4. PREDICTING DUNG BEETLE DISTRIBUTIONS IN SOUTHEAST AUSTRALIA

BACKGROUND

Maps were prepared to indicate areas of predicted suitability in southeast Australia for 21 species of introduced dung beetle.

HOW WERE THE MAPS DERIVED?

To prepare the maps of predicted distributions, models were developed to identify areas of Australia that are climatically suitable for each species of introduced dung beetle. The models are derived from the climate in the countries where the beetles originate. The program used was BIOCLIM.
BIOCLIM uses monthly (or weekly) values of:

1 Annual mean temperature

2 Mean monthly temperature range

3 Isothermality (2/7) (*100)

4 Temperature seasonality (STD*100)

5 Max temperature of warmest month

6 Min temperature of coldest month

7 Temperature annual range

8 Mean temperature of wettest quarter

9 Mean temperature of driest quarter

10 Mean temperature of warmest quarter

11 Mean temperature of coldest quarter

12 Annual precipitation

13 Precipitation of wettest month

14 Precipitation of driest month

15 Precipitation seasonality (CV)

16 Precipitation of wettest quarter

17 Precipitation of driest quarter

18 Precipitation of warmest quarter

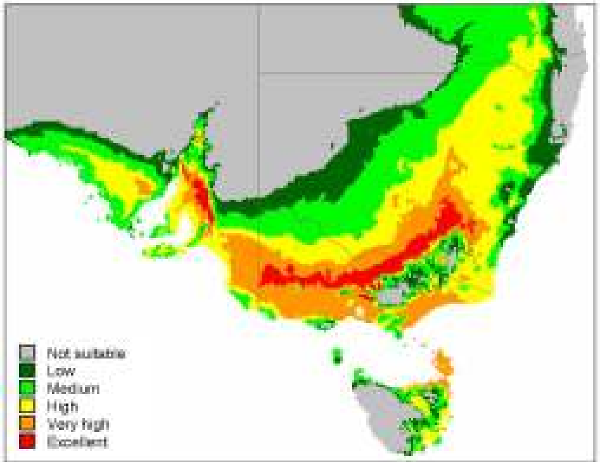
19 Precipitation of coldest quarter

The models either used all the climatic parameters, or a subset of four or five parameters. The parameters used are listed with each species on the pages that follow. The main climate parameters used to derive the models of predicted distribution were: total annual rainfall (parameter 12), amount of rain in winter (parameter 19), amount of rain in summer (parameter 18), mean winter temperature (parameter 11) and mean summer temperature (parameter 10).

The predicted distributions are based only on climate. They do not take into account other factors that might affect dung beetle distributions such as soil type, habitat or presence of cattle.

WHAT DO THE MAPS LOOK LIKE?

For each species a map is presented which shows areas of differing climatic suitability for that species. An example is shown below.



Areas in grey are climatically unsuitable for the species. The coloured areas range from dark green (low suitability) through to red (excellent suitability).

HOW TO USE THE MAPS

The maps provide an indication of the relative suitability of areas for a particular species. By comparing the known distribution of a species with the predicted distribution, the maps can be used as a guide to decide which species have potential for further redistribution, and general areas that might be suitable for such redistributions.

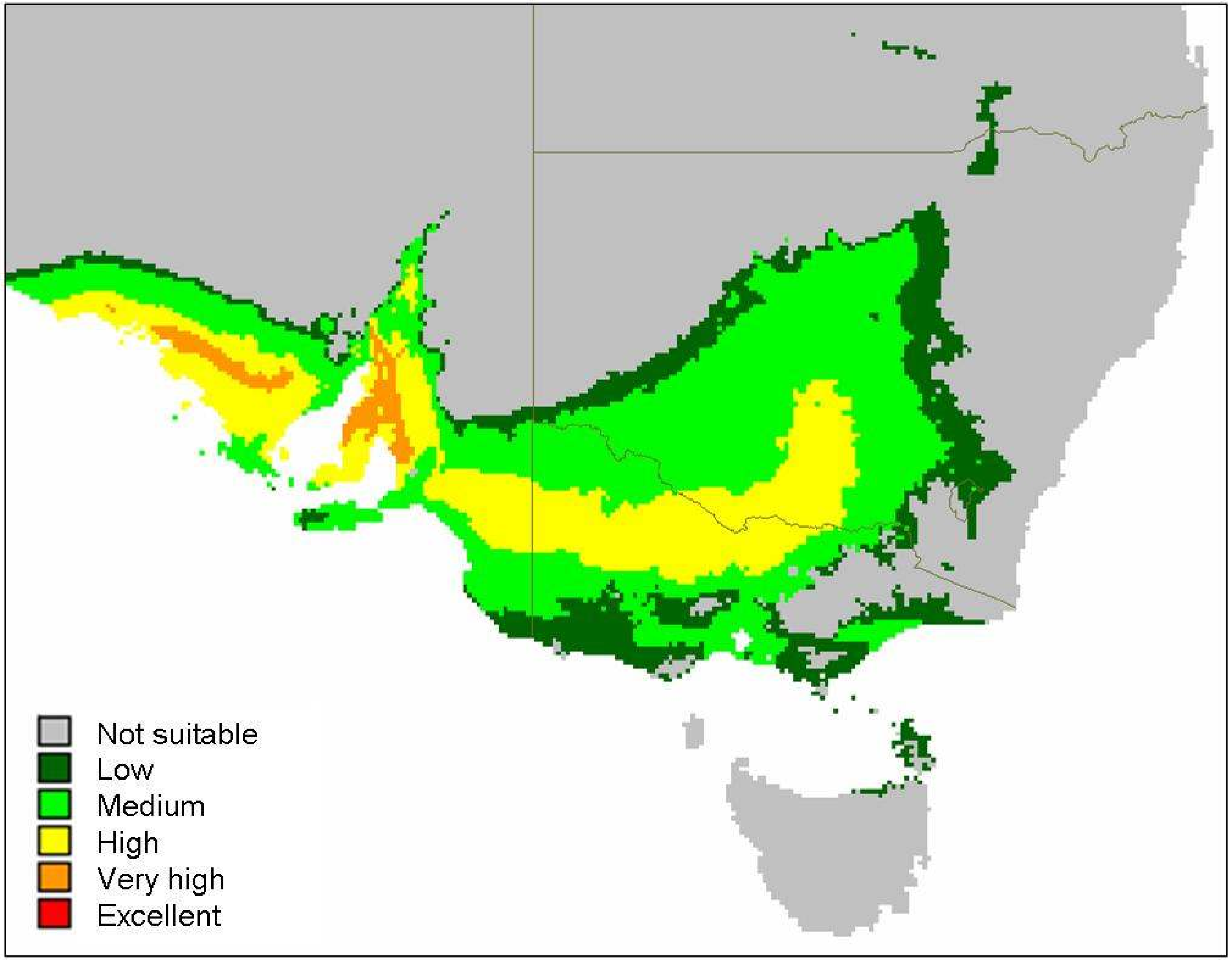
However the maps should not be used to demonstrate 'proof' that a species will establish in a particular area. The maps are based on models that are only as good as (i) the distribution data available from the region of origin, and (ii) the rather arbitrary selection of climatic parameters used to develop the models. Furthermore, other factors may be involved in determining a species' distribution.

For the same reasons, comparisons should not be made about the suitability of a particular area for different species. For instance, it is not valid to conclude that an area will be of low suitability for one species and high suitability for another species. The ranking of suitability is only applicable within a species.

OTHER SPECIES

Twenty-one species are included on the following pages. *Onthophagus obliquus* was not included, as its predicted distribution is restricted to northern Australia. *Onthophagus sagittarius* was also not included, as its predicted distribution is coastal Qld and NT. However it does occur on the far northern NSW coast and in southeast Qld.

Potential distribution of *Bubas bison*



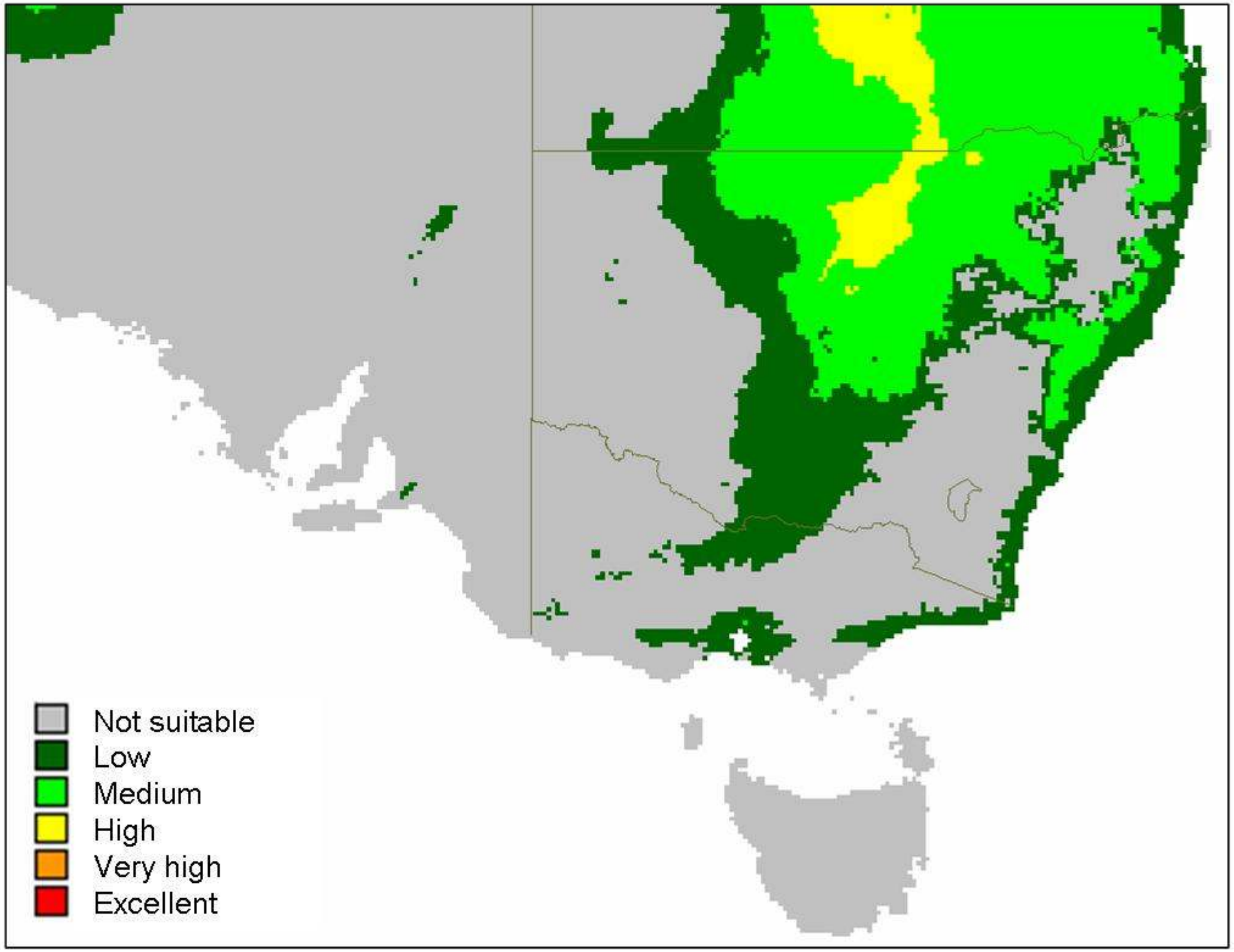
Potential Distribution:

The potential distribution of *Bubas bison* in Australia was modeled in BIOCLIM using distribution data from Spain, Portugal, France, Tunisia, Morocco, Algeria and Croatia. The model used four climate parameters (10, 11, 18, 19).

Comment:

Bubas bison is native to Europe. The strains introduced into Australia originated from Spain and France. In Spain, *Bubas bison* is one of the two dominant dung beetle species in spring (the other is *Copris hispanus*). It has one generation a year, with adults emerging in autumn and breeding mainly in spring. It has a Mediterranean distribution pattern, and is thus likely to be suited to similar climate zones in Australia. The species clearly has potential for further redistribution within Australia, and efforts should be concentrated in regions on the map shown in yellow and orange.

Potential distribution of *Copris elphenor*



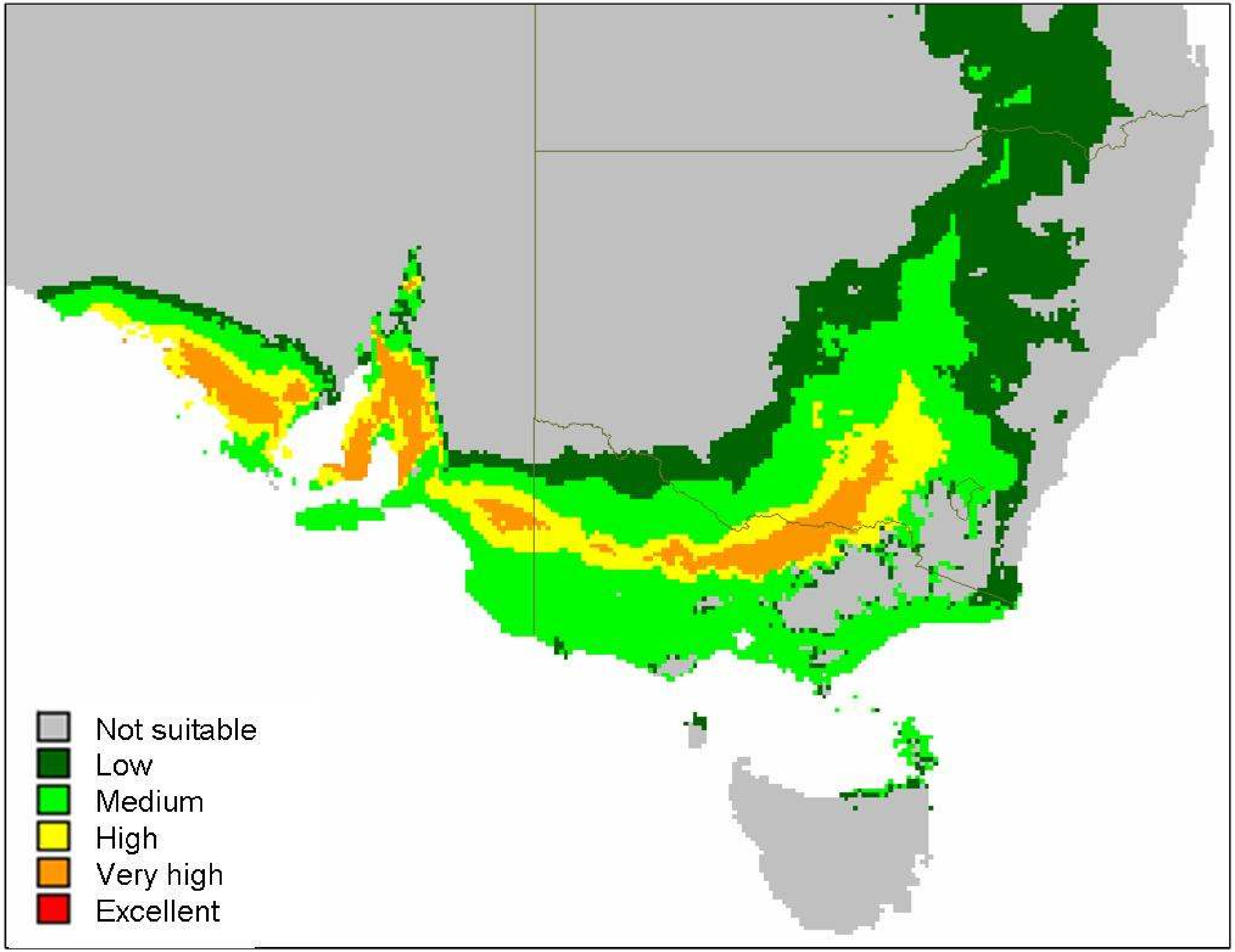
Potential Distribution:

The potential distribution of *Copris elphenor* in Australia was modeled in BIOCLIM using distribution data from Africa. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Copris elphenor is native to southern and east Africa. Beetles were brought in to Australia from South Africa. It is a large, brood-caring dung beetle, which buries large amounts of dung very rapidly to provision its nest. It thus has great potential for control of dung-breeding pest flies. Since it spreads very slowly, there is considerable scope for further redistribution of this species. While tropical areas of Queensland best suited for *C. elphenor*, the areas on the map shaded light green and yellow could be considered for redistribution if sufficient beetles became available.

Potential distribution of *Copris hispanus*



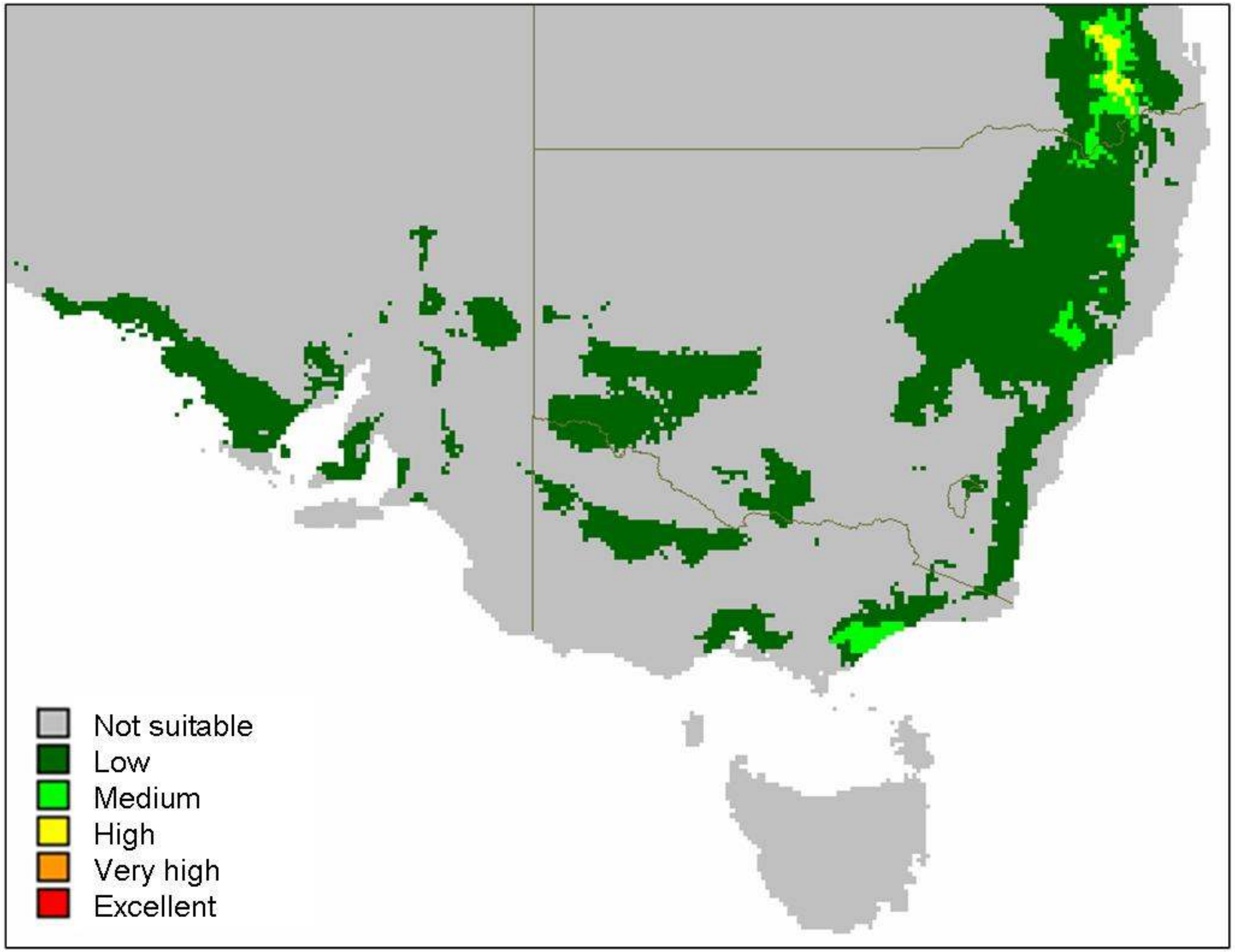
Potential Distribution:

The potential distribution of *Copris hispanus* in Australia was modeled in BIOCLIM, using distribution data from Spain, Portugal, France, Greece, Morocco and Majorca. The model used four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Copris hispanus is native to Mediterranean Europe. The strain introduced into Australia originated from Spain, where it is one of the most abundant species in spring. It is a large, brood-caring dung beetle. Although it is known to be established in WA, its current abundance needs to be assessed to determine if it is possible to commence redistribution. It is crucial that existing populations are not put in jeopardy through misguided attempts to redistribute the species. The model indicates *C. hispanus* should be suitable for much of the winter-rainfall regions of southern SA, Vic and inland NSW.

Potential distribution of *Euoniticellus africanus*



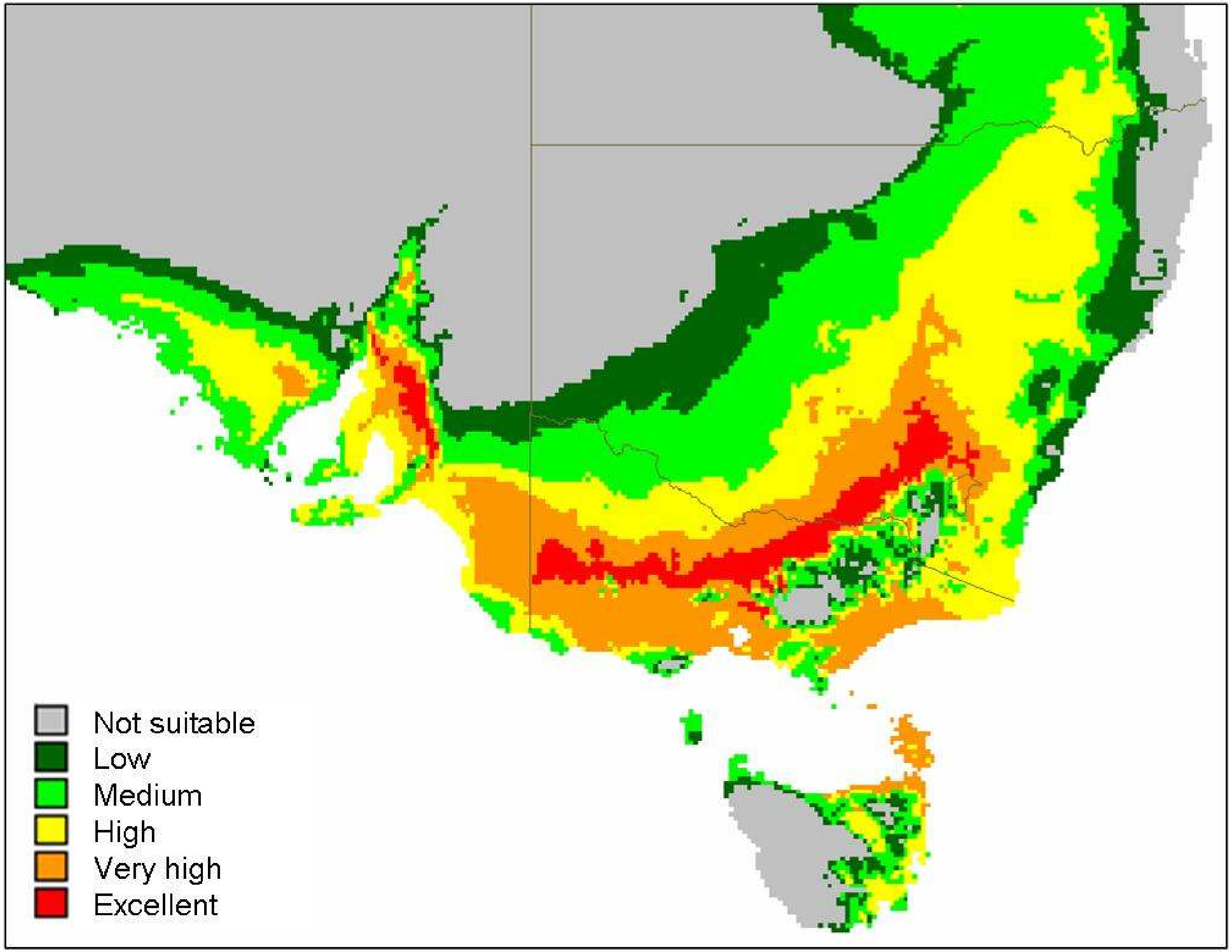
Potential Distribution:

The potential distribution of *Euoniticellus africanus* was modelled in BIOCLIM using the South African distribution of the species. All 19 climatic parameters were included in the model.

Comment:

The native range of *Euoniticellus africanus* is restricted to South Africa. Since its release into Australia, *E. africanus* has extended its distribution into southern Qld, and has probably reached its northern limit. The model provides an excellent fit to the current distribution of *E. africanus* in eastern Australia. However the model also indicates southern areas of WA, SA, Vic and NSW to be suitable for *E. africanus*. Since earlier releases in these areas were not successful, it is possible that separate climate strains exist in South Africa. It is likely that the summer-rainfall strain currently in Australia may not be suitable for winter-rainfall and even-rainfall regions, and therefore redistribution into these areas is not recommended.

Potential distribution of *Euoniticellus fulvus*

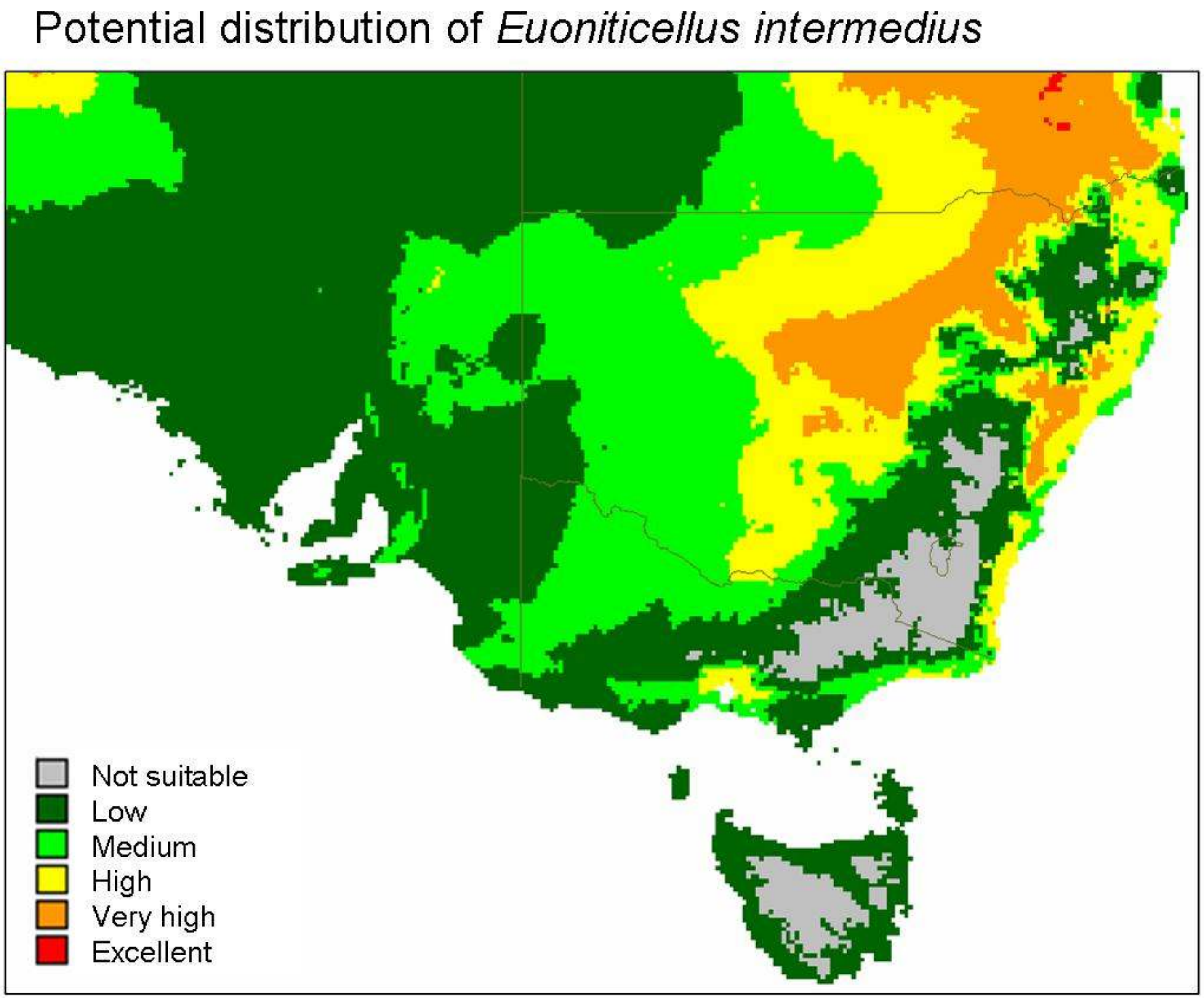


Potential Distribution:

The potential distribution of *E. fulvus* in Australia was modeled in BIOCLIM using distribution data from Austria, France, Iran, Spain, Morocco, Greece, Turkey and Portugal. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Euoniticellus fulvus is native to western and central Europe, the Middle East and north Africa. Introductions to Australia were made from Turkey and France. It occurs in a predominantly Mediterranean to even-rainfall climate in its native range. It now occupies a similar climate range in Australia. The model provides a good prediction of the observed distribution in Australia. There is thus little scope for further redistribution of *E. fulvus* in south-east Australia, except possibly in the Eyre Peninsula region of SA.



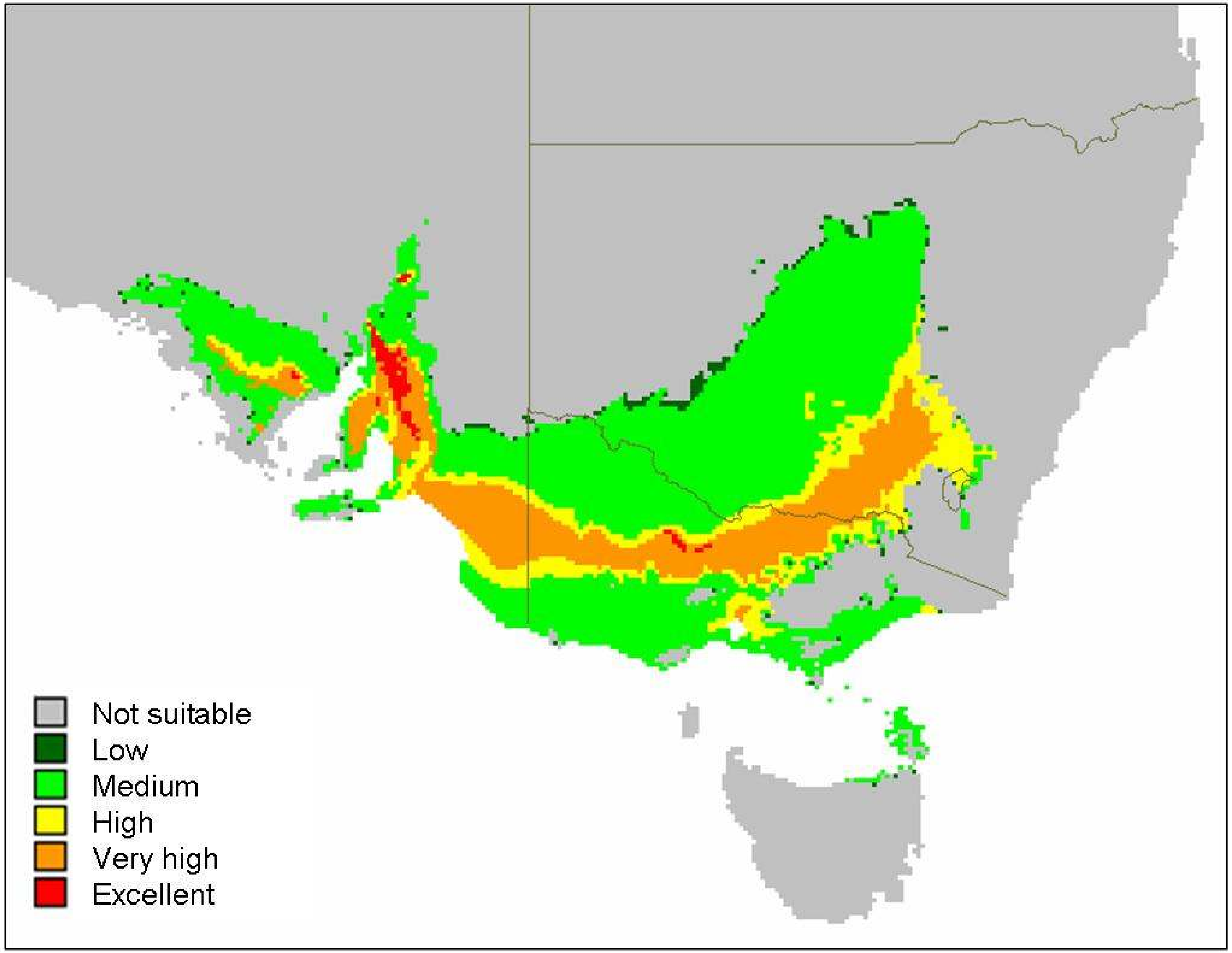
Potential Distribution:

The potential distribution of *E. intermedius* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Euoniticellus intermedius has a wide distribution in Africa, over a range of climate types. The model indicates much of southern Australia to be suitable for *E. intermedius*, albeit at a low to medium level. It was released in this region but did not establish. Furthermore it is a species that spreads very rapidly, and it has had ample opportunity to move into the area. The model thus appears to be unreliable for this species, possibly due to the influence of some unknown factor. It may be that different climatic strains of the species exist in Africa. Further redistribution of *E. intermedius* is not recommended.

Potential distribution of *Euoniticellus pallipes*



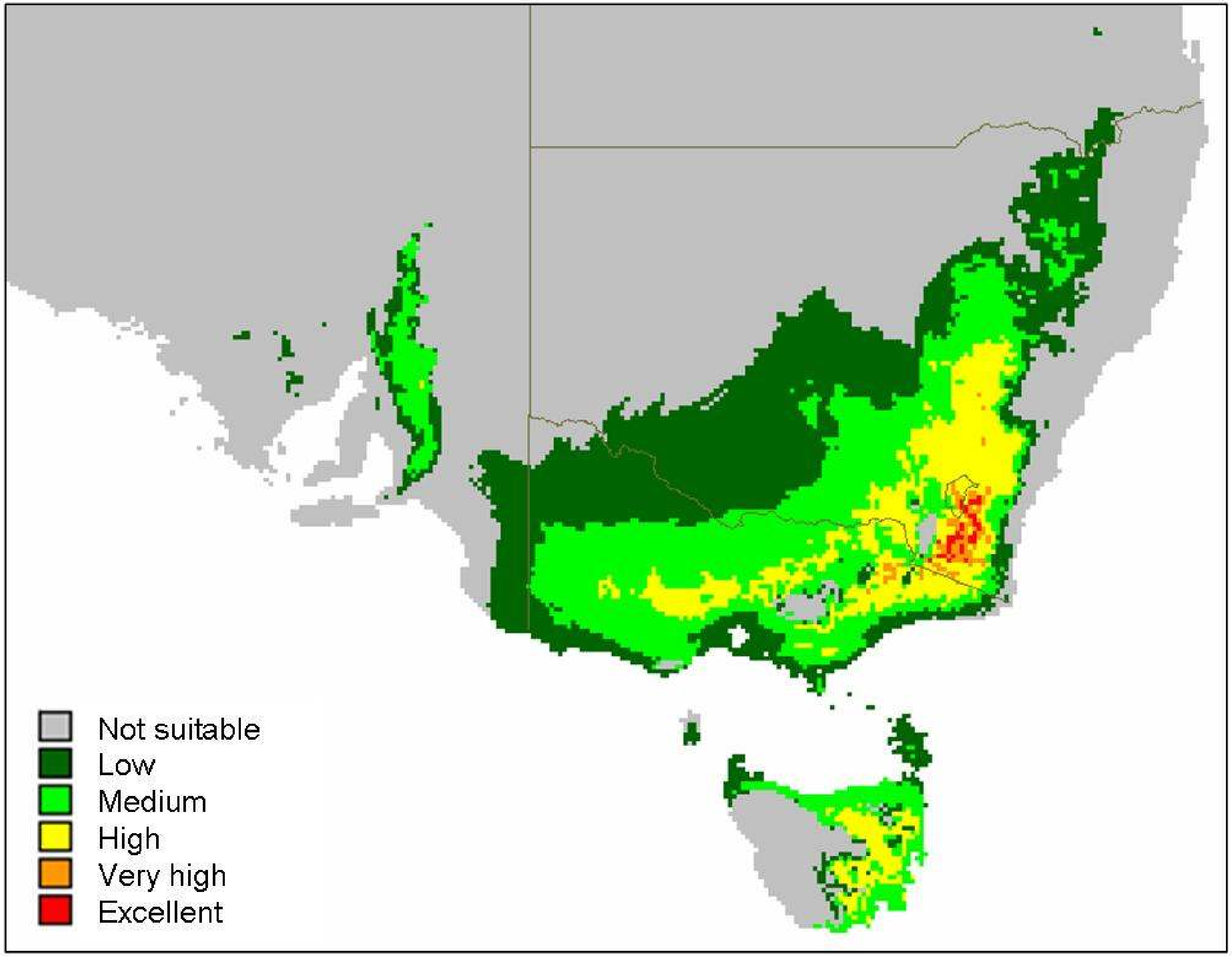
Potential Distribution:

The potential distribution of *E. pallipes* in Australia was modeled in BIOCLIM using the available world distribution data (from Portugal to Iran, and Pakistan to southern India). The resulting model (not shown) was unrealistic, largely due to the inclusion of southern India in the model. A model based on the Mediterranean and Middle East distribution (Portugal, Spain, France, Greece, Turkey, Iran), provided a realistic prediction for the species in Australia. Four temperature and rainfall variables were included in the model (10, 11, 18, 19).

Comment:

Euoniticellus pallipes originates from southern Europe through to India. The beetles introduced into Australia were from Iran and Turkey. It is likely that different strains of *E. pallipes* exist, and that the strain from the Mediterranean and Middle East region differs from that found in southern India. The species is probably close to its potential distribution in Australia.

Potential distribution of *Geotrupes spiniger*



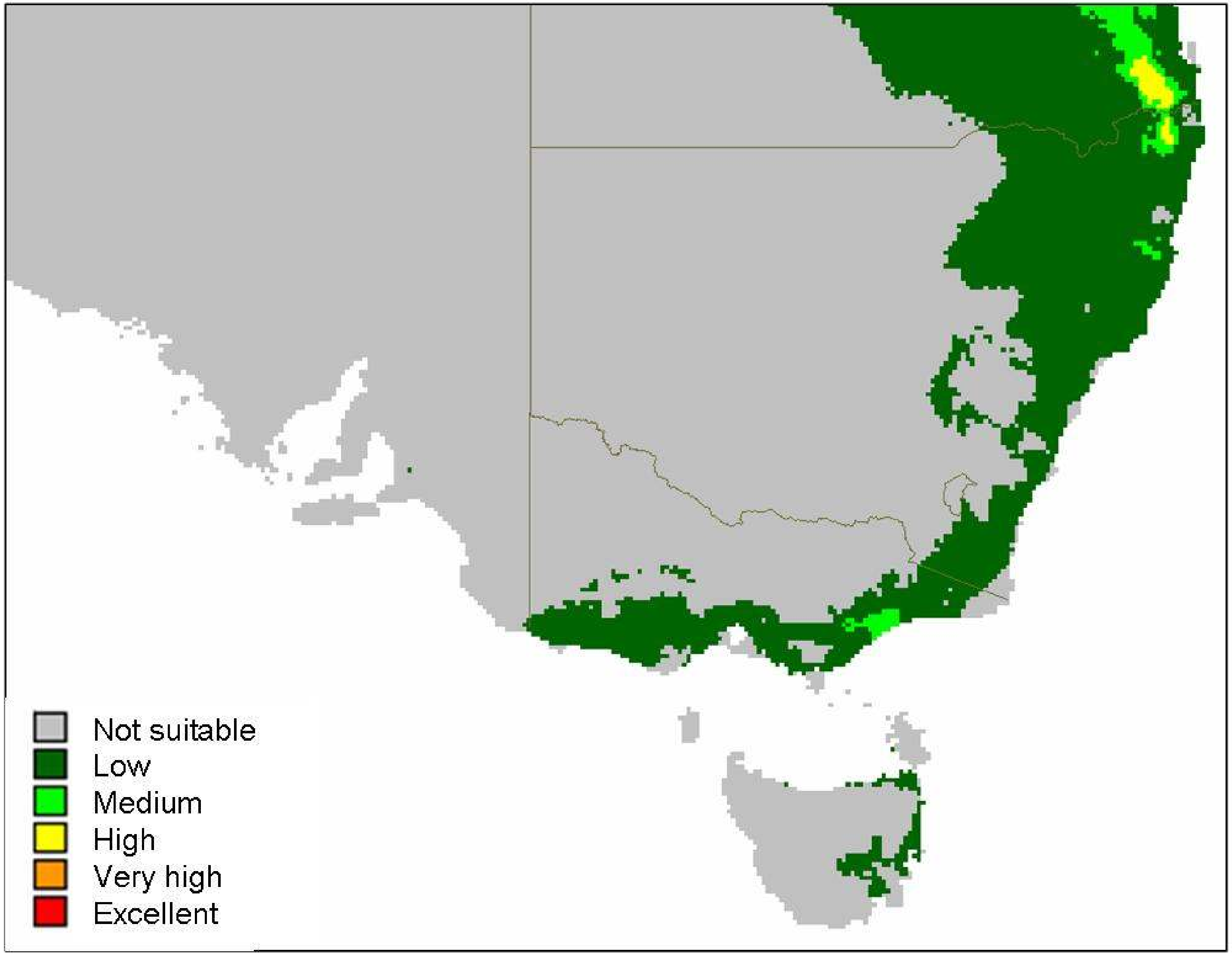
Potential Distribution:

The potential distribution of *G. spiniger* in Australia was modeled in BIOCLIM using the world distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Geotrupes spiniger occurs widely through Europe, including the British Isles. It occurs in the northern Mediterranean, in the Balkans, Ukraine and Middle East to the Pakistani border. Beetles introduced into Australia were collected in France, where it is a common species. It occurs mainly at low to medium altitudes (below 800m) and predominantly in heavy soils. In Europe it breeds in late autumn and early winter, and can be found feeding in spring and occasionally in summer. It is thus a very useful beetle in cooler climates, burying dung at a time when most other activity has ceased. Redistribution in Victoria, southern NSW and parts of SA should be beneficial.

Potential distribution of *Liatongus militaris*

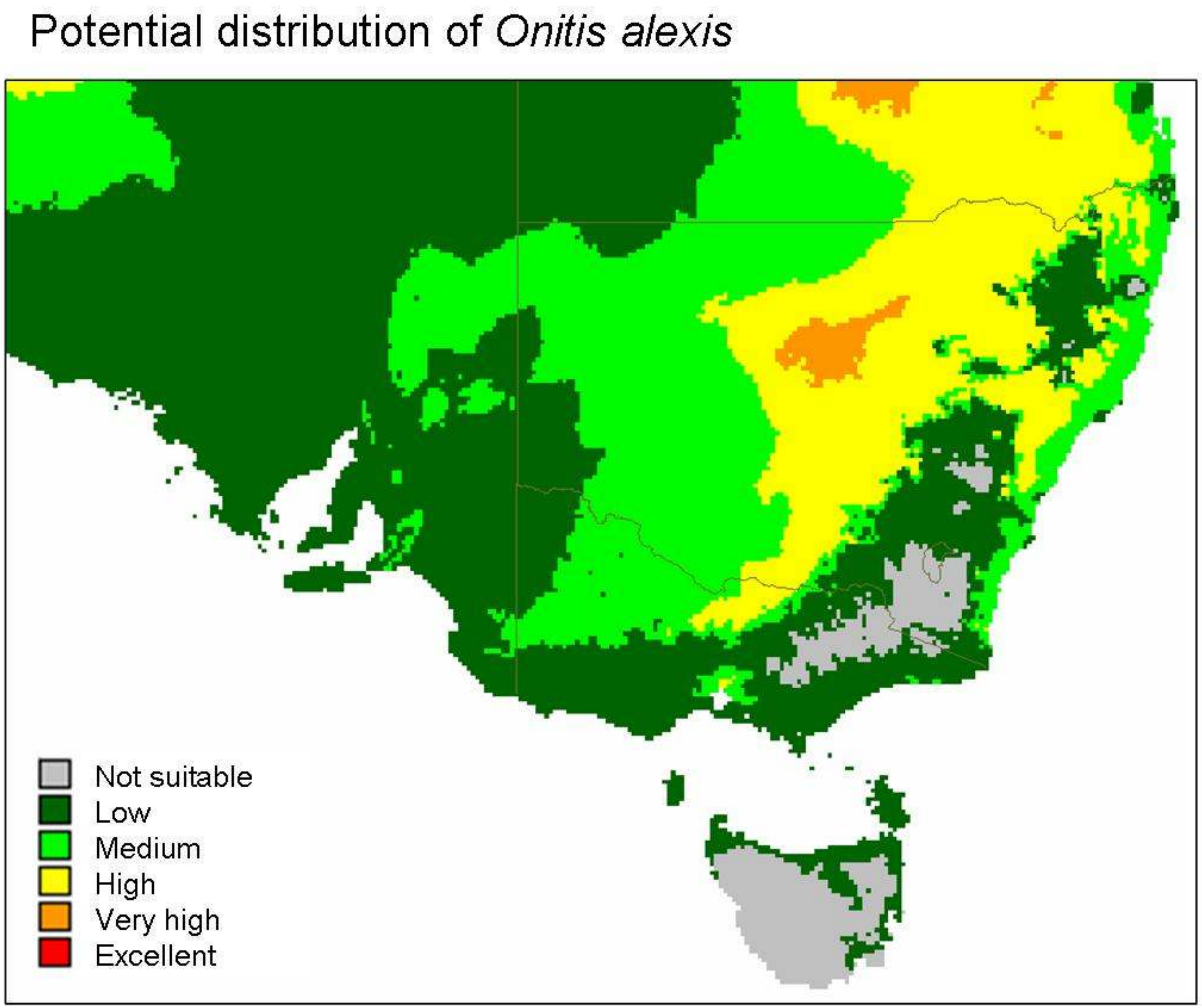


Potential Distribution:

The potential distribution of *L. militaris* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included all 19 climate parameters.

Comment:

Liatongus militaris originates from southern and east Africa. Stocks were introduced into Australia from South Africa, via Hawaii. It is well established in eastern Qld. The model indicate that eastern NSW and Vic may be suitable for *L. militaris*, however it has never been found south of the northeast corner of NSW. It is possible that the population introduced from Hawaii differs in its climatic tolerances from the original South African population. It is probably not worth considering further redistribution of this species in southeastern Australia.



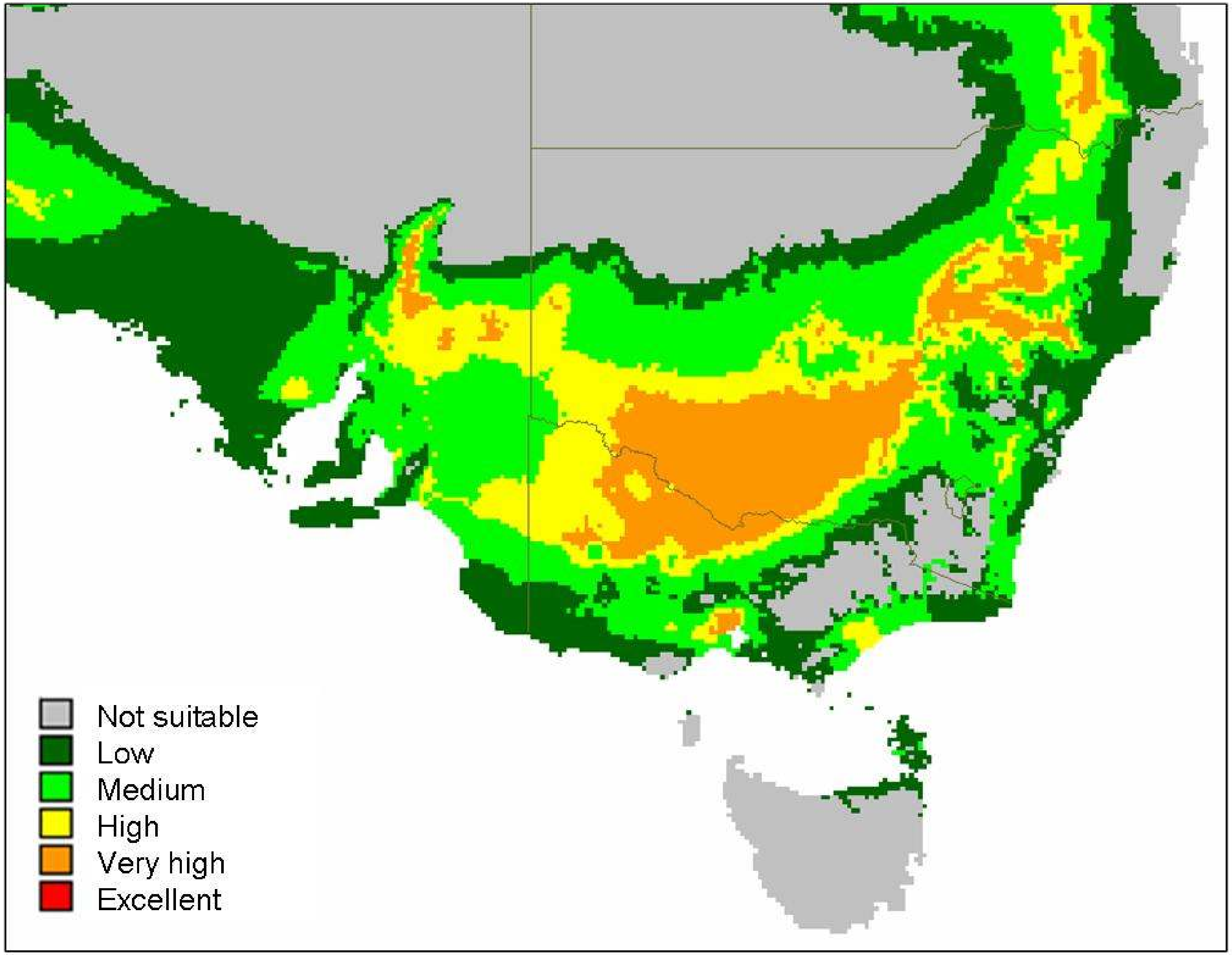
Potential Distribution:

The potential distribution of *O. alexis* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onitis alexis is widely distributed through warm dry parts of Africa, south of the Sahara, and in southern Europe. It is one of the most successful introduced dung beetle species in Australia, in terms of distribution and abundance. Two strains were introduced from South Africa, a 'cold strain' and a 'tropical strain'. The model predicts a wide distribution in Australia, with much of eastern Australia being particularly suitable. There is little scope for further redistribution of this species.

Potential distribution of *Onitis aygulus*



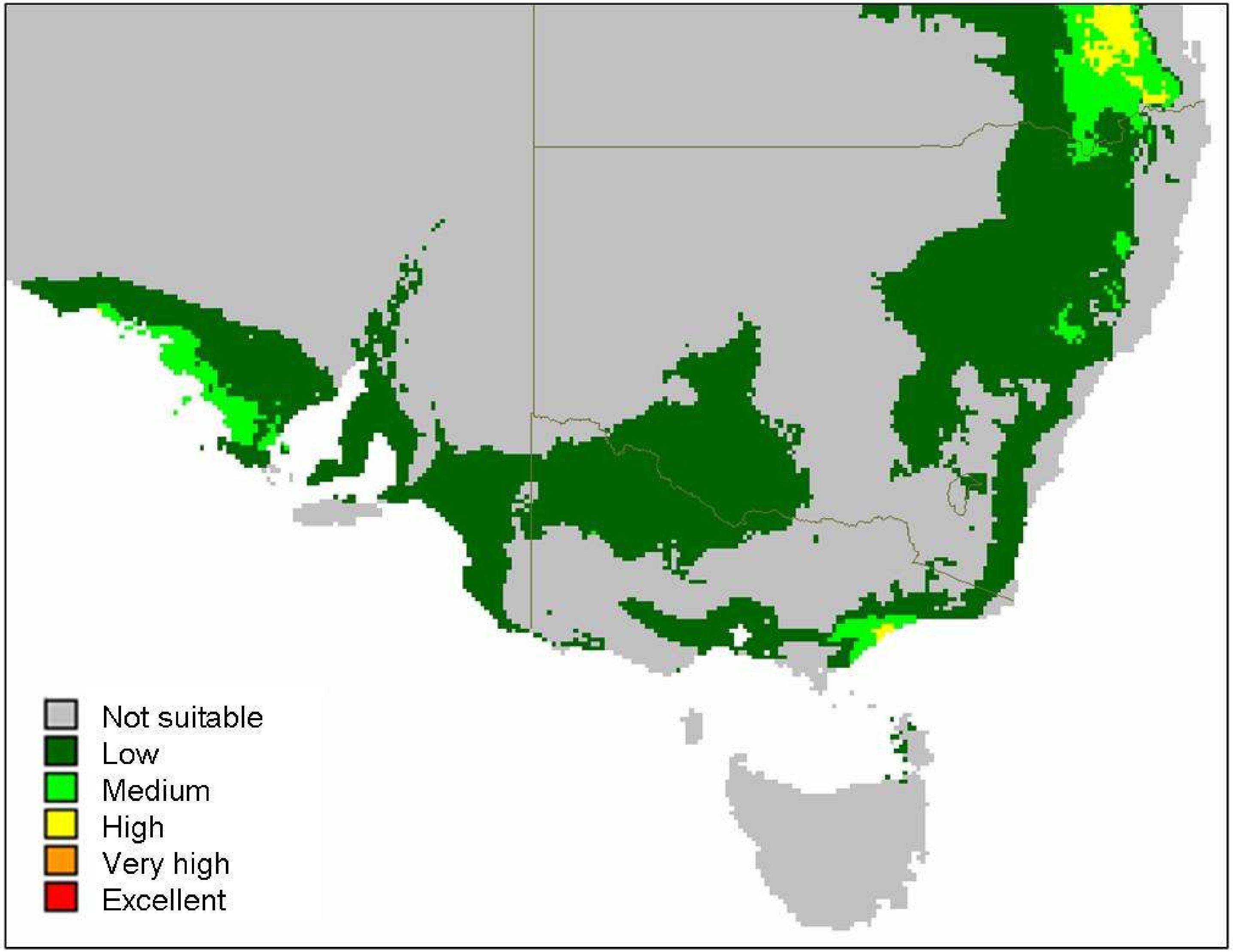
Potential Distribution:

The potential distribution of *O. aygulus* in Australia was modeled in BIOCLIM using the southern African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onitis aygulus occurs in the cooler drier parts of South Africa and Namibia, where rainfall is between 150 and 750 mm a year, and annual mean temperatures are between 13°C and 19.5°C. It is now well established in several parts of southern Australia. While there is evidence of it moving large distances unaided, it would certainly benefit from further redistribution. In addition to extensive winter-rainfall areas across southern Australia, the model indicates that northeast NSW and southeast Qld, on the western side of the Dividing Range, could be suitable for *O. aygulus*. The summer-rainfall strain (which was released in central NSW) should be used for redistributions into this region.

Potential distribution of *Onitis caffer*



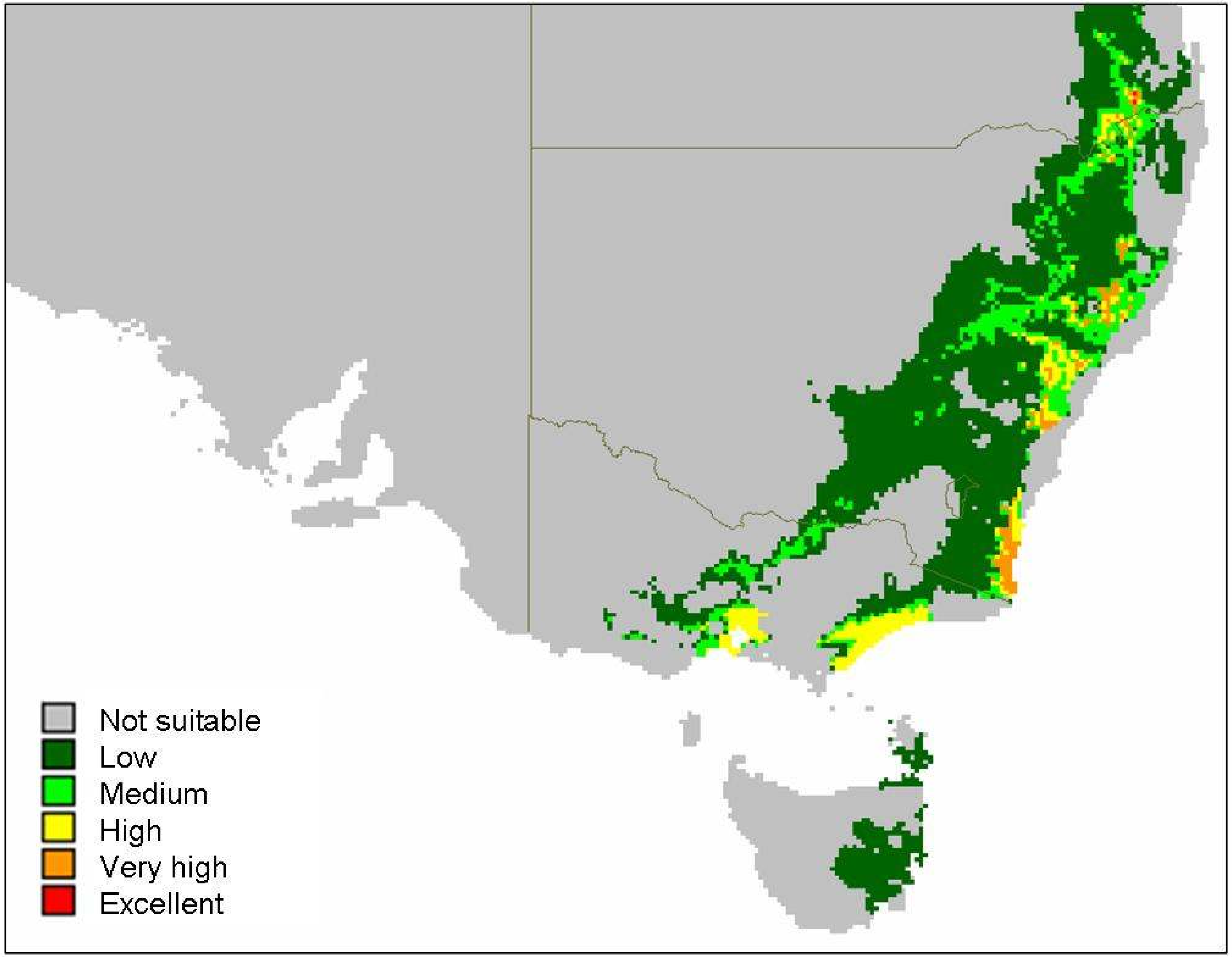
Potential Distribution:

The potential distribution of *O. caffer* in Australia was modeled in BIOCLIM using the South African distribution of the species. The model included all 19 climate parameters.

Comment:

Onitis caffer is native to South Africa. It has become an important component of the introduced dung beetle fauna in Australia, as it is active in autumn and early winter, a time when activity of other species declines. Spring activity may also occur in even-rainfall and winter-rainfall regions. The model indicates that there are many areas in eastern and southern Australia that provide a good climate match with the South African distribution of *O. caffer*. The break in the predicted distribution in NSW should be used as a guide to the limits for redistribution of the summer-rainfall and winter-rainfall strains of the species.

Potential distribution of *Onitis pecuarius*



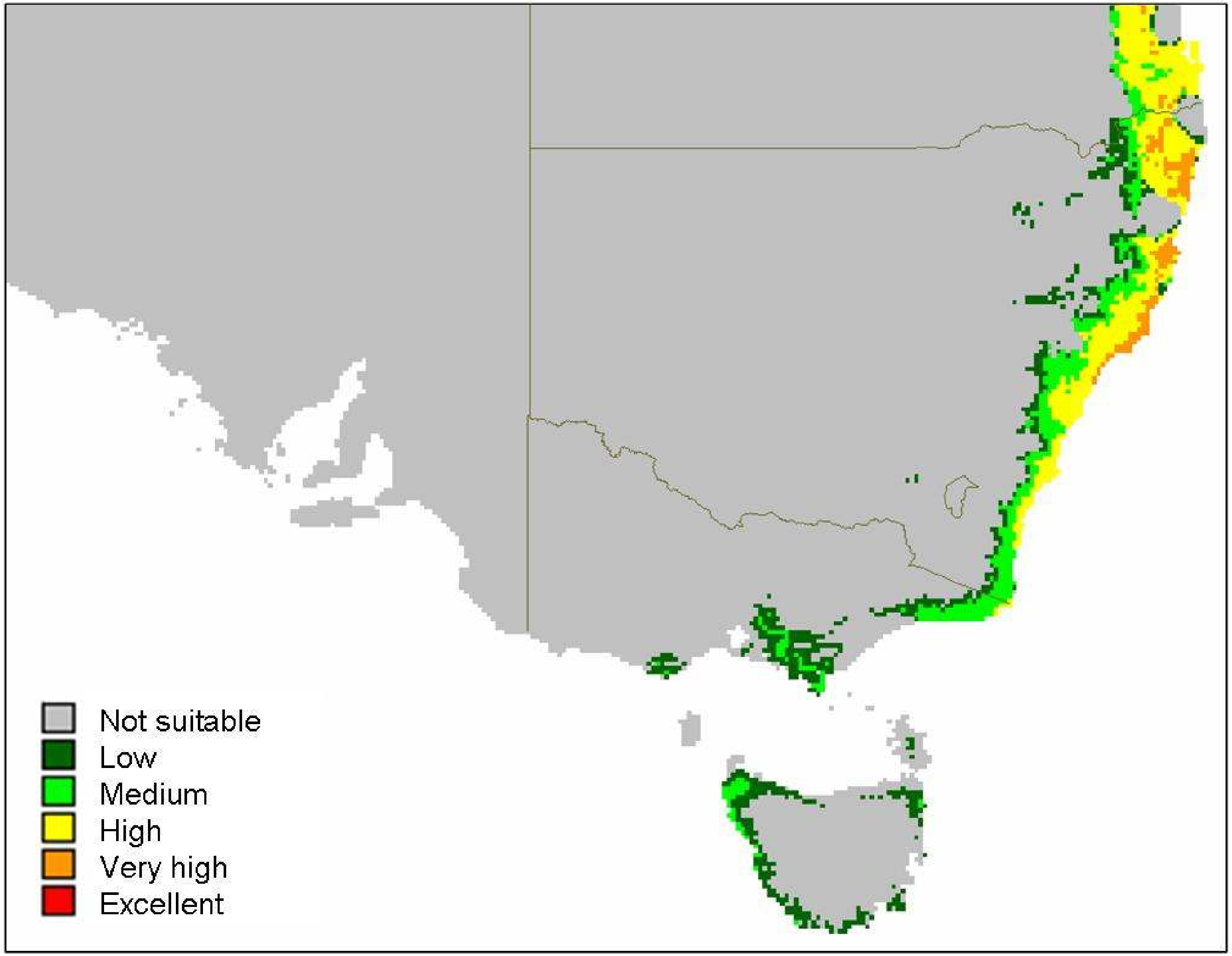
Potential Distribution:

The potential distribution of *O. pecuarius* in Australia was modeled in BIOCLIM using the South African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onitis pecuarius is restricted to southern and eastern South Africa. In Africa, *O. pecuarius* in the south complements the more northern species, *O. viridulus*. The two species have adopted the same pattern in Australia, with a small area of overlap in higher altitudes of southeast Qld. The model provides a good prediction of the observed distribution of *O. pecuarius* in Australia. In addition, it indicates that parts of Vic may be suitable, and these areas should be considered for any future redistribution.

Potential distribution of *Onitis vanderkelleni*



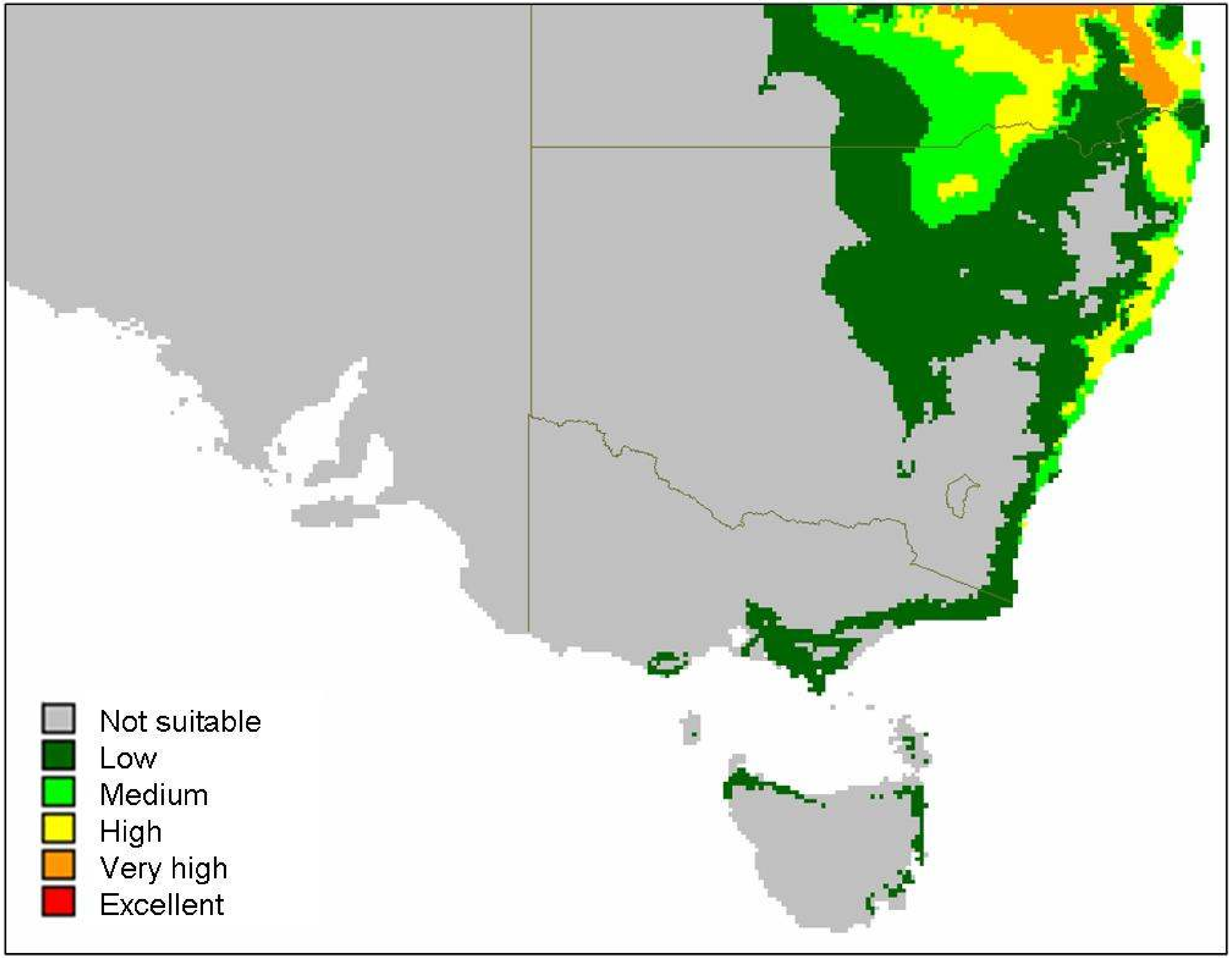
Potential Distribution:

The potential distribution of *O. vanderkelleni* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 12, 18).

Comment:

Onitis vanderkelleni occurs in the moist tropical highlands of Africa, particularly Kenya, Rwanda and Zaire. It occurs where the rainfall is between 800 and 2,000 mm a year, mainly at altitudes greater than 1,800 m. It is one of the few species suited to the very high rainfall areas of Australia, particularly in Qld. The model indicates it may also be suitable for coastal NSW. It is worth attempting to redistribute it to areas where kikuyu pasture occurs, particularly on deep volcanic soils.

Potential distribution of *Onitis viridulus*

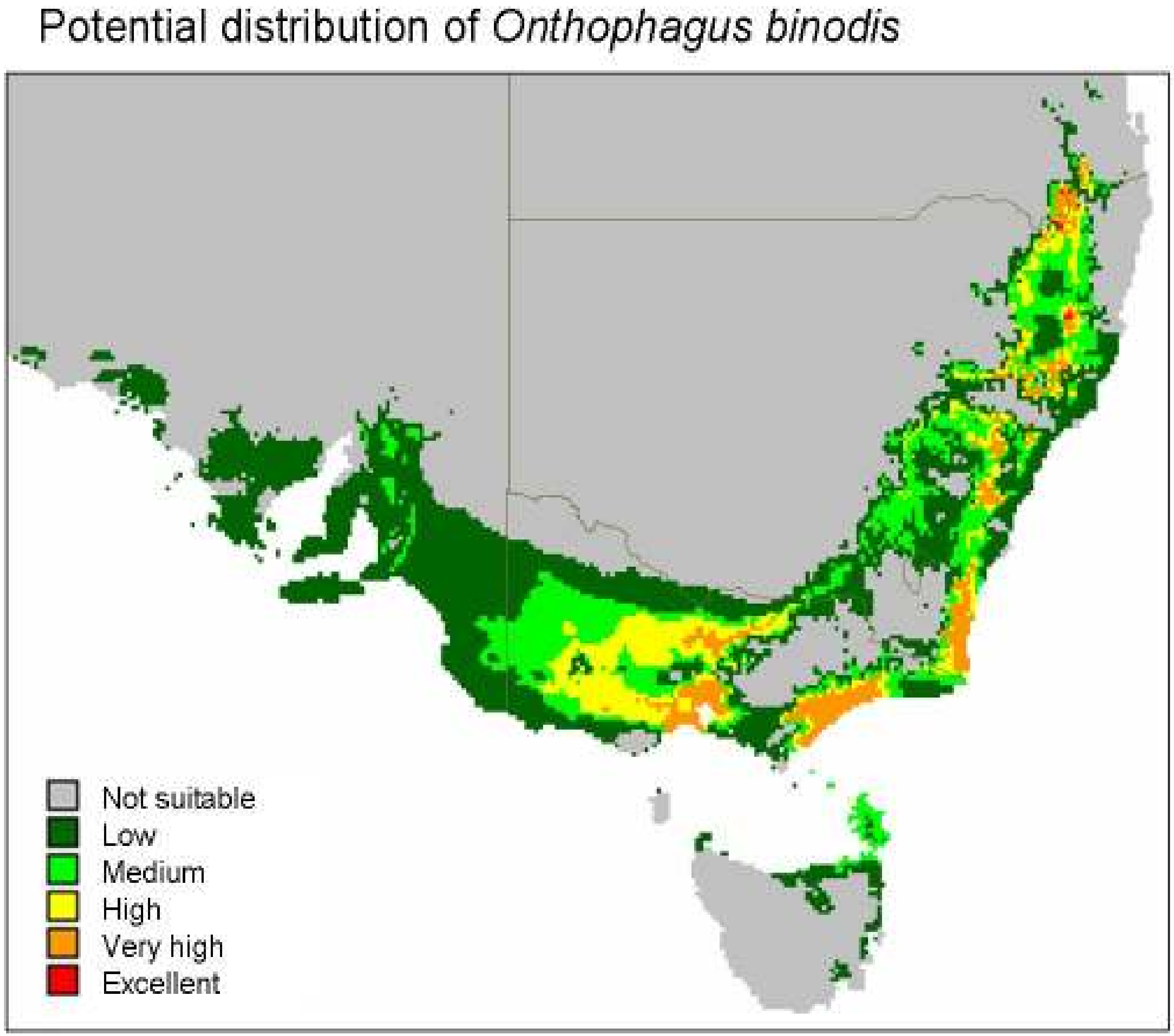


Potential Distribution:

The potential distribution of *O. viridulus* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onitis viridulus occurs in Africa, from Ethiopia to northern South Africa. It established in Australia from a small number of releases and is almost entirely restricted to Qld and NT. It tends to bury older dung, and probably contributes little to fly control. Possibly its main role is 'mopping up' dung after other species have left. There is little scope for redistribution of this species, although it may be suitable for northern inland NSW and parts of coastal NSW.

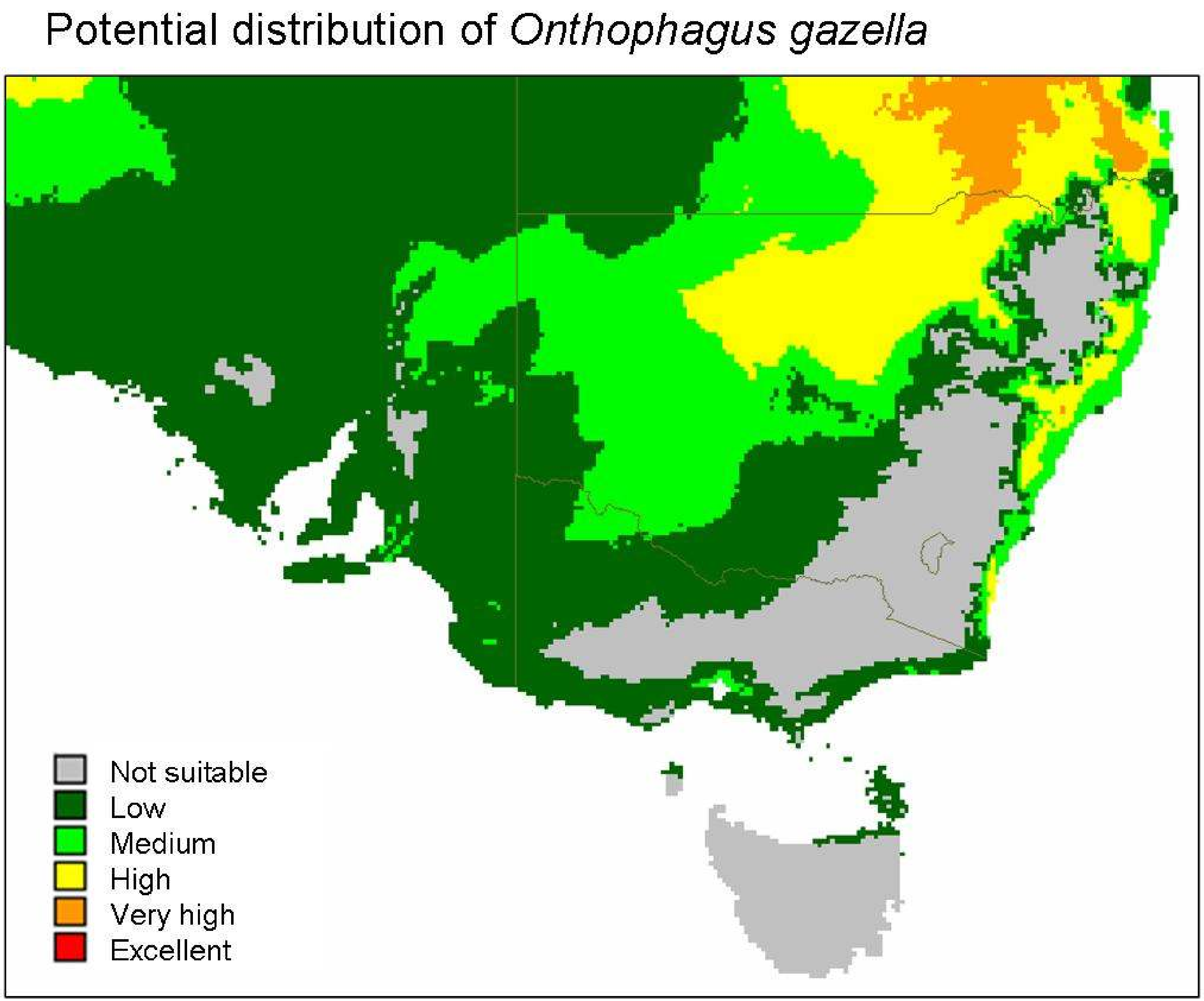


Potential Distribution:

The predicted distribution of *Onthophagus binodis* in Australia was modeled in BIOCLIM using distribution data from South Africa. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onthophagus binodis is native to South Africa. The predicted distribution of *O. binodis* in Australia is extremely close to the observed distribution. There is thus little potential for redistribution of this species.



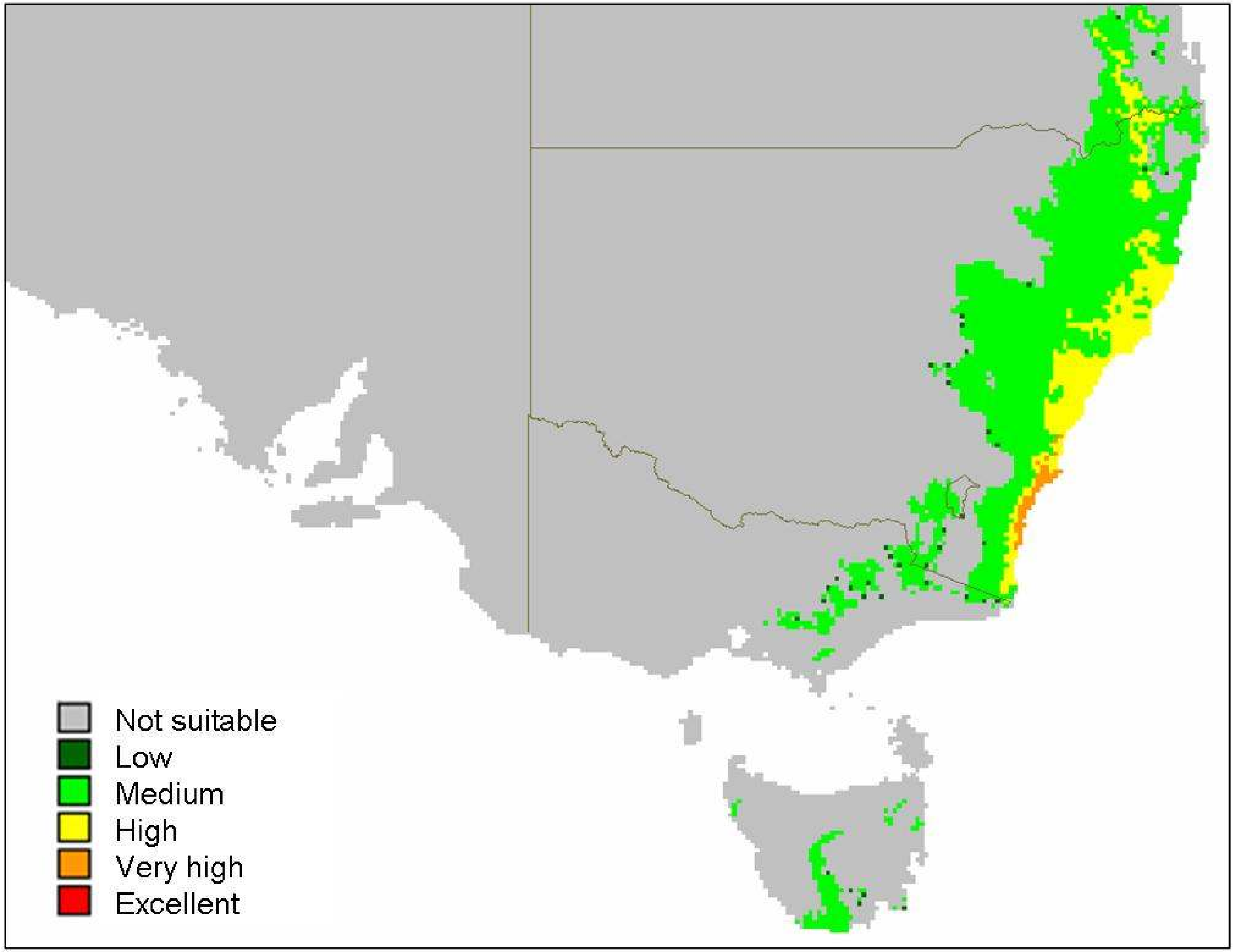
Potential Distribution:

The potential distribution of *O. gazella* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Onthophagus gazella occurs through much of Africa, south of the Sahara. It is now widespread across northern Australia, and is the dominant species in many subtropical areas. It occurs in some very low rainfall regions, where few other species have established. The model predicts southern Australia to be suitable. However *O. gazella* has failed to establish in these regions. Earlier modeling by CSIRO using CLIMEX also indicated these regions to be suitable. It is probable that a different strain would be required for this zone.

Potential distribution of *Onthophagus nigriventris*



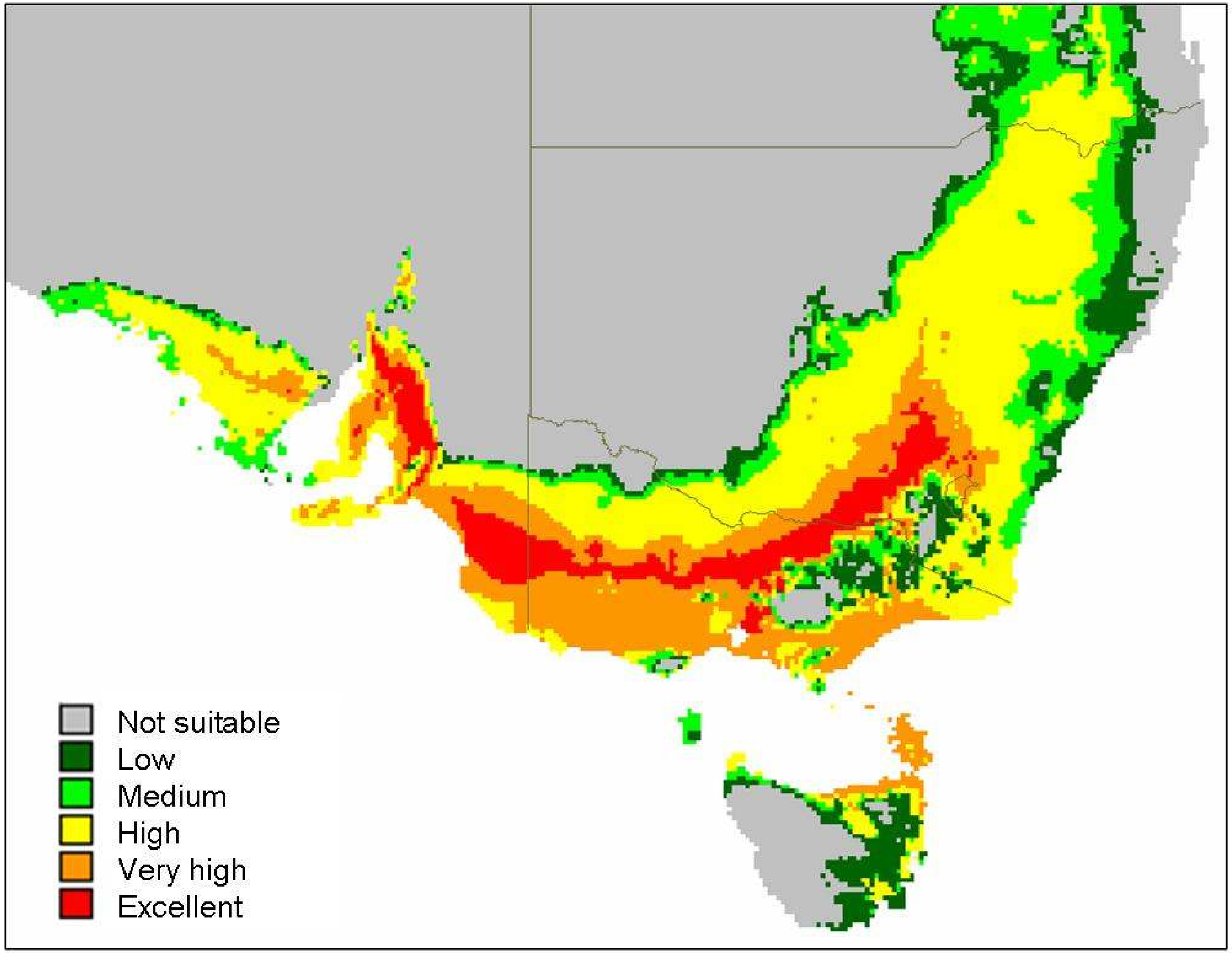
Potential Distribution:

The potential distribution of *O. nigriventris* in Australia was modeled in BIOCLIM using African distribution data. The model used four climate parameters (10 11 18 19).

Comment:

Onthophagus nigriventris occurs in the tropical highlands of Africa, and is widespread in Kenya. It was introduced to assist in dung burial in the high rainfall tropical highland areas of northern Australia. It has established in these areas and also in coastal areas of southeast Qld and northeast NSW. The model indicates that most of the NSW coast and small parts of Vic and Tas may be suitable. The presence of kikuyu grass can be used as an indicator of areas that may be suitable for redistribution.

Potential distribution of *Onthophagus taurus*



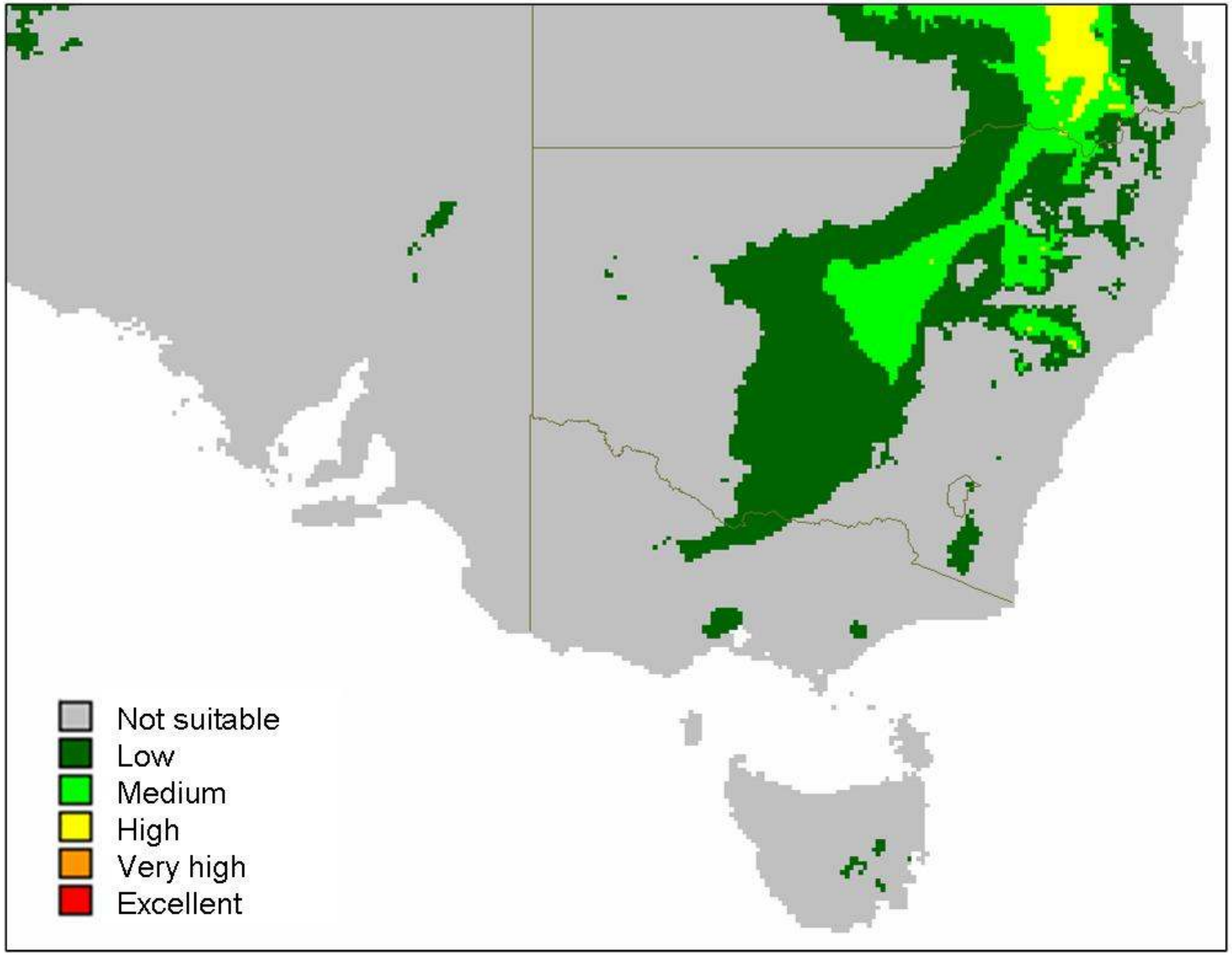
Potential Distribution:

The potential distribution of *O. taurus* in Australia was modeled in BIOCLIM using distribution data from the four countries from which the species was imported (Spain, Greece, Italy, Turkey). Four climate parameters were used (10, 11, 18, 19).

Comment:

Onthophagus taurus has a wide distribution in Europe, North Africa and the Middle East. A model based on inclusion of all countries within the natural range of *O. taurus* (not shown) gave a much wider predicted range than the observed distribution in Australia, suggesting that different strains of the species may exist. The predicted distribution based on the climate data from the four countries of origin (left) provides a close match to the observed distribution in Australia. *O. taurus* is probably close to its potential distribution in Australia. Redistribution could be attempted along the southeast coast of Vic and the Eyre Peninsula region of SA.

Potential distribution of *Sisyphus rubrus*



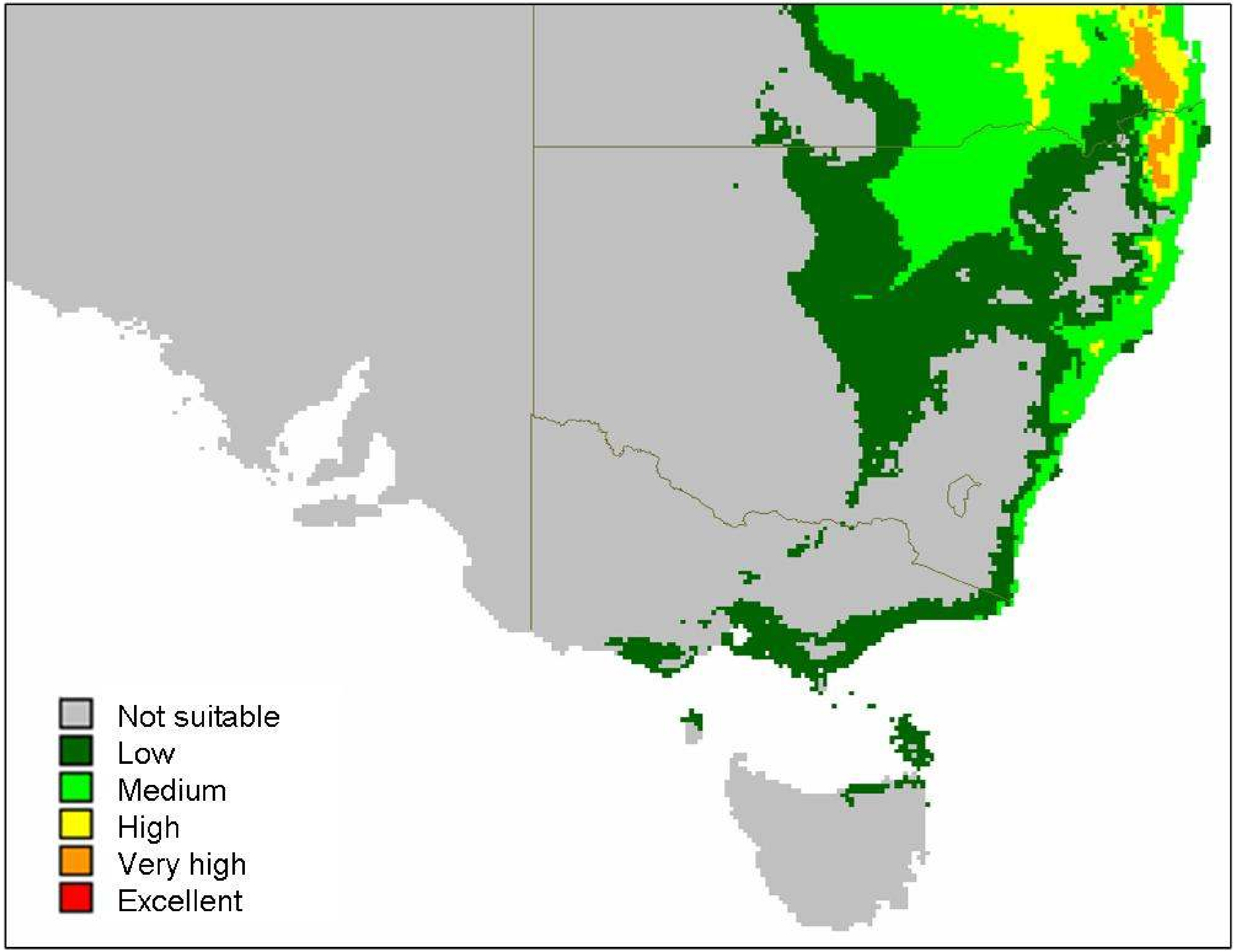
Potential Distribution:

The potential distribution of *S. rubrus* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Sisyphus rubrus is native to southern Africa, and occurs in South Africa, Zimbabwe and Mozambique. It is a ball-roller, and it buries its brood balls (compare with *S. spinipes* which does not bury its brood balls). *Sisyphus rubrus* occurs in Africa where rainfall exceeds 400 mm. This is slightly lower than for *S. spinipes* (500 mm), and is consistent with its range in Australia, which extends into drier regions of Qld than does that of *S. spinipes*. It is predominantly suited to Qld, but the model indicates it may extend further south into central NSW than its current distribution. Redistributions should probably be restricted to areas in NSW shaded light green.

Potential distribution of *Sisyphus spinipes*



Potential Distribution:

The potential distribution of *S. spinipes* in Australia was modeled in BIOCLIM using the African distribution of the species. The model included four temperature and rainfall parameters (10, 11, 18, 19).

Comment:

Sisyphus spinipes occurs in South Africa, Zimbabwe, Mozambique and Kenya. It is a ball-rolling dung beetle which does not bury its brood balls, but attaches them to vegetation. In Africa *S. spinipes* occurs where annual rainfall exceeds 500 mm. In Australia it is most abundant in central Qld, but in general does not occur in such high numbers as *S. rubrus*. The model indicates that the species could extend further south into NSW than its current distribution, but it is unlikely to become as abundant as it currently is in Qld. Redistributions should probably be restricted to areas of NSW shaded light green.