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# Climate Classification System–Based Determination of Temperate Climate Detection of *Cryptococcus gattii* sensu lato

## Appendix

### Methods for Updated Literature Review

To assess how historical (i.e., pre-1999) areas of *C. gattii* endemicity have been described in the literature, we searched for peer-reviewed English articles published from January 1970 through November 2018 that directly analyzed or reviewed the ecology and/or geographic distribution of *C. gattii*. We searched Google Scholar (http://scholar.google.com), ScienceDirect (http://www.sciencedirect.com), and Web of Science (http://thomsonreuters.com/thomson-reuters-web-of-science). For species, we selected the inputs "either/or" for "*Cryptococcus gattii*," "*Cryptococcus neoformans* var. *gattii*," or "*Cryptococcus bacillisporus*" in the search engine, where the last was considered synonymous with *C. gattii* in the late 1970s and early 1980s (*1*); for ecologic or geographic studies, we selected "either/or" for "ecolog*," "geograph*," "distribution," and "niche." In addition to assessing how historical areas of endemicity of *C. gattii* were described, we also identified which studies were used as the original sources of these statements.

We originally found 105 articles that studied *C. gattii* ecology or geographic distributions, but further narrowed our results down to 73 articles that directly discussed areas of *C. gattii* endemicity before the Vancouver Island outbreak. Articles were classed as "restricted" if they worded *C. gattii* distributions as "restricted to," "only found in," or "confined to" (sub)tropical areas, or variations thereof. Articles were classed as "general" if they worded *C. gattii* distributions as "mainly," "predominantly," or "primarily" in (sub)tropical areas, or variations thereof.

Of the 73 articles reviewed, 35 studies contained statements claiming *C. gattii* was restricted to the (sub)tropics before the Vancouver Island outbreak (i.e., "restricted" statements), while 38 studies also acknowledged other historical areas of endemicity outside the (sub)tropics (i.e., “general” statements) (Appendix Figure). The same studies were often cited as the sources of both statements. For example, 2 seminal papers published in 1984 on global *Cryptococcus neoformans* and *C. gattii* distributions (*2*,*3*) were primarily or secondarily cited in 24 of the 35 studies making “restricted” statements but were also cited in 10 of the 38 studies making “general” statements. The authors demonstrated a higher prevalence of *C. gattii* in (sub)tropical areas compared to temperate ones but stated the fungus was not entirely restricted to these warmer areas.

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**Appendix Table.** Unique georeferenced global environmental isolations of *Cryptococcus gattii* (n = 83) listed in chronologic order, 1989–2016*

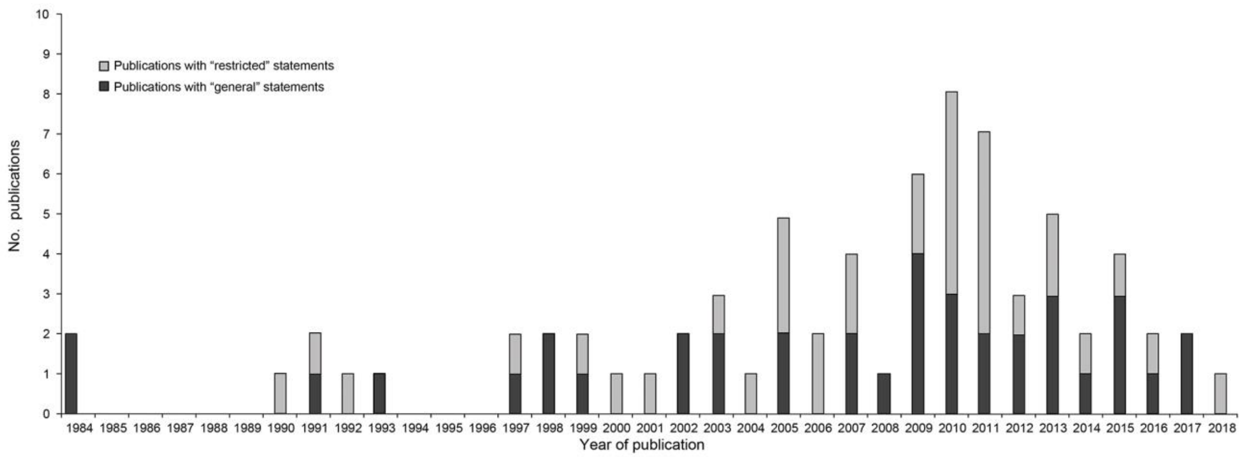
| Country | Area | Sample year(s) | Longitude | Latitude | Earliest year | Genotype | Mating type | Species | With ±40° limits | With ±35° limits | KG label | KG limits | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | Balranald, NSW | 1989 | 143.5633 | −34.6394 | 1989 | – | – | – | ST | ST | BSk | AR | (*4*) |
| Australia | Balranald, NSW | 1989–1990 | 143.5633 | −34.6394 | 1989 | AFLP4B/VGIb | – | *C. gattii* s.s. | ST | ST | BSk | AR | (*5*) |
| Australia | Balranald, NSW | 1989–1996 | 143.5633 | −34.6394 | 1989 | AFLP4/VGI | α, **a** | *C. gattii* s.s. | ST | ST | BSk | AR | (*6*) |
| Australia | Hay, NSW | 1989 | 144.5803 | −34.1573 | 1989 | – | – | – | ST | ST | BSk | AR | (*4*) |
| Australia | Hay, NSW | 1989–1990 | 144.5803 | −34.1573 | 1989 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | BSk | AR | (*6*) |
| Australia | Barossa Valley (Barossa Reservoir and Nuriootpa), SA | 1989 | 138.95 | −34.5333 | 1989 | – | – | – | ST | ST | Csa | TM | (*4*) |
| Australia | Barossa Valley, SA | 1989–1992 | 138.95 | −34.5333 | 1989 | AFLP4A/VGIa | – | *C. gattii* s.s. | ST | ST | Csa | TM | (*5*) |
| United States | Fort Point, San Francisco, California | 1990 | −122.477 | 37.81022 | 1990 | AFLP6A/VGIIa | – | *C. deuterogattii* | ST | TM | Csb | TM | (*7*) |
| Australia | Tocumwal, NSW | 1991 | 145.569 | −35.8122 | 1991 | AFLP4/VGI | – | *C. gattii* s.s. | ST | TM | BSk | AR | (*5*) |
| Australia | Currumbin, Gold Coast, QLD | 1991 | 153.4667 | −28.1333 | 1991 | – | – | – | ST | ST | Cfa | TM | (*8*) |
| Australia | Currumbin, Gold Coast, QLD | 1991–1993 | 153.4667 | −28.1333 | 1991 | AFLP4/VGI | – | *C. gattii* s.s. | ST | ST | Cfa | TM | (*5*) |
| Australia | Mt. Annan, Greater Sydney, NSW | 1991 | 150.7598 | −34.0529 | 1991 | – | – | – | ST | ST | Cfb | TM | (*8*) |
| Australia | Mt. Annan, Greater Sydney, NSW | 1991–1994 | 150.7598 | −34.0529 | 1991 | AFLP4/VGI | – | *C. gattii* s.s. | ST | ST | Cfb | TM | (*5*) |
| Australia | Busselton, WA | 1993 | 115.3708 | −33.6848 | 1993 | AFLP6/VGII | – | *C. deuterogattii* | ST | ST | Csb | TM | (*5*) |
| Brazil | Rio de Janeiro | <1993 | −43.16667 | −22.9 | 1993 | AFLP4/VGI | – | *C. gattii* s.s. | T | T | Am | T | (*9*) |
| Brazil | Teresina | 1993 | −42.8485 | −5.30175 | 1993 | AFLP6/VGII | α | *C. deuterogattii* | T | T | Aw | T | (*10*) |
| Brazil | Teresina | 1993–1997 | −42.8485 | −5.30175 | 1993 | AFLP6/VGII | α | *C. deuterogattii* | T | T | Aw | T | (*11*) |
| India | Ferozepur | 1995–1996 | 74.56 | 30.89 | 1995 | – | – | – | ST | ST | BSh | AR | (*12*) |
| Australia | Gold Coast, QLD | 1996 | 153.4309 | −28.0003 | 1996 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfa | TM | (*6*) |
| Australia | Adelaide, SA | 1996 | 138.5986 | −34.9287 | 1996 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Csa | TM | (*6*) |
| Brazil | Ibirapuera Park, Sao Paulo | 1996–1997 | −46.6581 | −23.6022 | 1996 | – | – | – | ST | ST | Cfa | TM | (*13*) |
| Italy | Apulia | 1996 | 16.619 | 40.985 | 1996 | – | – | – | TM | TM | Cfa | TM | (*14*) |
| United States | San Diego Zoo area, San Diego, California | <1996 | −117.157 | 32.71533 | 1996 | AFLP4/VGI<br>AFLP5/VGIII | – | *C. gattii* s.s.<br>*C. bacillisporus* | ST | ST | BSk | AR | (*5*) |
| Australia | Coffs Harbour, NSW | 1997–2000 | 153.10 | −30.30 | 1997 | – | α | – | ST | ST | Cfa | TM | (*15*) |
| Australia | Port Macquarie, NSW | 1997–2000 | 152.92 | −31.44 | 1997 | – | α | – | ST | ST | Cfa | TM | (*15*) |
| Australia | St. Ives, Sydney, NSW | 1997–1998 | 151.1667 | −33.7333 | 1997 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfa | TM | (*6*) |
| Australia | Eastern Sydney, NSW | 1997–2000 | 151.20 | −33.86 | 1997 | – | α, **a** | – | ST | ST | Cfa | TM | (*15*) |
| Colombia | Cúcuta | 1997 | −72.5 | 7.9 | 1997 | – | – | – | T | T | Am | T | (*16*) |
| Australia | Renmark, SA | 1998 | 140.747 | −34.177 | 1998 | AFLP4/VGI | α, **a** | *C. gattii* s.s. | ST | ST | BSk | AR | (*6*) |
| Australia | Breeza, NSW | 1998 | 150.4667 | −31.25 | 1998 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfa | TM | (*6*) |
| Australia | Pilliga, NSW | 1998 | 148.9 | −30.35 | 1998 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfa | TM | (*6*) |
| Australia | Port Macquarie, NSW | 1998 | 152.9167 | −31.4167 | 1998 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfa | TM | (*6*) |
| Brazil | Ilha de Maracá | 1998–1999 | −61.6667 | 3.41667 | 1998 | AFLP6/VGII | **a** | *C. deuterogattii* | T | T | Am | T | (*17*) |
| Egypt | Qutur and Tanta areas, Gharbia Governorate | 1998 | 30.95614 | 30.97225 | 1998 | – | – | – | ST | ST | BWh | AR | (*18*) |
| India | Delhi (northwestern India) | 1999–2000 | 77.22897 | 28.65381 | 1999 | – | – | – | ST | ST | BSh | AR | (*19*) |
| Mexico | Mexico City | <1999 | −99.1277 | 19.42847 | 1999 | – | – | – | T | T | Cwb | TM | (*20*) |
| Australia | Glenbrook, Blue Mountains National Park, Sydney | 2000 | 150.4731 | −33.6562 | 2000 | AFLP4/VGI | α | *C. gattii* s.s. | ST | ST | Cfb | TM | (*21*) |
| Argentina | Buenos Aires City | 2001 | −58.3772 | −34.6131 | 2001 | – | – | – | ST | ST | Cfa | TM | (*22*) |

| Country | Area | Sample year(s) | Longitude | Latitude | Earliest year | Genotype | Mating type | Species | With ±40° limits | With ±35° limits | KG label | KG limits | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | Rep. de Chile Park, de los Patricios Park, Centenario Park, and N. Avellaneda Park in Buenos Aires City | 2002 | −58.3772 | −34.6131 | 2002 | AFLP4/VGI | – | *C. gattii* s.s. | ST | ST | Cfa | TM | (*23*) |
| Canada | Cameron Lake, B.C. | 2002 | −124.619 | 49.29133 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | Courtenay, B.C. | 2002 | −124.994 | 49.68657 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | Duncan, B.C. | 2002 | −123.703 | 48.78293 | 2002 | AFLP4/VGI<br>AFLP6B/VGIIb | – | *C. gattii* s.s.<br>*C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | MacMillan Park, Cathedral Grove, B.C. | 2002 | −124.669 | 49.28293 | 2002 | AFLP6A/VGIIa | α | *C. deuterogattii* | TM | TM | Csb | TM | (*25*) |
| Canada | Nanaimo, B.C. | 2002 | −123.936 | 49.16634 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | Parksville, B.C. | 2002 | −124.314 | 49.32 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | Port Alberni, B.C. | 2002 | −124.808 | 49.234 | 2002 | AFLP6A/VGIIa, AFLP6B/VGIIb | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Canada | Rathtrevor Beach Provincial Park, Parksville, B.C. | 2002 | −124.266 | 49.32096 | 2002 | AFLP6A/VGIIa, AFLP6B/VGIIb | α | *C. deuterogattii* | TM | TM | Csb | TM | (*25*) |
| Canada | Victoria, B.C. | 2002 | −123.369 | 48.43294 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Colombia | Cali | 2002–2003 | −75.68333 | 5.0 | 2002 | AFLP6/VGII | **a** | *C. deuterogattii* | T | T | Af | T | (*26*) |
| Colombia | Cúcuta | 2002–2003 | −72.01667 | 6.933333 | 2002 | AFLP4/VGI<br>AFLP5/VGIII<br>VGIV (AFLP type not specified) | α | *C. gattii* s.s.<br>*C. bacillisporus*<br>– | T | T | Cfb | TM | (*26*) |
| Colombia | Bogota | 2002–2003 | −74.08333 | 4.6 | 2002 | AFLP6/VGII | **a** | *C. deuterogattii* | T | T | Cfb | TM | (*26*) |
| Colombia | Cundinamarca | 2002–2003 | −73.05 | 3.666667 | 2002 | AFLP6/VGII<br>VGIV (AFLP type not specified) | **a**<br>α | *C. deuterogattii*<br>– | T | T | Am | T | (*26*) |
| Colombia | Medellin | 2002–2003 | −73.88333 | 5.433333 | 2002 | AFLP6/VGII | **a** | *C. deuterogattii* | T | T | Cfb | TM | (*26*) |
| India | Jabalpur City (Central India) | 2002–2004 | 79.95006 | 23.16697 | 2002 | – | – | – | T | T | Csa | TM | (*27*) |
| United States | Lynden, Washington | 2002–2006 | −122.452 | 48.9465 | 2002 | AFLP6A/VGIIa | – | *C. deuterogattii* | TM | TM | Cfb | TM | (*24*) |
| Australia | Mt. Druitt, Sydney, NSW | <2003 | 150.8167 | −33.7667 | 2003 | AFLP4/VGI<br>AFLP6/VGII | α<br>α | *C. gattii* s.s.<br>*C. deuterogattii* | ST | ST | Cfa | TM | (*28*) |
| Colombia | La Calera | 2003 | −73.9693 | 4.72069 | 2003 | – | **a** | – | T | T | Cfb | TM | (*29*) |
| Canada | Saltspring Island, B.C. | 2004–2005 | −123.408 | 48.769 | 2004 | AFLP4/VGI | **–** | *C. gattii* s.s. | TM | TM | Csb | TM | (*30*) |
| Canada | Hornby Island | 2005 | −124.667 | 49.525 | 2005 | AFLP6A/VGIIa | **–** | *C. deuterogattii* | TM | TM | Csb | TM | (*24*) |
| Argentina | Resistencia, Chaco | 2006 | −58.9839 | −27.4606 | 2006 | AFLP5/VGIII | – | *C. bacillisporus* | ST | ST | Cfa | TM | (*31*) |
| Canada | Elk Falls Provincial Park, Campbell River | 2006 | −125.251 | 50.026 | 2006 | – | – | – | TM | TM | Cfb | TM | (*24*) |
| Argentina | Parque España, La Paz, Entre Rios | 2007 | −59.6434 | −30.7437 | 2007 | AFLP4/VGI | – | *C. gattii* s.s. | ST | ST | Cfa | TM | (*31*) |
| Argentina | Rosario, Santa Fe | 2007 | −60.6393 | −32.9468 | 2007 | AFLP4/VGI | – | *C. gattii* s.s. | ST | ST | Cfa | TM | (*31*) |
| Brazil | Botafogo district, Rio de Janeiro | 2008–2010 | −43.1856 | −22.969 | 2008 | AFLP4/VGI | – | *C. gattii* s.s. | T | T | Am | T | (*32*) |
| Colombia | Cúcuta | 2008–2009 | −72.51 | 7.913333 | 2008 | AFLP4/VGI<br>AFLP5/VGIII | **a**<br>α | *C. gattii* s.s.<br>*C. bacillisporus* | T | T | Cfb | TM | (*33*) |
| Brazil | Belem, Para | <2009 | −48.50417 | −1.45556 | 2009 | AFLP6/VGII | – | *C. deuterogattii* | T | T | Am | T | (*34*) |
| India | Guindy National Park, Chennai, South India | <2009 | 80.21941 | 12.99668 | 2009 | – | – | – | T | T | Aw | T | (*35*) |

| Country | Area | Sample year(s) | Longitude | Latitude | Earliest year | Genotype | Mating type | Species | With ±40° limits | With ±35° limits | KG label | KG limits | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Italy | Reggio Calabria (southern Italy) | 2009 | 15.65 | 38.07 | 2009 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | Csa | TM | (*36*) |
| Puerto Rico | Guanica Dry Forest | <2010 | −66.908 | 17.97163 | 2010 | AFLP6/VGII<br>AFLP7/VGIV | α<br>α | *C. deuterogattii*<br>*C. tetragattii* | T | T | Aw | T | (*37*) |
| United States | Near Silver Falls State Park, Oregon (based on Figure 1 in main text) | 2010–2011 | −122.6336 | 44.90544 | 2010 | AFLP4/VGI, AFLP6A/VGIIa, AFLP6B/VGIIb, AFLP6C/VGIIc | – | *C. gattii* s.s., *C. deuterogattii* | TM | TM | Csb | TM | (*38*) |
| The Netherlands | Berg en Dal | 2011 | 5.916667 | 51.82167 | 2011 | AFLP4/VGI | α | *C. gattii* s.s. | TM | TM | Cfb | TM | (*39*) |
| Tunisia | Sfax region (southern Tunisia) | <2011 | 10.76028 | 34.74056 | 2011 | – | α | – | ST | ST | BSh | AR | (*40*) |
| United States | Los Angeles, California | 2011–2012 | −118.244 | 34.05223 | 2011 | AFLP4/VGI<br>AFLP5A/VGIIIa<br>AFLP5B/VGIIIb | α<br>α<br>**a,** α | *C. gattii* s.s. | ST | ST | Csb | TM | (*41*) |
| Botswana | Francistown | 2012 | 27.50788 | −21.17 | 2012 | – | **a,** α | – | T | T | BSh | AR | (*42*) |
|  | Gaborone | 2012 | 25.933 | −24.651 | 2012 | – | α | – | ST | ST | BSh | AR |  |
|  | Maun | 2012 | 23.415 | −20.007 | 2012 | – | **a,** α | – | T | T | BSh | AR |  |
| Brazil | Manaus | 2012–2014 | −60.052 | −3.109 | 2012 | AFLP6/VGII | α | *C. deuterogattii* | T | T | Af | T | (*43*) |
| Kenya | Nairobi | 2012–2013 | 36.83333 | −1.28333 | 2012 | AFLP4/VGI | – | *C. gattii* s.s. | T | T | Cfb | TM | (*44*) |
| Spain | Alicante | <2012 | −0.48149 | 38.34517 | 2012 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | BSk | AR | (*45*) |
| Spain | Barcelona | <2012 | 2.158987 | 41.38879 | 2012 | AFLP4/VGI | α | *C. gattii* s.s. | TM | TM | Csa | TM | (*45*) |
| Bonaire | Lagun Goto, Rincon village, Hato village | 2013 | −68.3258 | 12.21501 | 2013 | AFLP6/VGII | α | *C. deuterogattii* | T | T | BSh† | AR | (*46*) |
| Greece | Athens | 2013 | 23.71622 | 37.97945 | 2013 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | Csa | TM | (*47*) |
| Greece | Salamina Island | 2013 | 23.50677 | 37.92189 | 2013 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | Csa | TM | (*47*) |
| Italy | Ragalna, Catania | 2013 | 15.08233 | 37.43505 | 2013 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | Csa | TM | (*47*) |
| Italy | Route Brindisi-Fasano | 2013 | 17.69123 | 40.60921 | 2013 | AFLP4/VGI | **a** | *C. gattii* s.s. | TM | TM | Csa | TM | (*47*) |
| Italy | Route Gallipoli-Collepasso | 2013 | 17.99538 | 40.0559 | 2013 | AFLP4/VGI | **a** | *C. gattii* s.s. | TM | TM | Csa | TM | (*47*) |
| Spain | El Perello, Tarragona | 2013 | 0.71335 | 40.87642 | 2013 | AFLP7/VGIV | α | *C. tetragattii* | TM | TM | Csa | TM | (*47*, *48*) |
| Spain | Campello, Alicante | 2014 | −0.398 | 38.429 | 2014 | AFLP4/VGI | α | *C. gattii* s.s. | ST | TM | BSk | AR | (*47*) |
| Spain | Mendivil, Navarra | 2014 | −1.451 | 42.66366 | 2014 | AFLP4/VGI | α | *C. gattii* s.s. | TM | TM | Cfb | TM | (*47*) |
| Brazil | Santa Isabel do Rio Negro, Amazonas state | <2015 | −65.01889 | −0.41417 | 2015 | AFLP6/VGII | α, **a** | *C. deuterogattii* | T | T | Af | T | (*49*) |
| Thailand | Queen Sirikit Botanic Garden, Chiang Mai Province | <2016 | 98.86 | 18.89953 | 2016 | AFLP4/VGI | – | *C. gattii* s.s. | T | T | Aw | T | (*50*) |

*For longitude, positive numbers refer to degrees east of the prime meridian and negative numbers refer to degrees west of the prime meridian. For latitude, positive numbers refer to degrees north of the equator and negative numbers refer to degrees south of the equator. The latitudinal boundaries of ±40° and ±35° refer to degrees north (+) and south (-) of the equator. For each isolation, we recorded the country and area of isolation, the range of years when the isolations were collected (if the earliest year yielding positive isolations was provided, this would be the start of the range), the coordinates where the isolation was found, the earliest possible year of collection recorded for this analysis, and the climate classifications for each isolation, as designated by solar definitions with ±40° and ±35° limits as well as by the KG system. Genotype (including subtype), mating type, and species (*51*) are also provided, if specified by the study. It is important to note that some studies have only used phenotypic methods (e.g., CGB agar) to differentiate *C. gattii* sensu lato from *C. neoformans* s.l.. This is, however, not always a reliable method. Thus, data from this list need to be interpreted with caution. AR, arid; B.C., British Columbia; KG, Köppen-Geiger; NSW, New South Wales; QLD, Queensland; ref., reference; SA, South Australia; ST, subtropical; T, tropical; TM, temperate; WA, Western Australia.

†The KG system does not classify the island of Bonaire (Dutch Caribbean) in its map of observed climates during 1976–2000. We, therefore, obtained the classification of Bonaire from (*52*) in addition to our own categorization using the KG climate classification criteria (*53*) and present-day climate averages of the island (https://www.ncdc.noaa.gov/).




**Appendix Figure.** Publications from 1984 through November 2018 discussing pre-1999 areas of endemicity of *Cryptococcus gattii* (n = 73). Publications containing statements claiming *C. gattii* was strictly found in tropical and subtropical areas before the 1999 Vancouver Island outbreak were labeled as "restricted" (n = 35), while those containing statements that also acknowledged other areas of endemicity before the 1999 Vancouver Island outbreak were labeled as "general" (n = 38).