | | | | x | von Brandenstein 1970; Kohn 2012; Sharp & Thieberger 1992 |
| Ngen'giwumirri (Ngan'gityemerri) | nam | Southern Daly | | x | | | | x | | | | | x | Hoddinott & Kofod 1988; Palmer et al. 2021; Reid 1990 |
| Ngiyampaa (Ngiyambaa) | wyb | PN Southeastern (Wiradhuric) | | | | | | | | | | x | x | Donaldson 1980 |
| Noongar (Nyunga) | xrg | PN South-West (Nyunga) | x | x | x | | x | x | | | | | x | Bindon & Chadwick 2011; von Brandenstein 1988; Smith-Ali et al. 2021; Wykman 2005 |
| Nyamal | nly | | | | | | | x | | | | | | |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|--------------------------------|-----|--|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|---|
| Nyangumarta | nna | PN South-West (Pilbara) PN Desert Nyungic (Marrngu) | x | | | | | | | | | | x | Brown & Geytenbeek 1992; Burg- man 2007 Sharp 2004; Sharp & Thieberger 1992; Thomas et al. 1990 |
| Nyawaygi | nyt | PN Nyawaygic | x | | | | x | x | | | | | x | Dixon 1983 |
| Nyulnyul | nyu | Nyulnyulan | x | | x | | | x | | | | | x | McGregor 2011a, 2011b |
| Pintupi | piu | PN Desert Nyungic (Wati) | x | | x | | | | | | | | | Hansen & Hansen 1974, 1978, 1992; Lewis 1976a, 1976b |
| Pitjantjatjara | pjt | PN Desert Nyungic (Wati) | x | | x | | | | | | | | x | Defina, pers. comm.; Eckert & Hud- son 1988; Goddard 1992, pers. comm.; Goddard & Defina 2020 |
| Pitta Pitta | pit | PN Karnic | x | | | | | | | | | | x | Blake 1979b |
| Rembarrnga | rmb | Gunwinyguan | x | | | | | x | | | | | x | McKay 1975, 1988; Saulwick 2003, 2009 |
| Ritharrngu (Ritarungo) | rit | PN Yuulngu | x | | | | | x | | | | | x | Heath 1980a |
| Roper Kriol | rop | Creole | | x | | | | x | | | | | x | Hoffmann 2011, 2019; Lee 2014 |
| Taungurung (Thagungwurrung) | dgw | PN Southeastern (Victorian) | x | | x | | | | | | | | x | Healy 2011 |
| Thalanyji (Dhalandji) | dhl | PN South-West (Pilbara) | x | | | | | | | | | | | Austin 1992c |
| Tiwi | tiw | Isolate | | x | | | x | | | x | | | x | Lee 2013; Osborne 1974 |
| Umpithamu (Umbidhamu) | umd | PN Paman (North- eastern Pama) | x | | | | | x | | | | | x | Verstraete 2008, 2009, 2010a, 2010b, 2011a, 2011b, 2011c, 2012; Verstraete & de Cock 2008 |
| Wagiman | wag | Isolate | | | | | | x | | | | | x | Anonymous 2009; Cook 1987; Har- vey, pers. comm.; Palmer et al. 2021; A. Wilson 2006; S. Wilson 1999 |
| Wajarri | wbv | PN South-West (Kartu-Nhanda) | x | | | | x | | | | | | | Douglas 1981; Marmion 2021; Yamaji Language Centre 1992 |
| Walmajarri | wmt | PN Desert Nyungic (Ngumpin-Yapa) | x | | | | | | | | | | x | Hudson 1978; Hudson et al. 1984; Richards & Hudson 1990, 2011 |
| Wardaman | wrr | Yangmanic | x | | | | | x | | | | | x | Merlan 1994 |
| Warlpiri | wbp | | x | | x | | | | | | | | x | |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|---|-----|---|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|--|
| Warndarrang (Warndarang) | wnd | PN Desert Nyungic (Ngumpin-Yapa) Mangarrayi-Maran | x | | | | x | x | | | | | x | Laughren 1978; Nash 1986; Simpson 1991; Swartz 1982, 2012 Heath 1980b |
| Warnman | wbt | PN Desert Nyungic (Wati) | x | | | | | | | | | | | Anonymous 2003; Burgman 2010; MacCallum 1992; Nash 1997; Sharp & Thieberger 1992 |
| Warray | wrz | Gunwinyguan | | | | | | x | | | | | x | Harvey 1986, n.d.b, n.d.c, n.d.d, pers. comm. |
| Warrgamay | wgy | PN Warrgamay | x | | | | | x | | | | | x | Dixon 1981 |
| Warrungu (Warrongo) | wrg | PN Greater Maric | x | | | | | x | | | | | x | Tsunoda 2011 |
| Warrwa | wwr | Nyulnyulan | x | | | | | x | | | | | x | McGregor 1994, 2006 |
| Wemba Wemba (Western Victoria) | xww | PN Southeastern (Victorian) | | x | | x | | | | | | | | Hercus 1986, 1992 |
| Westside Kriol | rop | Creole | | | | | | x | | | | | x | Hoffmann 2011 |
| Wik-Mungkan | wim | PN Paman (Wik) | x | | | | | | | | | | x | Kilham 1974, 1977; Kilham et al. 1986, 2011 |
| Wiradjuri | wrh | PN Southeastern (Wiradhuric) | x | | | | | | | x | | | | Grant & Rudder 2010; Wafer & Lissarrague 2008 |
| Woiwurrung | wyi | PN Southeastern (Victorian) | x | | x | | | | | | | | | Blake 1991 |
| Wubuy (Nunggubuyu) | nuy | Gunwinyguan | | | x | | x | x | | | | | x | Heath 1980d, 1982, 1984; Hore 1994; Horrack 2018 |
| Yalarnnga | ylr | PN Kalkatungic | x | | | | | x | | | | | | Breen & Blake 2007; Blake 2006 |
| Yandruwantha (Yandruwandha, Innamincka) | ynd | PN Karnic | x | x | x | x | | x | | | | | x | Breen 2004a, 2004b, 2015 |
| Yankunytjatjara | kdd | PN Desert Nyungic (Wati) | x | | | | | | | | | | x | Goddard 1985; Nash 1997 |
| Yanyuwa | yao | PN Ngarna | x | | | | x | x | | | | | x | Bradley et al. 1992; Kirton & Charlie 1996; Kirton & Timothy 1982 |
| Yawuru | ywr | Nyulnyulan | x | | x | | x | | | | | | x | Hosokawa 1991 |
| Yaygirr | xya | PN Southeastern (North Coast) | x | | | | | | | | | | x | Crowley 1979; Morelli 2012; Wafer & Lissarrague 2008 |
| Yidiny | yii | | x | | | | | x | | | | | x | Dixon 1977 |

(continued)

| Language | ISO | Language family (PN = Pama- Nyungan) | Cardinal | Sun | Wind | Climate | Coast | River | Tide | Cultural | Elev. only | Elev. attest. | Elevation | Sources |
|---|-----|--|----------|-----|------|---------|-------|-------|------|----------|---------------|------------------|-----------|--|
| Yindjibarndi | yij | PN Yimidhirr- Yalanji-Yidinic PN South-West (Pilbara) | x | | x | | x | x | | | | | x | Dench 1995; Mark & Turk 2003; Sharp & Thieberger 1992; von Brandenstein 1970; Wordick 1982 Verstraete & Rigsby (2015) |
| Yintyingka | ayd | PN Paman (North- eastern Pama) | x | | | | x | | | | | | x | |
| Yir Yoront | yyr | PN Paman (South- west Pama) | x | x | x | | x | x | | | | | x | Alpher 1991 |
| Yugambeh (Tweed-Al- bert Bandjalang) | | PN Southeastern (NSW) | x | | | | x | | | | | | x | Sharpe 1998, 2005 |
| Yuwaalaraay/ Gamilaraay | kld | PN Southeastern (Wiradhuric) | | | | | | x | | | | | x | Ash et al. 2003; Austin 1992a, 1993; Giacon 2017; Sim & Giacon 1998 |