TECHNICAL SUBCOMMITTEE COMPONENT REPORT

Species Richness and Summed Irreplaceability in B.C.

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Species Richness and Summed Irreplaceability in British Columbia

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Background:

The goal of this project was to perform a spatial analysis of 'species richness' and 'summed irreplaceability' for all species with available location data in British Columbia (BC). The focus was on updating and adding data to the species occurrence database used in previous species richness and irreplaceability analyses in BC to provide a more complete assessment of the relative biodiversity values in BC. Although these data are biased to where people have surveyed, they provide the best data available at the time of this project.

Species richness is calculated as the number of species within a site (e.g. 1:50,000 NTS grid cell). 'Irreplaceability' is a measure of the likelihood that a site will be required to represent each of the species in a region (Pressey et al. 1994), and summed irreplaceability is simply the sum of the irreplaceability values for all species within a site. Summed irreplaceability provides an estimate of the relative value of each site towards the representation of species within BC. For this project, summed irreplaceability is calculated using a software program called 'C-Plan' (National Parks & Wildlife Service 1999). C-Plan is a systematic conservation planning tool that identifies a set of sites that represent the biodiversity of a region.

There are many different factors that influence the calculations of both species richness and summed irreplaceability. For example, the calculations are influenced by the geographic region, size and shape of the sites (e.g. grid cells), and the quality and quantity of the species data included in the analysis. The calculation for summed irreplaceability is also strongly influenced by the conservation target used for each species. Species' targets identify how many grid cells need to be included in a final set of sites that adequately represents the habitat for conserving species. Although the analyses for this project do not identify a final set of sites for conservation, summed irreplaceability provides the relative values for selecting a final set of sites. Therefore, the interpretation of the results must consider the effect of each of these factors on the calculation of both species richness and summed irreplaceability.

Goals and Objectives:

The original objectives of this project were to:
(a) acquire, correct, format, and filter (by date) species location data
(b) separate terrestrial from freshwater species
(c) include global and sub-national ranks (G- and S-ranks) in the analyses and identify the species without ranks
(d) run species richness and irreplaceability analyses at a 1:50,000 NTS grid resolution using the updated species observation data for terrestrial species, freshwater species, and all species combined, with modifications for species vulnerability by G- and S-ranks and for the exclusion of historical records.

It became apparent during the course of this project, that more detailed filtering and cleaning of the data was required to produce reliable results. It was decided that the irreplaceability analyses would not be updated as the data were being filtered and cleaned. Therefore, the revised species richness maps are based on a different (smaller) dataset than the summed irreplaceability maps. The original database used for the irreplaceability analyses is explained in the earlier sections of this report. The differences between the original database and the database used for the species richness maps are explained in an amendment, which is included after the "Methods and Results" section of this report.

Concept and Potential Uses of Irreplaceability:

There are slight variations in the definition of irreplaceability in the scientific literature. Some of the definitions include:

1. Potential contribution of a site to a reservation goal (Pressey et al. 1993, Pressey et al. 1994).
2. Extent to which the options for achieving the reservation goal are lost if the site is lost (Pressey et al. 1993, Pressey et al. 1994, Margules and Pressey 2000).
3. Likelihood that a given site will need to be protected (i.e. managed for conservation) to ensure achievement of a set of regional conservation targets (Ferrier et al. 2000). Areas with lower values have more replacements within the region and are less likely to be required as part of the conservation area system.
4. Overall importance of a site for achieving the conservation targets of the features (e.g. species) that occur within the site (Ferrier et al. 2000).
5. Irreplaceability of an individual site is operationally defined as the percentage of alternative reserve networks (i.e. sets of sites) in which the site occurs (Pressey et al. 1994).

Essentially, irreplaceability is a measure of the conservation value of a site (Pressey et al. 1993), which is based on the number of times that a particular site occurs in a combination of sites that represents the biodiversity of interest within the region. Irreplaceability is a dynamic value (Pressey et al. 1994) that changes based on the features (e.g. species) that are included in the analysis, conservation target for each feature, inclusion/exclusion of existing protected areas (i.e. identifies features that already have habitat protected), regional extent, grain size (i.e. spatial unit or site size), and changes over time (Pressey et al. 1994). In large regions, such as BC, the irreplaceability value is calculated in C-Plan as a predicted value that uses the central limit theorem to estimate the expected frequency distribution of a feature (e.g. species) protected by all possible combinations of a set of sites (Ferrier et al. 2000). The predicted value is used since it is computationally intensive to calculate all potential combinations of sites that represent the biodiversity within the region. The calculation used in C-Plan is comparable to methods that calculate irreplaceability using simulated annealing algorithms, where multiple combinations of a set of sites are identified (Csutsi et al. 1997, Carwardine et al. 2007).

A simple example of the irreplaceability calculation:
If a species range is confined to one site, then the site is 100% irreplaceable for conserving that species. Likewise, if a species range covers ten sites and the conservation target is to conserve the species in only one site, then there are ten options for conservation of the species and each site would have a low irreplaceability value (Warman 2001).

The calculation of irreplaceability using C-Plan requires quantitative targets for each feature (Ferrier et al. 2000). The conservation targets can either be set as a percentage of the sites and/or area that the feature (e.g. species) has been recorded in or as a specific number and/or area of sites (e.g. if the conservation target is set to one site for each feature, then the final combination of sites will contain at least one site with an occurrence of each feature). Irreplaceability values will change for each site with any change in the conservation targets that are used for each feature.

The irreplaceability calculation in C-Plan is based on a predictive approach that estimates the expected frequency distribution of the area selected by all possible site combinations of a predetermined size for a given species (Ferrier et al. 2000). The expected distribution is used to estimate the total number of these site combinations that achieve the conservation target for the species, which in turn is used to estimate the number of times that a particular site of interest is included in the site combinations. The irreplaceability of a site (site *x*) for an individual species is expressed as a proportion of the estimated total number of site combinations where site *x* is included in a set of sites (i.e. the number of representative combinations where site *x* plays a critical role in achieving targets expressed as a proportion of all representative site combinations).

Irreplaceability (Irr) is calculated as:

$$Irr_x = \frac{(R_{x\_\text{included}} - R_{x\_\text{removed}})}{(R_{x\_\text{included}} + R_{x\_\text{excluded}})}$$

Where:
$R_{x\_included}$ is the number of representative combinations that include site *x*
$R_{x\_excluded}$ is the number of representative combinations that do not include site *x*
$R_{x\_removed}$ is the number of representative combinations that include site *x* but would still be representative if site *x* were removed (i.e. combinations where site *x* is redundant).

The calculations required to derive each of these estimates for a single feature *i* at a given site *x* are illustrated diagrammatically in Figure 1. To determine the irreplaceability value for each site based on multiple species, the proportion of combinations that achieve targets for individual species are multiplied together. For example, if the proportion of combinations that include site *x* and achieve the conservation targets for three species are 0.4 for Species A, 0.5 for Species B, and 0.2 for Species C, then the proportion of combinations that achieve all three species' targets is 0.4*0.5*0.2=0.04. $R_{x\_included}$ is calculated by multiplying this value by the number of possible combinations of sites that include site *x*. Irreplaceability is a relative measure that takes into account the number of features (e.g. species) that occur within a site, the number of sites each feature occurs in within the region, and the conservation target for each feature (Pressey et al. 1994). The final values range from 0 to 1, where 0 represents a low irreplaceability value and 1 represents a high irreplaceability value.

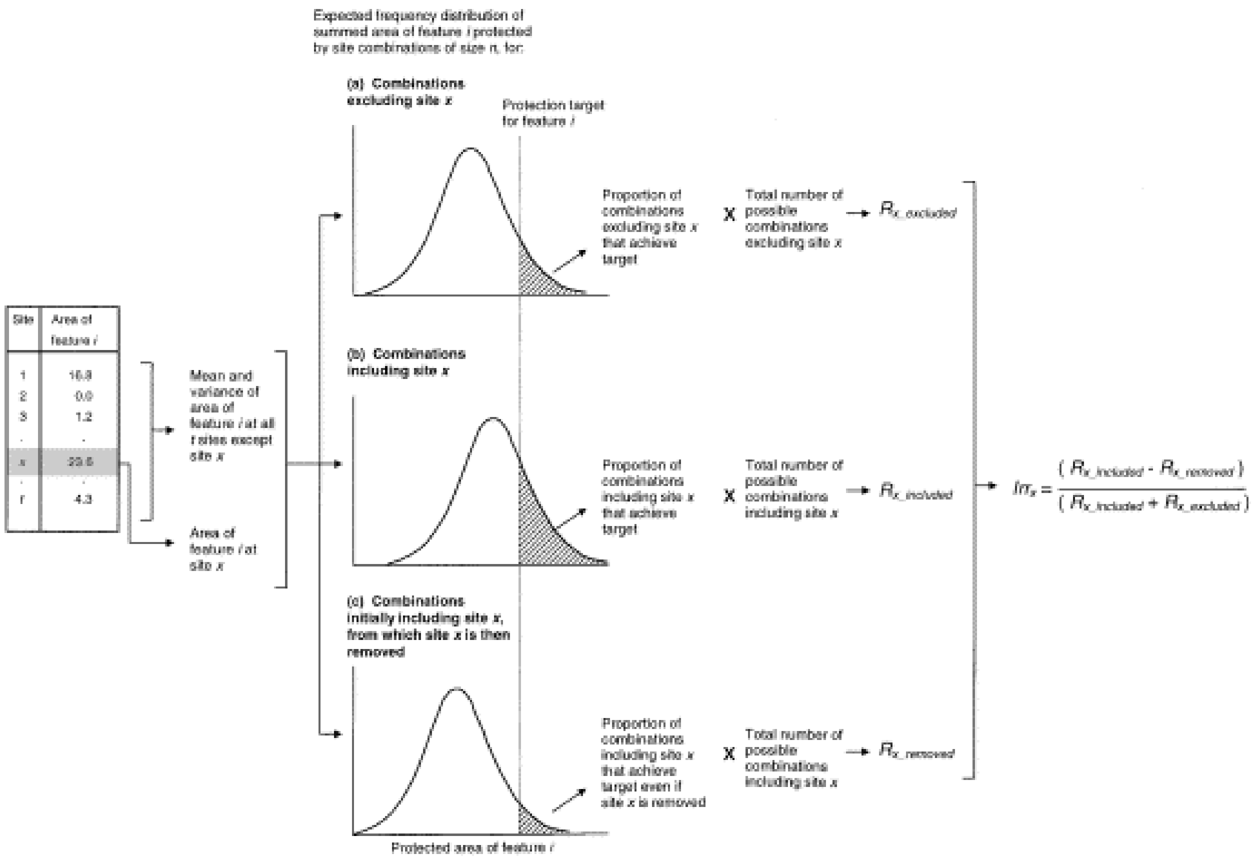

Figure 1. Diagrammatic illustration of the steps involved in statistically estimating the irreplaceability of a given site *x* in achieving a protection target for a single feature *i* (Ferrier et al. 2000).

Potential uses of irreplaceability include:

1. One-off picture of irreplaceability – can use as a guide for decisions about the impacts of development projects or location of protective zonings or reserves (Ferrier et al. 2000).
2. Interactive conservation planning – can be used to identify a set of areas that represent all features of interest (e.g. species) within a region at their conservation target (Ferrier et al. 2000); irreplaceability is based on concepts of efficiency (i.e. minimize unnecessary duplication of features in a reserve system by identifying sites that are complementary) and flexibility (i.e. identify all possible configurations of a representative reserve system; Pressey et al. 1994). See Appendix I for more on irreplaceability and conservation planning.
3. Guide to feasibility of changes to a conservation plan – use initial irreplaceability values of both selected (e.g. reserved) and unselected sites to make alternate conservation networks (Ferrier et al. 2000, Margules and Pressey 2000).
4. Scheduling of conservation action – irreplaceabilty of sites can be plotted against vulnerability (i.e. the risk of an area being transformed by extractive uses) to help prioritize conservation effort (Figure 2); areas with high values for both indices should receive higher priority (Margules and Pressey 2000).

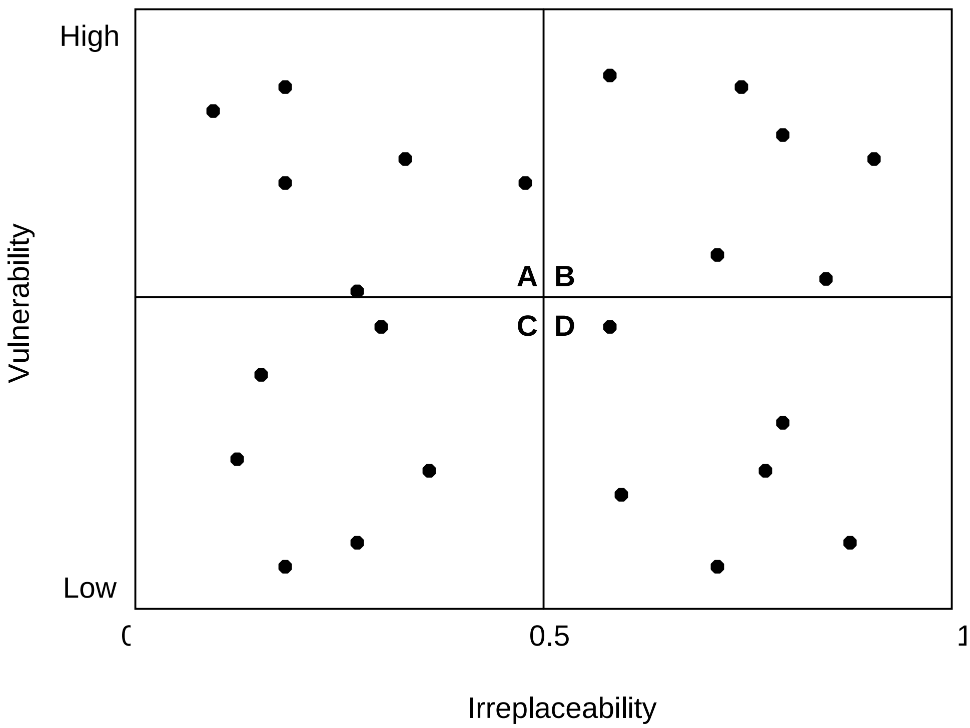

Figure 2. A framework for prioritizing conservation action in both time and space (Margules and Pressey 2000). Dots represent individual sites. Quadrant A: sites are vulnerable to loss but have many replacements, either because features are relatively common and extensive relative to targets or because targets have been partially met in existing reserves. Quadrant B: sites are most likely to be lost and have the fewest replacements (i.e. high priority for conservation action). Quadrant C: sites are likely stable and require the least intervention. Quadrant D: sites with lower present risk of conversion but high irreplaceability (e.g. rocky ranges).

Methods and Results:

1. Databases and taxa available for analyses

We obtained 24 databases for species occurrences from various sources for use in the species richness and irreplaceability analyses (Table 1). The locations in the Birds of BC database were recorded as 1:50,000 NTS grid cells, since occurrences with actual coordinates were not available. There were 36 separate datasets for herptiles, collected by various authors, which were combined into one database. In general, the 24 databases had a different format for species name, date, and location coordinates. There were also many errors that needed correcting so that the record could be used in the analyses. Therefore, it was necessary to format, clean, and filter the data. Scientific names were checked against the species database used in 2003 and the BC Species and Ecosystem Explorer website because of typos and name changes. Species were identified by “Genus” and “Species” for the species richness and irreplaceability analyses, since not all databases recorded data to the subspecies and variant level. However, subspecies and variants were used to identify the appropriate Genus and Species name for synonyms when they were available. Synonyms were identified primarily by using E-Flora BC, NatureServe Explorer, MoF Biogeoclimatic Ecosystem Classification (BEC) Plant Codes, and United States Department of Agriculture Plants Plant Checklist websites (http://plants.usda.gov/). Extinct, extirpated, exotic, and accidental species as listed on the BC Species and Ecosystem Explorer website (http://srmapps.gov.bc.ca/apps/eswp/, 18 April 2006) were removed from the databases. Locations that plotted outside of the BC boundary with a geographic description for a location within BC were checked and obviously incorrect records (i.e. a systematic search was not done) were corrected where possible. Terrestrial plant communities, hybrids, marine mammals, and marine invertebrates were removed from the CDC databases. Since the spatial format of the CDC occurrences includes a buffer distance around the location coordinates, which forms a circular polygon, a species was considered present in each grid cell that overlaps the circular polygon. A more detailed explanation of the CDC occurrence data can be found at the following URL (http://www.env.gov.bc.ca/cdc/methods.html). After deleting records that could not be corrected during the formatting and cleaning process, the record total was 2,046,193 for the 24 databases (Table 1). The cleaned data was overlaid with the 1:50,000 NTS grid cells to determine species presence within each grid cell.

There were two databases that were not of species occurrences. One dataset was for probability distributions of freshwater fish referenced to 3rd order watersheds provided by E. Parkinson (MoE) and the other was for ungulate ranges identified as presence within a 1:50,000 NTS grid cell, which was provided by E. Lofroth (MoE). We converted the fish probability distributions to presence within a 1:50,000 NTS grid cell with the aid of E. Parkinson so that the values were comparable to those obtained using occurrence records. Fish occurrences provided by E. Parkinson (8145 FISS and 342 non-FISS records) and 3911 records from D. McPhail (UBC Museum) were used to determine the probability value where it is likely that a species was actually “present” within a grid cell. A species was considered to be present within a grid cell that had more than one occurrence record for that species from more than one database source with dates that ranged from 1961 to 2006. The minimum species distribution probability value for the grid cells that met these requirements was identified. Since there are grid cells in BC that have not been sampled for fish species and/or recorded in the fish databases, a species was considered to be “present” in grid cells with probabilities equal to or greater than the minimum probability that met the occurrence record requirements.

Species distributions may have shifted over time because of the effect of climate change and both natural and human disturbances. Therefore, historical data were separated from more current species’ observations to potentially increase the relevance of the data for assessing the status of biodiversity in BC. Current data were identified as records with dates from 1961 to 2006, since climate data currently used by the BC government is summarized on a 30 year average that ranges from 1961 to 1991 (Table 1). Historical data consisted of records from before 1961 and those where the date was blank or incorrect (e.g. 3-digits, >2006, etc.) and could not be corrected. This filter had a large impact on the databases for small mammals, on most of the invertebrate databases, and on plants from the National Herbarium of Canada. Although there were many records lost when restricting the dates to 1961 to 2006, only the datasets that included records for fungi, other insects, and vascular plants had a large proportion of species that did not have records during this time period (Table 2).

Table 1. Number of records in the databases that were used for the irreplaceability analyses.

Database and Source	Number of Records: All Dates	Number of Records: 1961 to 2006	Number Lost	% Lost
CDC Non-sensitive Species	4909	4378	531	10.8
CDC Sensitive Species	560	547	13	2.3
Small Mammals, D. Nagorsen	23,302	6123	17,179	73.7
Birds of BC, Passerines (Vol. 3 & 4), CWS[1]	477,781	401,532	76,249	16.0
Herptiles, MoE databases (multiple authors), L. Friis	11,543	9075	2468	21.4
Freshwater Fish, UBC Fish Museum, D. McPhail[2]	29	17	12	41.4
Copepods, G. Sandercock[3]	1732	949	783	45.2
Neuropteroids, G.G.E. Scudder	2963	1091	1872	63.2
Plecoptera, G.G.E. Scudder	2878	599	2279	79.2
Carabidae, G.G.E. Scudder	32,217	12,934	19,283	59.9
Heteroptera, G.G.E. Scudder	33,671	20,812	12,859	38.2
Odonata, G.G.E. Scudder	32,786	29,573	3213	9.8
Butterflies, Agriculture & Agrifood Canada, A. Jessop	29,163	19,217	9946	34.1
South Okanagan Butterflies, O. Dyer	1713	1704	9	0.5
Peace Butterflies, C. Guppy	1309	1309	0	0.0
South BC Butterflies, N. Kondla	6314	6314	0	0.0
Vascular Plant, UBC Herbarium	33,408	23,323	10,085	30.2
Plants, National Herbarium of Canada, Canadian Museum of Nature	9283	3941	5342	57.5
Vascular Plants, RBCM Herbarium Database	46,803	40,441	6362	13.6
MoF BEC Vegetation Plots, W. MacKenzie	1,212,268	1,032,071	180,197	14.9
Bryophytes, UBC Herbarium & Devonian Botanical Garden	46,795	33,465	13,330	28.5
Algae, UBC Herbarium	28,059	22,846	5213	18.6
Fungi, UBC Herbarium	3460	2892	568	16.4
Lichen, UBC Herbarium	3247	3138	109	3.4

[1] Records are recorded as presence within a 1:50,000 NTS grid cell (i.e. actual coordinates were not available).

[2] Records used are only for two species (*Cottus hubbsi* and *Hypomesus pretiosus*) that did not have 3rd order watershed distribution models (i.e. probability of occurrence models developed by E. Parkinson).

[3] No dates were provided; only "old" versus "new". We assumed that "old" records were pre-1961 and "new" records were from 1961 to 2006.

Table 2. Number of species by taxonomic group for all records available in the original database and for records from 1961 to 2006.

Taxonomic Group	Number of Species All Dates	1961-2006	% Lost
Algae	598	588	1.7
Amphibian	20	20	0.0
Bird	186	186	0.0
Bivalve	1	1	0.0
Bryophyte	1111	1099	1.1
Butterfly	180	177	1.7
Fish[1]	71	71	0.0
Fungi	1452	1245	14.3
Gastropod	4	4	0.0
Copepod	30	26	13.3
Other Insects[2]	1451	1211	16.5
Lichen	1024	1008	1.6
Mammal[3]	86	86	0.0
Reptile	11	11	0.0
Turtle	1	1	0.0
Vascular Plant	3600	3350	6.9

[1] This group includes occurrences for six species (two species from D. McPhail and four species from the CDC) and probability distributions for 65 species.
[2] This group includes neuropteroids, plecoptera, carabidae, heteroptera, and odonata.
[3] This group includes occurrences for small and medium-sized mammals and range maps referenced to 1:50,000 NTS grid cells for ungulates.

2. Terrestrial versus freshwater species

Species were grouped as requiring predominately terrestrial or freshwater habitats (Table 3). Some species require both terrestrial and freshwater ecosystems for their life requisites and have therefore been included in both groups. Species richness and irreplaceability have been calculated for the terrestrial and freshwater groups because the conservation of these species will require different types of action. G.G.E. Scudder separated the terrestrial and freshwater insects. L. Warman separated the remaining species groups based on habitat descriptions on the BC Species and Ecosystem Explorer website and other sources when necessary. A partial list of wetland plant species is available on the United States Department of Agriculture Plants Database website (http://plants.usda.gov/wetland.html). However there was not enough time to identify the habitat requirements of species that were not included in this list. Therefore, all vascular plants were included in the terrestrial group for the irreplaceability analyses. Also, timing did not permit the separation of algae, bryophyte, and fungi species into terrestrial and freshwater groups. Therefore, these species were included in the terrestrial group for the irreplaceability analyses.

The irreplaceability values for the freshwater group could change dramatically with the addition of the freshwater species from these four taxonomic groups, since there are far fewer species currently included in this group relative to the terrestrial group. The effect of the removal of freshwater species from the terrestrial group will likely be less dramatic given the number of species included in this group. Algae were excluded from the terrestrial group, as most of this taxonomic group are expected to be freshwater species, to demonstrate the effect on irreplaceability calculations (Appendix II). The summed irreplaceability values decrease slightly with the exclusion of algae but the overall pattern of relative irreplaceability in BC does not change significantly. Algae were not added to the freshwater group to identify the associated effect on species richness and irreplaceability. If the algae, bryophyte, lichen, and vascular plant species can be classed as terrestrial or freshwater in the future, then irreplaceability can be recalculated for these two groupings of species.

Table 3. Number of species of each taxonomic group classed as occurring in freshwater, terrestrial, or both habitat types in the original database.

		Number of Species	
Species Habitat	Taxonomic Group	All Records	1961-2006
Freshwater	Bird	7	7
Freshwater	Bivalve	1	1
Freshwater	Fish	71	71
Freshwater	Gastropod	2	2
Freshwater	Copepod	30	26
Freshwater	Other Insects	198	139
Terrestrial	Algae[1]	598	588
Terrestrial	Bird	163	163
Terrestrial	Bryophyte[1]	1111	1099
Terrestrial	Butterfly	180	177
Terrestrial	Fungi[1]	1452	1245
Terrestrial	Gastropod	2	2
Terrestrial	Other Insects	1167	987
Terrestrial	Lichen	1024	1008
Terrestrial	Mammal	83	83
Terrestrial	Reptile	11	11
Terrestrial	Vascular Plant[1]	3600	3350
Both	Amphibian[2]	20	20
Both	Bird[3]	16	16
Both	Other Insects[2]	86	85
Both	Mammal	3	3
Both	Turtle	1	1

[1] Some of the species in these groups should be listed as "freshwater" or as "both". Complete lists were not available at the time of the analyses. Therefore all species in these taxonomic groups were classed as "terrestrial".

[2] Amphibian and odonata species were included in both habitat types because the adults spend considerable time in the terrestrial habitat and are important predators.

[3] Some bird species were included in both habitat types because they required land for nesting and freshwater for all other life requisites.

3. Species without G- and S-ranks

The summed irreplaceability measure is based on both the number of species occurring within a site and how rare the species are within the region. The rarity calculation in C-Plan is based on the number of grid cells within the region that contain data (i.e. locations) for a particular species. However, irreplaceability can also be calculated with 'species vulnerability weightings', which reflect the relative priority for a species to be included in a reserve system.

This could be based on each species' risk of extinction (Vennesland et al. 2002). The vulnerability rating scheme consists of five classes, 1 (highest reservation priority) to 5 (lowest reservation priority). Because a species' vulnerability to extinction may be different than their rarity value calculated in C-Plan, the pattern of summed irreplaceability with and without vulnerability weightings may be different. The vulnerability weightings used for these analyses are based on the global (G) and sub-national (S) rankings for each species.

Global and sub-national (i.e. provincial) ranks were assigned to species using the ranking identified by Anion (2006) for BC and using the Species and Ecosystem Explorer ranking (as of 9 May 2006) for species not included in Anion's report. The highest ranking was used for species that had more than one G- or S-rank (e.g. ranking of 2 for G2G3). The highest ranking was also used for species that were listed with subspecies or variants, even though it may not have applied to the taxon identified by only the Genus and Species name. Global T-ranks were used instead of G-ranks when available because the T-rank is associated with the subspecies or variety that occurs in BC. Species with a S-rank of SH or SX and were not listed on the Species and Ecosystem Explorer website or by the Committee on the Status of Endangered Wildlife in Canada as being extinct or extirpated were given a rank of 1. There were 6331 species that did not have G- or S-ranks (Table 4). These species were assigned a rank of 5.

Table 4. Number of species by taxonomic group without G- and S-ranks in the original database.

Taxonomic	Number of Species		% Without
Group	Total	No Ranks	Ranks
Algae	598	593	99.2
Amphibian	20	0	0.0
Bird	186	0	0.0
Bivalve	1	0	0.0
Bryophyte	1111	421	37.9
Butterfly	180	4	2.2
Fish	71	0	0.0
Fungi	1452	1452	100.0
Gastropod	4	0	0.0
Copepod	30	30	100.0
Other Insects	1451	1349	93.0
Lichen	1024	1019	99.5
Mammal	86	0	0.0
Reptile	11	0	0.0
Turtle	1	0	0.0
Vascular Plant	3600	1463	40.6

4. Irreplaceability analyses

Summed irreplaceability and weighted summed irreplaceability (i.e. with species G- and S-ranks) were calculated for 1:50,000 NTS mapsheet grid cells in British Columbia. Irreplaceability was calculated using C-Plan software (National Parks & Wildlife Service 1999). There were 9826 taxa in total for these analyses. The taxa included in these analyses were from 24 different databases and included records for birds, mammals, amphibians, reptiles, turtles, fish, other insects, butterflies, copepods, gastropods, bivalves, vascular plants, bryophytes, lichen, fungi, and algae (Tables 1 & 2). Taxa were recognised by their genus and species name (i.e. subspecies were not recognised separately). Species that did not have a G- or S-rank were assigned a rank of five, as suggested by M. Austin. Summed irreplaceability (Table 5) was calculated for different groupings of species and using different conservation targets. Targets are identified for individual species and represent the number of grid cells that are required to "conserve" each species.

Table 5. Species groups used to calculate and map summed irreplaceability values for three different vulnerability rankings (i.e. without vulnerability ranks, with G-ranks, and with S-ranks). Deliverables are identified in Appendix III.

Species Group	Targets	All Records	Records from 1961 to 2006
All species	1 grid cell, 10%, 30%*	9826 taxa	9084 taxa
Terrestrial species	1 grid cell, 10%	9517 taxa	8838 taxa
Terrestrial spp. without algae	1 grid cell, 10%	8919 taxa	8250 taxa
Freshwater species	1 grid cell, 10%	435 taxa	371 taxa

* The 30% target was run only for the 9084 taxa with records from 1961 to 2006 as a comparison to the 10% target (Appendix IV). Values have not been submitted as a deliverable but are available upon request.

Two different targets were used to calculate irreplaceability. One target was based on representing each species in at least one grid cell in a final set of sites (Appendix IV). The other target was based on representing each species in a percentage of the grid cells that have records for a species (Appendix IV). The first three maps in this appendix illustrate the differences in irreplaceability without the effect of rankings (e.g. G-ranks or S-ranks) on the pattern. The percentage target was calculated as an "adjusted" 10% of the species extent in the database. The 10% target needed to be adjusted because a non-adjusted 10% target resulted in targets that were less than one grid cell for species that had an extent of less than 10 grid cells. Therefore, the irreplaceability values were not comparable with the uniform target of 1 grid cell for each species. The targets for the adjusted 10% target were set at 1 grid cell for species with an extent of less than or equal to 10 grid cells, 2 grid cells for species with an extent of 11 to 20 grid cells, 3 grid cells for species with an extent of 21 to 30 grid cells, etc. The 10% adjusted target was used to demonstrate how the relative irreplaceability values in BC change with different targets for each species. The 10% target does not imply that 10% of the grid cells of each species' extent would be enough to adequately represent the habitat to conserve each species in BC. Ultimately, species targets should be set with respect to the area required to maintain the life requisites of each species. Unfortunately, time did not permit species specific targets to be identified for this project.

The percentage target was also calculated as a 30% adjusted target for all species records with dates from 1961 to 2006 (Appendix IV). This target was used to compare the pattern of irreplaceability values with the pattern associated with the 10% target. The 30% target was chosen because other conservation analyses in BC (e.g. The Nature Conservancy of Canada ecoregional assessments) have been performed using a 30% target. The adjusted 30% targets were set at 1 grid cell for species with an extent of 1 to 3 grid cells, 2 grid cells for species with an extent of 4 to 6 grid cells, 3 grid cells for species with an extent of 7 to 10 grid cells, etc.

There seems to be a trend between the target of 1 grid cell for each species and the 10% adjusted target for each species grouping (see Appendix IV for corresponding maps). The relative summed irreplaceability values for areas in central and northern BC are greater in the 10% adjusted target analyses compared to the target of 1 grid cell (see Appendix IVa, b, and c for an example of this trend). The 10% target is likely lessening the effect of peripheral species on the irreplaceability calculations by increasing the number of grid cells required for wide ranging species. A target of one grid cell for peripheral species, which only occur in one to a few grid cells along the southern BC border, will affect the calculations of irreplaceability significantly since these grid cells would be essentially 100% irreplaceable for these species. There is very little difference in the relative irreplaceability values between the 10% and 30% targets; the pattern is roughly the same but the relative values of the highest range value class increase with the 30% targets (Appendix IV). The absolute irreplaceability values of each grid cell are also greater using the 30% targets.

Interestingly, it looks like there is also a trend between the irreplaceability analyses that use all records and the analyses that use records from 1961 to 2006 (see Appendices IVa and Va for an example of this trend). In the 1961 to 2006 analyses, the relative irreplaceability values are greater in areas north of the high irreplaceability values identified using all records (e.g. South Okanagan - only the most southern grid cell is classed in the range with the highest irreplaceability values using all records [includes historical records], however the grid cells that cover the entire valley are classed as the highest irreplaceability values using records from 1961 to 2006). This trend could be illustrating a shift in species' ranges over time however changes in individual species ranges would need to be assessed to determine why there is a difference in the relative irreplaceability values. The occurrence records may not be the best measure of shifts in species ranges, since they are associated with locations that are accessible to observers and often based on individual observers (e.g. species experts), both of which change with time. For example, accessible areas will change with the construction and decommissioning of roads, which may also have a trend of moving northward.

Species Richness Amendment:

During the course of the project it became apparent that further filtering and cleaning of the original dataset was necessary to get reliable results from the analyses (Table 6). It was decided that only records from 1961 to 2006 would be used to illustrate biodiversity patterns in British Columbia. Records for some groups did not provide a complete (or close to complete) set of species and were removed completely from the analyses. In other groups, more detailed filtering was done including further checking of synonyms, spelling errors, and species lists for BC. It was decided that the BC Conservation Data Centre provided the most accurate list of species for BC. The final list was based on the species recorded as native on the BC Species and Ecosystems Explorer website as of 29 May 2007 (i.e. exotic, accidental, extinct, extirpated, marine, and hybrid species were removed). Some modifications were made based on consultation with experts. Vascular plants were categorized into freshwater versus terrestrial by B. Constanzo, with some modifications based on the Species and

Ecosystems Explorer data and confirmation by J. Penny (Table 7). Freshwater status for birds was modified based on the BC Species and Ecosystems Explorer website.

The changes included:

- Removal of algae, fungi, lichen, and copepod species groups from the all species database.
- "Other insect" subgroups consisting of neuropteroid, heteroptera, plecoptera, and carabid beetles were removed from the all species database (i.e. odonata and butterflies were not removed). The removed other insect subgroups were mapped as a separate "insect" group along with odonata and butterflies.
- Addition of one passerine species (*Poecile rufescens*) that was missed in the original database.
- Removal of bryophytes that were not native moss species as identified by the UBC Herbarium (with aid of A. Leslie); UBC Herbarium list provided in May 2007; some of these species had not been identified on BC Species and Ecosystem Explorer as of 29 May 2007.
- Removal of five butterfly species (with aid of A. Eriksson), which were synonyms for other species in the database.
- Removal of one fish species (*Hypomesus pretiosus*), which was considered to be marine (identified by A. Eriksson and E. Parkinson).
- Addition of carnivore species, which were provided by E. Lofroth as range maps referenced to 1:50,000 NTS grid cells.
- Removal of vascular plant species that were exotic, accidental, synonyms, occurred only in marine habitats, or had spelling errors; generally those species that did not match the CDC list (with aid of A. Leslie and A. Eriksson); some species that were included in the database by consultation with J. Penny were not listed on the BC Species and Ecosystem Explorer website as of 29 May 2007 but have since been added; vascular plants were also checked against the E-Flora BC and NatureServe Explorer websites and the 2004 BC Ministry of Forests Biogeoclimatic Ecosystem Classification vascular plant list (http://www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-becdb.html#description).
- Update of G- and S-ranks using the 29 May 2007 database from the BC Species and Ecosystems Explorer website (Table 8); the highest ranking was used when there was more than one rank (e.g. ranking of 2 for G2G3) and the mid-point for rankings with a range (e.g. ranking of 2 for G1G3); global T-ranks were not used in place of G-ranks.
- It was also decided that it would be useful to have species richness maps for individual taxonomic and species groupings (Table 9), rather than maps only for the combined species groupings (i.e. all, terrestrial, and freshwater).

Table 6. Number of species by taxonomic group for records from 1961 to 2006 available in the original versus modified database.

Taxonomic Group	Number of Taxa Original DB	Modified DB
Amphibian	20	20
Bird	186	187
Passerines only	141	142
Bivalve*	1	1
Bryophyte*	1099	690
Butterfly	177	172
Fish	71	70
Gastropod*	4	4
Odonata	85	85
Mammal	86	102
Reptile	11	11
Turtle	1	1
Vascular Plant	3350	1992

* Included in the rare species richness maps but not the all species richness maps. Bryophytes (i.e. mosses) were mapped as a separate species richness map.

Table 7. Number of species of each species group classed as occurring in freshwater, terrestrial, or both habitat types in the original versus modified database.

		Number of Taxa	
Species Habitat	Taxonomic Group	Original DB	Modified DB
Freshwater	Bird	7	2
Freshwater	Fish	71	70
Freshwater	Vascular Plant	0	274
Terrestrial	Bird[2]	163	169
Terrestrial	Butterfly	177	172
Terrestrial	Mammal	83	99
Terrestrial	Reptile	11	11
Terrestrial	Amphibian	0	3
Terrestrial	Vascular Plant	3350	1592
Both	Amphibian[1]	20	17
Both	Bird[2]	16	16
Both	Odonata[1]	85	85
Both	Mammal	3	3
Both	Turtle	1	1
Both	Vascular Plant	0	126

[1] Amphibian and odonata species were included in both habitat types because the adults spend considerable time in the terrestrial habitat and are important predators.

[2] Some bird species were included in both habitat types because they required land for nesting and freshwater for all other life requisites. Some marine birds were included in the terrestrial habitat classification because they required land for nesting.

Table 8. Number of species by taxonomic group without G- and S-ranks in the modified database.

Taxonomic Group	Number of Taxa Total	No Ranks	% Without Ranks
Amphibian	20	0	0.0
Bird	187	0	0.0
Bivalve	1	0	0.0
Moss[1]	690	15	2.2
Butterfly[2]	172	1	0.6
Fish	70	0	0.0
Gastropod	4	0	0.0
Odonata	85	0	0.0
Mammal	102	0	0.0
Reptile	11	0	0.0
Turtle	1	0	0.0
Vascular Plant	1992	0	0.0

[1] These species were listed on the UBC Herbarium list, but not on the CDC list.
[2] *Speyeria coronis* was included in the list because it was recorded by a reputable butterfly expert and may now occur in BC.

Table 9. Species groups used to calculate species richness values in the modified database. Deliverables are identified in Appendix III and maps are provided in Appendix VI.

Species Group	Number of Taxa
All species	2640
Terrestrial	2294
Freshwater	294
G1 to G3 ranks	182
S1 to S3 ranks	1460
COSEWIC listed	99
Red listed	385
High Global Responsibility	82
Endemics	24
Vascular Plant	1992
Moss	690
Insects[1]	1383
Odonata	85
Butterfly	172
Amphibian	20
Reptile and Turtle	12
Mammal	102
Bird	187
Passerine	142
Freshwater Fish	70

[1] This group includes “other insects” (“number of taxa” in Table 2) and butterflies (“number of taxa” in this table).

Discussion:

Ideally, for a comprehensive assessment of biodiversity in BC, complete distributions of all species are necessary. Since the available species observation data are often found along road networks and areas of the province with high human density, there are areas of the province where species may be present that have not been adequately surveyed. If species location data only consist of the available observation data, the assessment of the status of biodiversity in British Columbia will be biased to areas where people have surveyed.

Species richness and irreplaceability are influenced by many different factors. For example, the geographic region, size and shape of the sites (e.g. grid cells), and the quality and quantity of the species data included in the analysis influence the calculations. The provincial boundary was used as the region for these analyses. Many species are at the northern extent of their range within this regional context, and as a consequence these species influence the richness along the southern boundary and the rarity value in the summed irreplaceability calculations. The 1:50,000 NTS mapsheet grid was used as the sites for calculating the relative values of species richness and irreplaceability. This resolution was necessary since The Birds of BC Volumes 3 and 4 data (Campbell et al. 1997; 2001) were only available by 1:50,000 NTS grid cells. A smaller grid cell would alter the calculations of both species richness and irreplaceability because the data are sampled differently. The species data represent as many taxonomic groups as possible in BC, however the quality of the data varies across datasets. The largest influence on species richness and summed irreplaceability is the accuracy and precision of the species locations, because the calculations will be incorrect if a species is recorded in the wrong grid cell.

In addition to these influences, the calculation for summed irreplaceability is strongly influenced by the conservation target used for each species. The target identifies how many grid cells need to be included in a final set of sites that represent all species in the database. Two different types of targets were used for the analyses; a uniform target of one grid cell for each species and a percentage target based on each species' extent within the database. The uniform target results in each species being represented in at least one grid cell. The irreplaceability of grid cells for restricted range species will be high, since one grid cell is a high proportion of their range, and irreplaceability of grid cells for wide-ranging species will be low, since one grid cell is a low proportion of their range. The percentage target gives equal weight to the restricted range and wide-ranging species because the target is an equal proportion of each species' extent in the database. Although the analyses for this project do not identify a final set of sites for conservation, summed irreplaceability provides the relative values for selecting a final set of sites. Since the irreplaceability calculations depend on the target used for each species, the implication of the different targets needs to be considered in the interpretation of the resulting irreplaceability values.

There are some additional considerations for including species richness and irreplaceability in the Biodiversity Status Report.

- The species richness and irreplaceability calculations are scale dependent. The values calculated based on the species recorded within the 1:50,000 NTS mapsheet grid can only be reliably interpreted at this grid cell resolution. Both species richness and irreplaceability of an area within the 1:50,000 NTS grid cell will likely be different than the value for the entire grid area given the variability within an individual grid cell. Irreplaceability values would also change if the regional extent was extended beyond the BC border or decreased to a smaller region within BC.

- Conservation targets identified for each feature (e.g. species) affect the irreplaceability calculations of each grid cell. Simple analyses can be done by setting the conservation targets to include one site for each species in a conservation network of sites. However, it may be more appropriate to scale the conservation targets based on species' range size, since wide-ranging species will require more area for survival than species with small ranges. The scaling of conservation targets would potentially result in irreplaceability values that are more equally weighted across species. Ultimately, species specific targets based on the area needed to maintain species life requisites should be used.
- Irreplaceability is based on the extent of the data for a particular region. The C-Plan calculation considers a species to be rare within the region if it occurs in very few grid cells, even though it may be more common outside of the region. Therefore, including species weightings based on G-ranks, S-ranks, and global responsibility can help to decrease the irreplaceability values for these types of species. The weighted irreplaceability values for BC biodiversity should be more defensible than those calculated without rankings, since the results include scientific evidence of a species' risk of extinction or regional responsibility for conservation of particular species.
- Both species richness and irreplaceability calculations are dependent on the quality of the data. The locational accuracy and the coverage of an entire species' range are important to the calculations. Furthermore, biases in species location data (e.g. along road networks) will affect the patterns of both species richness and irreplaceability. Southern BC has been sampled more extensively across different species groups than northern BC. Therefore it is difficult to determine whether higher values for grid cells in southern BC are influenced more by sampling effort or the latitudinal gradient in species' distributions.
- Irreplaceability can be plotted against values such as vulnerability (i.e. threat of disturbance), land condition, degree of protection, current human-population and growth estimates, etc. to identify areas of conservation concern. These types of analyses will provide a better understanding of relative conservation value compared to methods that combine irreplaceability with other indices (e.g. additively) to produce one overall value.

Although the calculation of irreplaceability is more complex than for species richness, irreplaceability may provide a better measure of conservation value because irreplaceability incorporates the importance of the site in terms of achieving a regional conservation target (i.e. representing all biodiversity of interest in a set of sites). Furthermore, irreplaceability incorporates a measure of the conservation importance of each species located in a site and is not based solely on the number of species within a site. This project has identified different variations of how irreplaceability can be calculated depending on the types of species, dates of records, and rankings used to indicate species conservation value that are included in the analysis. Each set of irreplaceability calculations are valid and potentially useful for identifying the relative importance of sites within BC for conservation. However, the utility of irreplaceability is dependent on the understanding of the potential effects of the input parameters and data on the relative summed irreplaceability patterns in BC.

Conclusions, Problems, and Future Considerations:

1. The irreplaceability analyses will need to be redone with the updated database (used for species richness), so that the results are reliable and comparable to the species richness results.
2. In most of the databases, subspecies were not identified consistently, only genus and species. Therefore, genus and species provide the most accurate results and were used for all analyses. For example, a grid square could contain a record for both *Ardea herodias herodias* and *Ardea herodias*. If both were considered as separate entities (i.e. features), then the species richness and irreplaceability value is artificially inflated for that grid cell.
3. There were many location errors evident in the databases (i.e. a species recorded outside of its range, geographic location description did not match the coordinates, etc.). The precision of the location is also important to note, since some of the records could be out by more than a kilometre. These positional errors could result in a species being recorded in the wrong grid cell, which influences the species richness and irreplaceability calculations. Verifying species locations is a necessary, but time consuming process. Unfortunately, it was not possible to systematically verify the species locations for these analyses in the time available for the project.
4. The data were formatted and cleaned as much as possible for use in these analyses. The types of problems that were identified and corrected are described in a document related to each database, which is available upon request. Corrections were not identified by individual records, but in most cases it is possible to identify the modifications using the original and corrected databases. Some of the modifications were automated using different programming scripts (with the aid of A. Blachford and A. Tautz). There may be errors that were not identified or not corrected properly through the automated process. Consequently, further formatting, cleaning, and filtering are necessary to use the original database containing all available species and records in future analyses.
5. Many species did not have G- and S-ranks in the original database. These species were given a ranking of G5 and S5, respectively, for the analyses of weighted summed irreplaceability. This assumption decreases the influence of these species on the irreplaceability calculation. Typos and synonyms are a problem for assigning G- and S-ranks. Observed problems were corrected, but some names may have been missed. For future analyses, the BC Species and Ecosystem Explorer website, along with other sources, should be consulted for updates to ranks for species.
6. The grid cell resolution chosen for the analysis will influence both the species richness and summed irreplaceability calculations and resulting patterns within BC (Warman 2001). However, it is not possible to identify species richness and summed irreplaceability at other scales for all taxa considered in these analyses because the Birds of BC data were only available at a 1:50,000 NTS grid cell resolution. The geographic descriptions associated with the 1:50,000 NTS grid cell locations for passerine birds (Birds of BC data) have been used to associate the record with a 1:20,000 scale mapsheet grid cell. Species richness and irreplaceability could be run at this resolution. If occurrence records for the bird data become available in the future, species richness and irreplaceability could be performed at any desired resolution.

7. Subsequently, range maps for ungulates and carnivores were developed based on presence within a 1:50,000 NTS grid cell. These data would also need to be modified for use at a different resolution.
8. Both species richness and summed irreplaceability may be strongly correlated with the location of highways and roads within BC. Future analyses of biodiversity patterns should take this into consideration. One method to compensate for observer bias is to predict where species could be based on climatic and physical variables. The predictions can then be refined using vegetation, physical barriers to dispersal and expert opinion to produce a more accurate map. Species richness and irreplaceability could then be rerun using the predicted distributions of species to obtain a more comprehensive map of biodiversity and conservation value within BC.

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Appendix I. Irreplaceability and conservation value (excerpt from Pressey et al. 1994).

(i) Irreplaceability, as defined in this paper, relates to the potential contribution of a site to a conservation goal by virtue of the features it contains. Any chance of achieving reservation goals requires that the components of reserve systems are complementary and that unnecessary duplication of features is minimized. Clearly then, the irreplaceability of one site is dependent to some extent on the features contained in other sites and, moreover, on decisions as to which of these other sites are to be reserved. Irreplaceability is not an absolute but a relative and dynamic index that will change through time, even during the course of a single exercise in reserve planning.

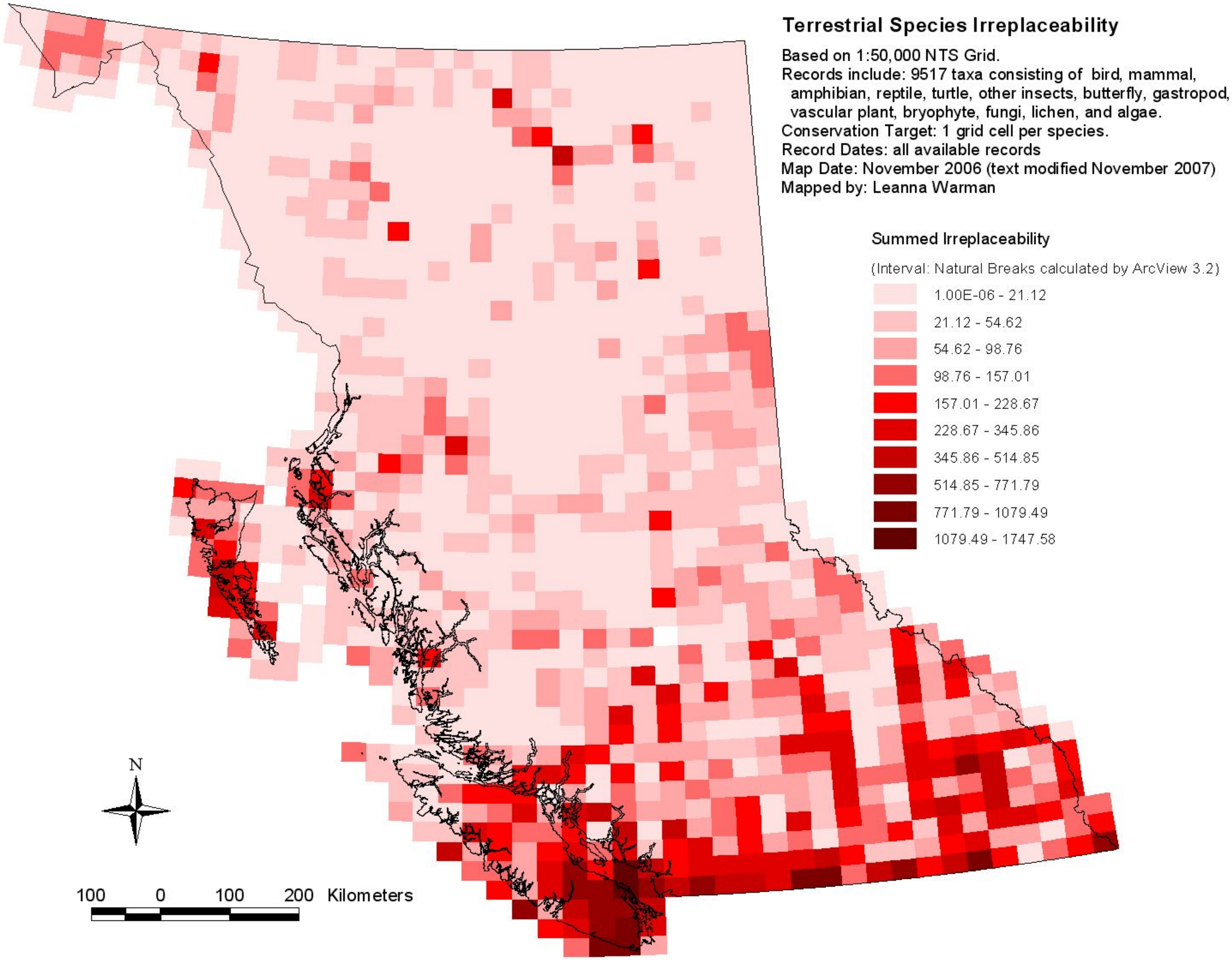
(ii) Irreplaceability must also be defined according to an explicit reservation goal and is assessed in a particular geographical context. The influence of context on assessments of rarity and other indices has been widely recognized. However, if reservation goals (as they must) are to deal with targets for the representation of natural environments and species, then the whole notion of 'value' must be seen to depend to some extent on a particular goal. Irreplaceability values will vary if some features are considered unimportant for reservation in a region because, for example, they are very extensive or already reserved in other regions. Values will also vary depending on how representation targets are expressed, for example as 5% or 10% of the extent of each vegetation type in a region.

(iii) Minimum sets of sites required to represent all nominated features in a region to some specified extent do not indicate the 'value' of those sites but an indicative threshold of site number or area above which planners must work. Some of the components of a minimum set, or any other single set of sites, will be totally irreplaceable, others replaceable to varying extents. Only by exploring this flexibility in reserve selection can the 'value' or contribution of a site to the reservation goal be properly assessed. This can be partly achieved by deriving a range of systems from minimum set algorithms, for example by repeated applications starting with different random sets of sites. However, the predictive approach described here is likely to more accurately reflect the actual irreplaceability of sites.

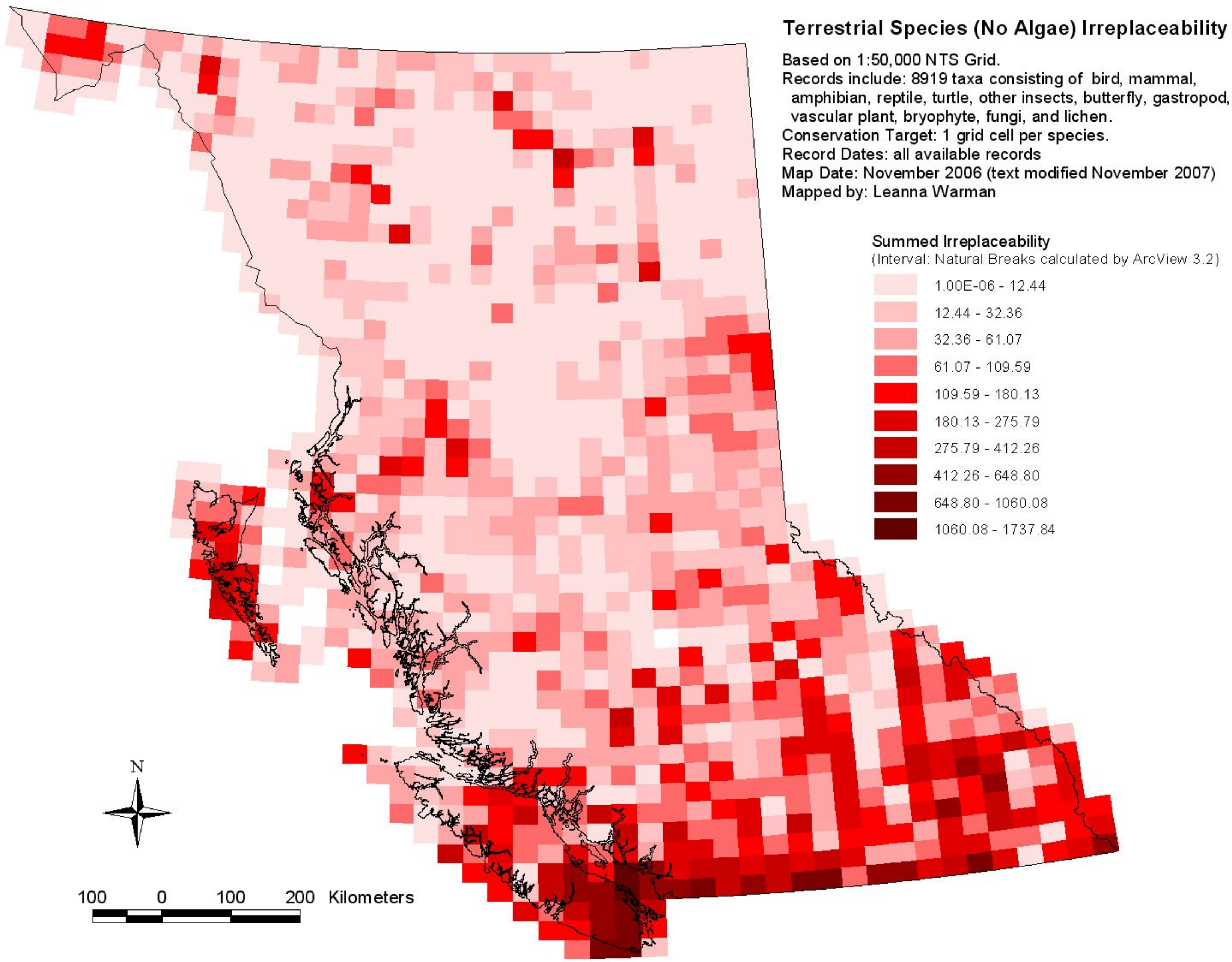
(iv) Measures of irreplaceability, geared solely to the representation of features in a system of protected areas, need to be combined with considerations such as reserve design and land suitability in practical planning exercises. Factors such as tenure, condition, threat, management requirements and contiguity with existing reserves are all dynamic, although on varying time scales. Design factors, in particular, will vary quickly as certain sites are reserved and the adjacency and connectedness to reserves of other sites changes. 'Value' and 'significance' for conservation therefore have many facets that need to be carefully defined and are ephemeral to some extent.

(v) The dynamic nature of irreplaceability and other aspects of conservation value undermine the notion of a reserve plan for a region that is fixed for any substantial period. Any reserve plan, no matter how rigorous, is simply one way of achieving a particular reservation goal in the face of a particular set of opportunities and constraints. Some components of the proposed system will be affected by changes in goals, data, available sites, feasible total area for reservation and other factors within weeks or months of the original plan. These components will then have to be reassessed and, because a system is a set of complementary sites, any changes will affect other sites involved in the initial design. Until the options for reservation in a region are exhausted, a realistic reserve plan should, therefore, be in dynamic adjustment under a variety of influences.

Appendix IIa. Map of summed irreplaceability for terrestrial species using all records with a target of one grid cell for each species.



Appendix IIb. Map of summed irreplaceability for terrestrial species excluding algae using all records with a target of one grid cell for each species.



L. Warman & G.G.E. Scudder
30 November 2007

Appendix III. Deliverables.

1. Species Richness of Species with records from 1961 to 2006

Filename: richness50k_2007_final2.xls

Fields:

SITE_ID = field used in C-Plan referencing the 1:50K mapsheet

B50K_TAG = 1:50K mapsheet

R_All_P1960_Bird = species richness for 2640 species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, reptile, turtle, butterfly, odonata, vascular plant

R_All_P1960_Passerine = species richness for 2595 species; taxonomic groups consist of freshwater fish, passerine, mammal, amphibian, reptile, turtle, butterfly, odonata, vascular plant

R_Terr_All = species richness for 2294 terrestrial obligate species; taxonomic groups consist of bird, mammal, amphibian, reptile, turtle, butterfly, odonata, vascular plant

R_FW_All = species richness for 594 freshwater obligate species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, turtle, odonata, vascular plant

R_G1G3 = species richness for 182 species with a global rank (G-rank) of 1, 2, or 3; taxonomic groups consist of amphibian, bird, bivalve, moss, butterfly, freshwater fish, gastropod, mammal, vascular plant

R_S1S3 = species richness for 1460 species with a sub national (provincial) rank (S-rank) of 1, 2, or 3; taxonomic groups consist of amphibian, odonata, bird, bivalve, moss, butterfly, freshwater fish, gastropod, mammal, reptile, turtle, vascular plant

R_COSEWIC = species richness for 99 species listed as endangered or threatened by COSEWIC; taxonomic groups consist of amphibian, bird, moss, butterfly, fish, gastropod, mammal, reptile, turtle, vascular plant

R_Redlist = species richness for 385 species listed as “Red” by the BC CDC; taxonomic groups consist of amphibian, odonata, bird, bivalve, bryophyte, butterfly, freshwater fish, gastropod, mammal, reptile, vascular plant

R_GlobResp = species richness for 82 species with a global responsibility ranking of 1, 2, 3 (i.e. high rankings based on F. Bunnell’s rankings for BC); taxonomic groups consist of amphibian, bird, moss, butterfly, freshwater fish, gastropod, mammal, vascular plant

R_Endemic = species richness for 24 endemic species in BC; species with records (not restricted by date) include *Bidens amplissima*, *Cottus sp. 2*, *Dicranella stickinensis*, *Enemion savilei*, *Gasterosteus sp. 1*, *Gasterosteus sp. 2*, *Gasterosteus sp. 3*, *Gasterosteus sp. 4*, *Gasterosteus sp. 5*, *Gasterosteus sp. 16*, *Gasterosteus sp. 17*, *Gasterosteus sp. 18*, *Gasterosteus sp. 19*, *Heterophyllium haidensis*, *Lampetra macrostoma*, *Limnanthes macounii*, *Marmota vancouverensis*, *Physella wrighti*, *Saxifraga taylori*, *Schistidium vancouverense*, *Seligeria careyana*, *Sinosenecio newcombei*, *Spirinchus sp. 1*, *Wijkia carlottae*

R_VascPlant = species richness for 1992 vascular plants

R_Moss = species richness for 690 moss species

R_Insect = species richness for 1383 insects; taxonomic groups consist of butterfly, heteroptera, neuropteroid, carabid beetles, plecoptera, and odonata

R_Odonata = species richness for 85 odonata

R_Butterfly = species richness for 172 butterflies

R_Amphib = species richness for 20 amphibians

R_Reptile = species richness for 11 reptiles and 1 turtle

R_Mammal = species richness for 102 mammals

R_Birds = species richness for 187 birds (includes passerines and CDC recorded species)

R_Passerine = species richness for 142 passerines
R_FWFish = species richness for 70 freshwater fish

2. Summed Irreplaceability for All Available Records in the Original Database
Filename: irr50k_alldates_2006.xls
Fields:
SITE_ID = field used in C-Plan referencing the 1:50K mapsheet
B50K_TAG = 1:50K mapsheet
All_T1 = summed irreplaceability for all 9826 species; uniform target of 1 grid cell for each species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, reptile, turtle, other insects, butterfly, copepod, bivalve, gastropod, vascular plant, bryophyte, fungi, lichen, algae
All_GT1 = summed irreplaceability for all 9826 species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see All_T1)
All_ST1 = summed irreplaceability for all 9826 species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see All_T1)
Terr_T1 = summed irreplaceability for all 9517 terrestrial species; uniform target of 1 grid cell for each species; taxonomic groups consist of bird, mammal, amphibian, reptile, turtle, other insects, butterfly, gastropod, vascular plant, bryophyte, fungi, lichen, algae; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available
Terr_GT1 = summed irreplaceability for all 9517 terrestrial species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see Terr_T1)
Terr_ST1 = summed irreplaceability for all 9517 terrestrial species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see Terr_T1)
TnoA_T1 = summed irreplaceability for all 8919 terrestrial species excluding algae; uniform target of 1 grid cell for each species; taxonomic groups are the same as Terr_T1 with the exclusion of algae; note that there are freshwater species in vascular plant, bryophyte, and fungi that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available
TnoA_GT1 = summed irreplaceability for all 8919 terrestrial species excluding algae; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see TnoA_T1)
TnoA_ST1 = summed irreplaceability for all 8919 terrestrial species excluding algae; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see TnoA_T1)
FW_T1 = summed irreplaceability for all 435 freshwater species; uniform target of 1 grid cell for each species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, turtle, other insects, copepod, bivalve, and gastropod; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that were not included in this analysis because complete classification for all species in these taxonomic groups was not available
FW_GT1 = summed irreplaceability for all 435 freshwater species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see FW_T1)
FW_ST1 = summed irreplaceability for all 435 freshwater species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see FW_T1)
All_TP = summed irreplaceability for all 9826 species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of freshwater fish, bird, mammal, amphibian,

reptile, turtle, other insects, butterfly, copepod, bivalve, gastropod, vascular plant, bryophyte, fungi, lichen, algae
All_GTP = summed irreplaceability for all 9826 species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see All_TP)
All_STP = summed irreplaceability for all 9826 species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see All_TP)
Terr_TP = summed irreplaceability for all 9517 terrestrial species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of bird, mammal, amphibian, reptile, turtle, other insects, butterfly, gastropod, vascular plant, bryophyte, fungi, lichen, algae; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available
Terr_GTP = summed irreplaceability for all 9517 terrestrial species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see Terr_TP)
Terr_STP = summed irreplaceability for all 9517 terrestrial species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see Terr_TP)
TnoA_TP = summed irreplaceability for all 8919 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; taxonomic groups are the same as Terr_T1 with the exclusion of algae; note that there are freshwater species in vascular plant, bryophyte, and fungi that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available
TnoA_GTP = summed irreplaceability for all 8919 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see TnoA_TP)
TnoA_STP = summed irreplaceability for all 8919 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see TnoA_TP)
FW_TP = summed irreplaceability for all 435 freshwater species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, turtle, other insects, copepod, bivalve, and gastropod; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that were not included in this analysis because complete classification for all species in these taxonomic groups was not available
FW_GTP = summed irreplaceability for all 435 freshwater species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see FW_TP)
FW_STP = summed irreplaceability for all 435 freshwater species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see FW_TP)

3. Summed Irreplaceability for Records with Dates from 1961 to 2006 in the Original Database
Filename: irr50k_post1960_2006.xls
Fields:
SITE_ID = field used in C-Plan referencing the 1:50K mapsheet
B50K_TAG = 1:50K mapsheet

All_T1 = summed irreplaceability for all 9084 species; uniform target of 1 grid cell for each species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, reptile, turtle, other insects, butterfly, copepod, bivalve, gastropod, vascular plant, bryophyte, fungi, lichen, algae

All_GT1 = summed irreplaceability for all 9084 species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see All_T1)

All_ST1 = summed irreplaceability for all 9084 species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see All_T1)

Terr_T1 = summed irreplaceability for all 8838 terrestrial species; uniform target of 1 grid cell for each species; taxonomic groups consist of bird, mammal, amphibian, reptile, turtle, other insects, butterfly, gastropod, vascular plant, bryophyte, fungi, lichen, algae; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available

Terr_GT1 = summed irreplaceability for all 8838 terrestrial species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see Terr_T1)

Terr_ST1 = summed irreplaceability for all 8838 terrestrial species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see Terr_T1)

TnoA_T1 = summed irreplaceability for all 8250 terrestrial species excluding algae; uniform target of 1 grid cell for each species; taxonomic groups are the same as Terr_T1 with the exclusion of algae; note that there are freshwater species in vascular plant, bryophyte, and fungi that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available

TnoA_GT1 = summed irreplaceability for all 8250 terrestrial species excluding algae; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see TnoA_T1)

TnoA_ST1 = summed irreplaceability for all 8250 terrestrial species excluding algae; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see TnoA_T1)

FW_T1 = summed irreplaceability for all 371 freshwater species; uniform target of 1 grid cell for each species; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, turtle, other insects, copepod, bivalve, and gastropod; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that were not included in this analysis because complete classification for all species in these taxonomic groups was not available

FW_GT1 = summed irreplaceability for all 371 freshwater species; uniform target of 1 grid cell for each species; species vulnerability weighted by G-ranks; taxonomic groups (see FW_T1)

FW_ST1 = summed irreplaceability for all 371 freshwater species; uniform target of 1 grid cell for each species; species vulnerability weighted by S-ranks; taxonomic groups (see FW_T1)

All_TP = summed irreplaceability for all 9084 species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, reptile, turtle, other insects, butterfly, copepod, bivalve, gastropod, vascular plant, bryophyte, fungi, lichen, algae

All_GTP = summed irreplaceability for all 9084 species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see All_TP)

All_STP = summed irreplaceability for all 9084 species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see All_TP)

Terr_TP = summed irreplaceability for all 8838 terrestrial species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of bird, mammal, amphibian, reptile, turtle, other insects, butterfly, gastropod, vascular plant, bryophyte, fungi, lichen, algae; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available

Terr_GTP = summed irreplaceability for all 8838 terrestrial species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see Terr_TP)

Terr_STP = summed irreplaceability for all 8838 terrestrial species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see Terr_TP)

TnoA_TP = summed irreplaceability for all 8250 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; taxonomic groups are the same as Terr_T1 with the exclusion of algae; note that there are freshwater species in vascular plant, bryophyte, and fungi that should not be included in this analysis because they are freshwater but complete classification for these taxonomic groups was not available

TnoA_GTP = summed irreplaceability for all 8250 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see TnoA_TP)

TnoA_STP = summed irreplaceability for all 8250 terrestrial species excluding algae; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see TnoA_TP)

FW_TP = summed irreplaceability for all 371 freshwater species; target is an adjusted* 10% of each species' extent in the database; taxonomic groups consist of freshwater fish, bird, mammal, amphibian, turtle, other insects, copepod, bivalve, and gastropod; note that there are freshwater species in vascular plant, bryophyte, fungi, and algae that were not included in this analysis because complete classification for all species in these taxonomic groups was not available

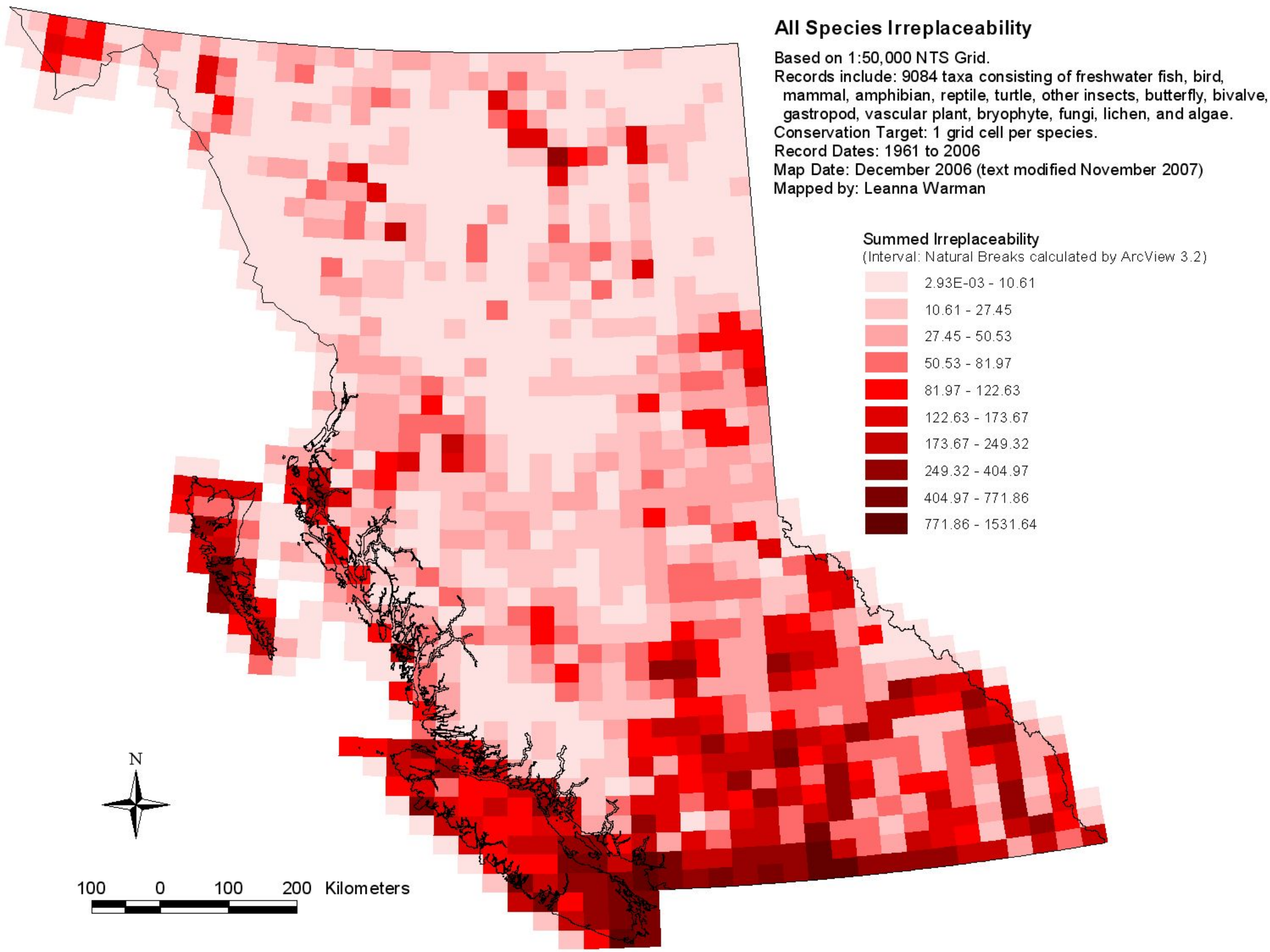
FW_GTP = summed irreplaceability for all 371 freshwater species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by G-ranks; taxonomic groups (see FW_TP)

FW_STP = summed irreplaceability for all 371 freshwater species; target is an adjusted* 10% of each species' extent in the database; species vulnerability weighted by S-ranks; taxonomic groups (see FW_TP)

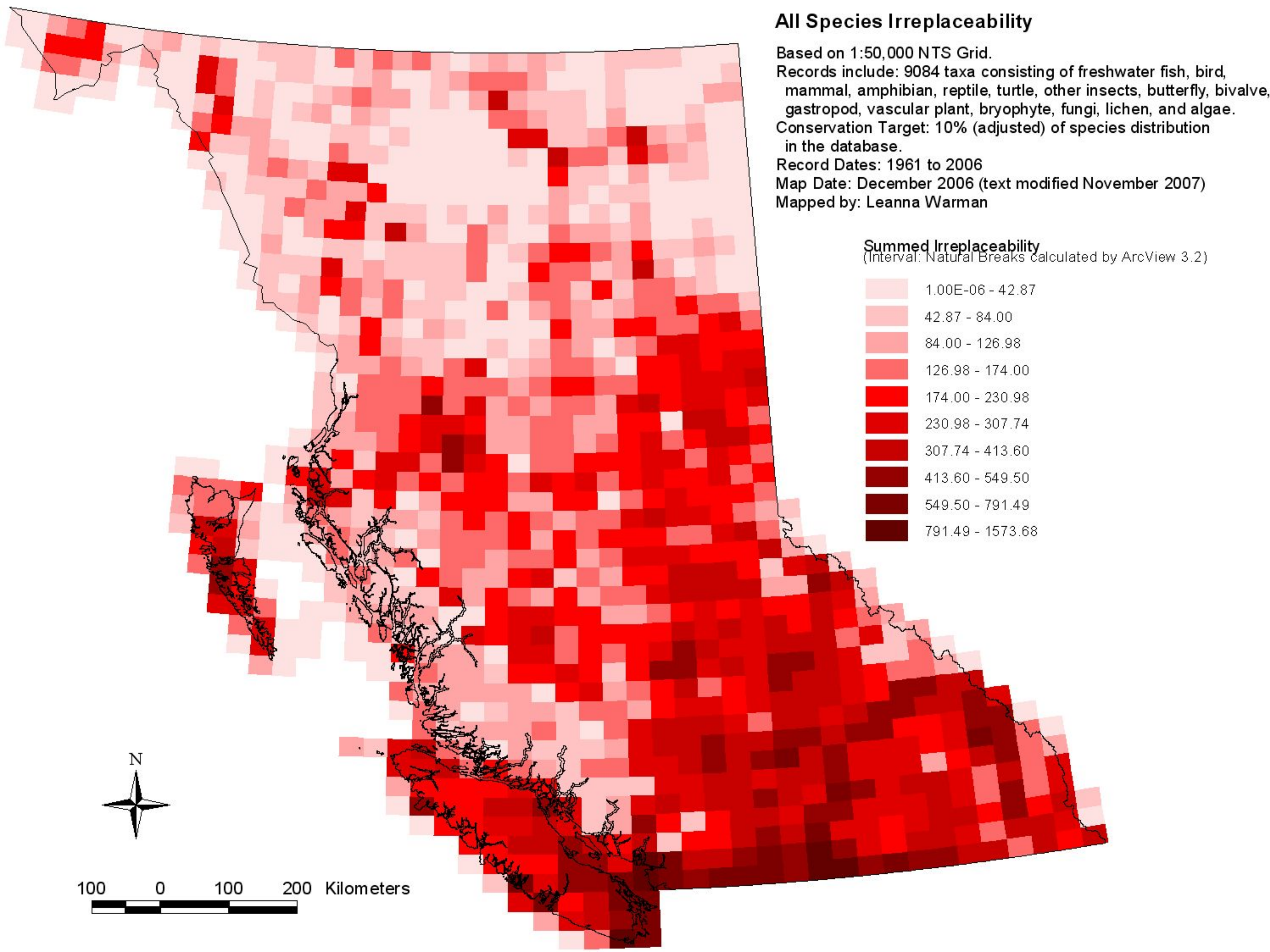
* adjusted 10% target = for species with an extent of ≤10 grid cells, the target is 1 grid cell; for species with an extent of 11-20 grid cells, the target is 2 grid cells; for species with an extent of 21-30 grid cells, the target is 3 grid cells, etc.; a 10% target without the adjustment was not comparable to the uniform target of 1, since the non-adjusted targets were less than 1 grid cell for species with an extent of <10 grid cells

4. Maps not included in this report are available by request.

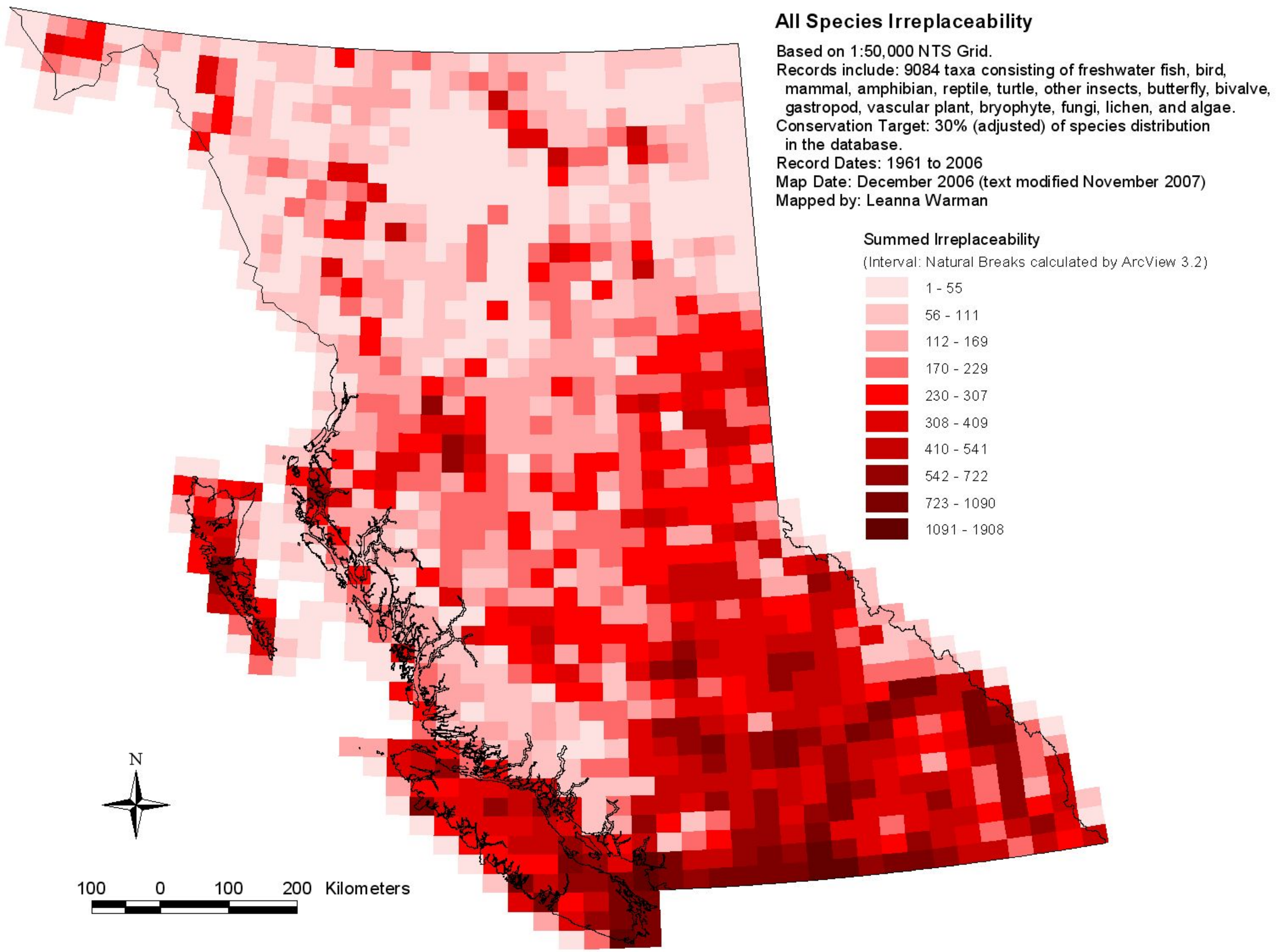
Appendix IVa. Map of summed irreplaceability for all species with records from 1961 to 2006 with a target of one grid cell for each species.



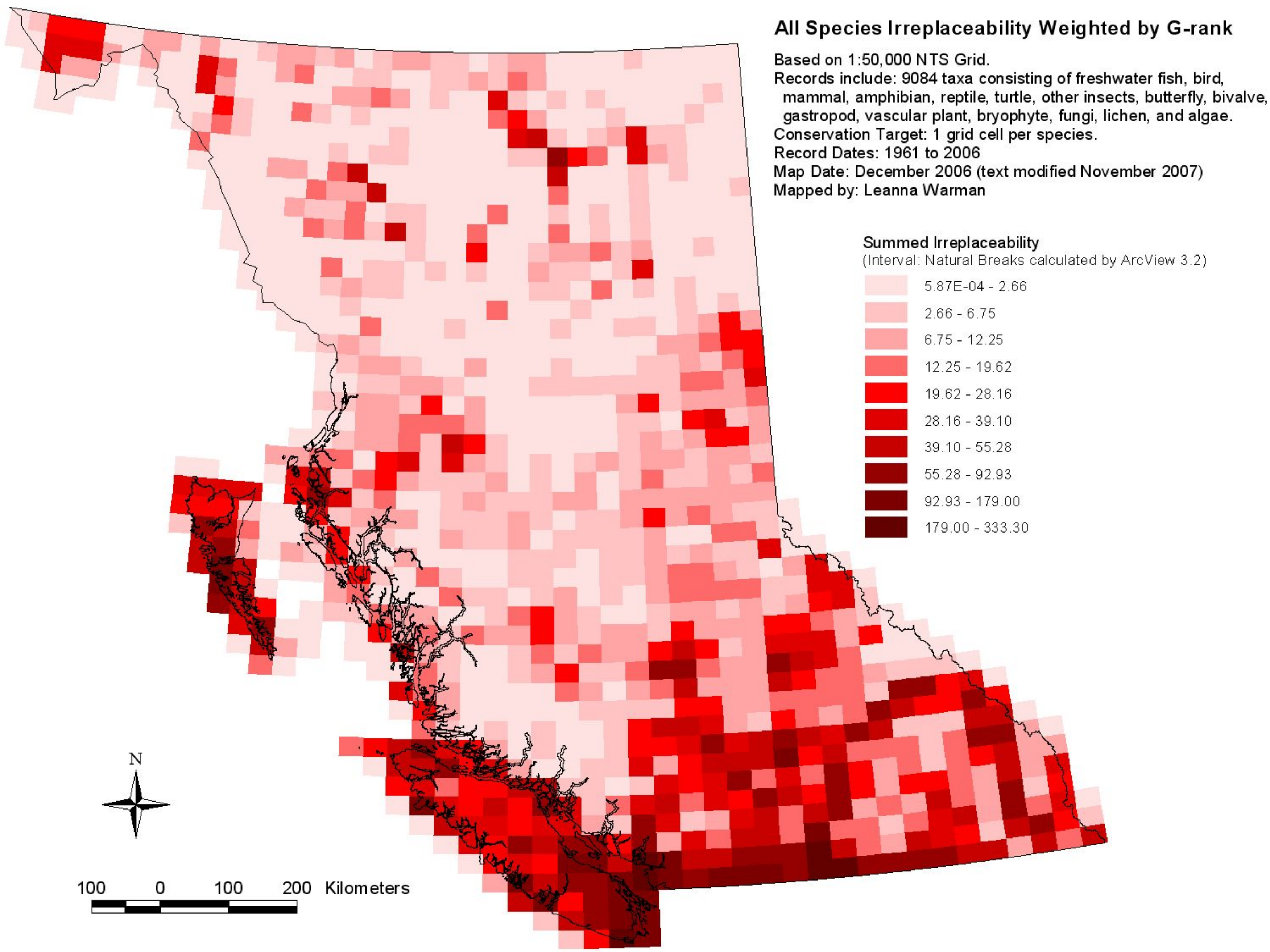
Appendix IVb. Map of summed irreplaceability for all species with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



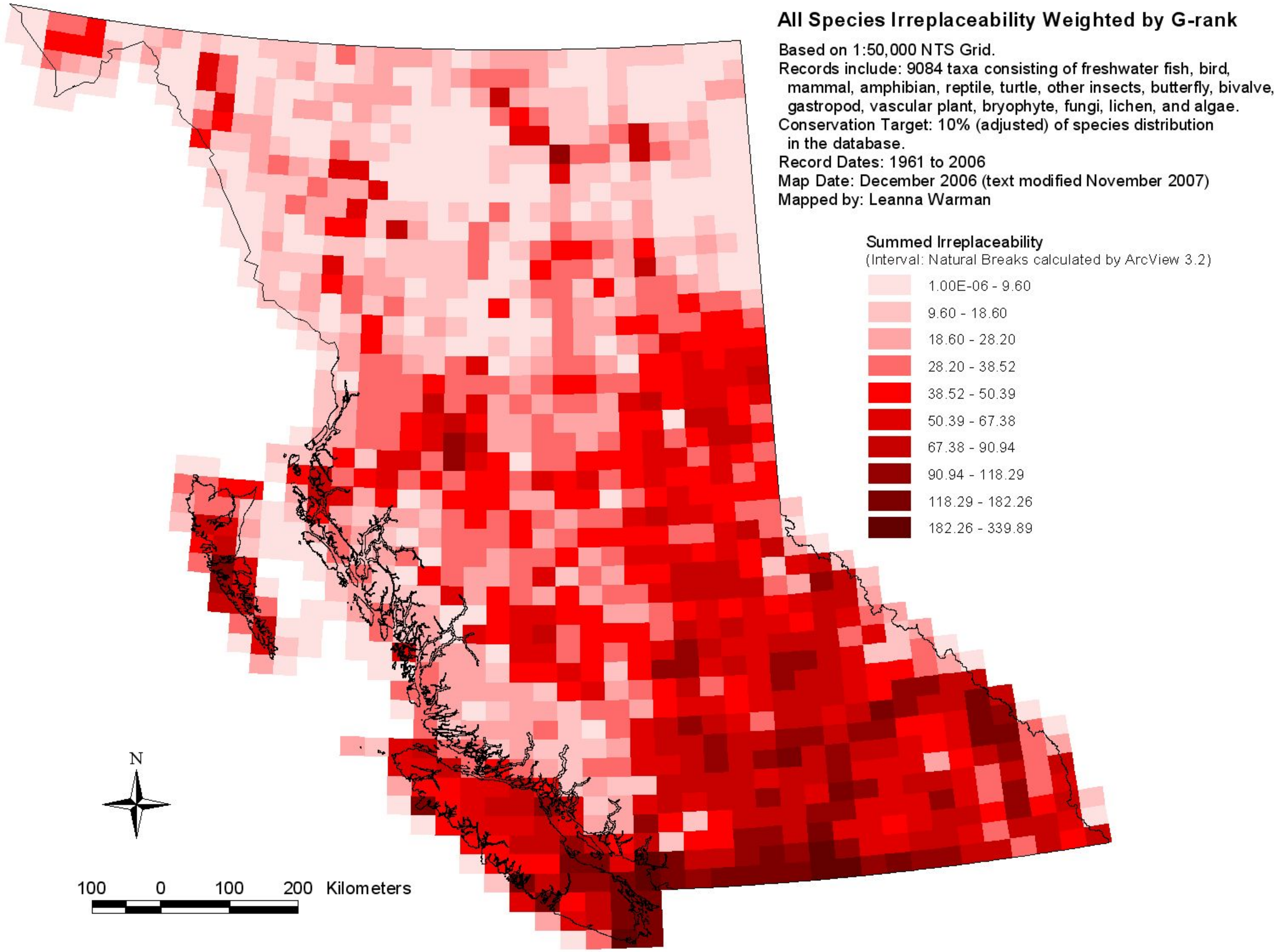
Appendix IVc. Map of summed irreplaceability for all species with records from 1961 to 2006 with a target of 30% (adjusted) of each species' extent in the database.



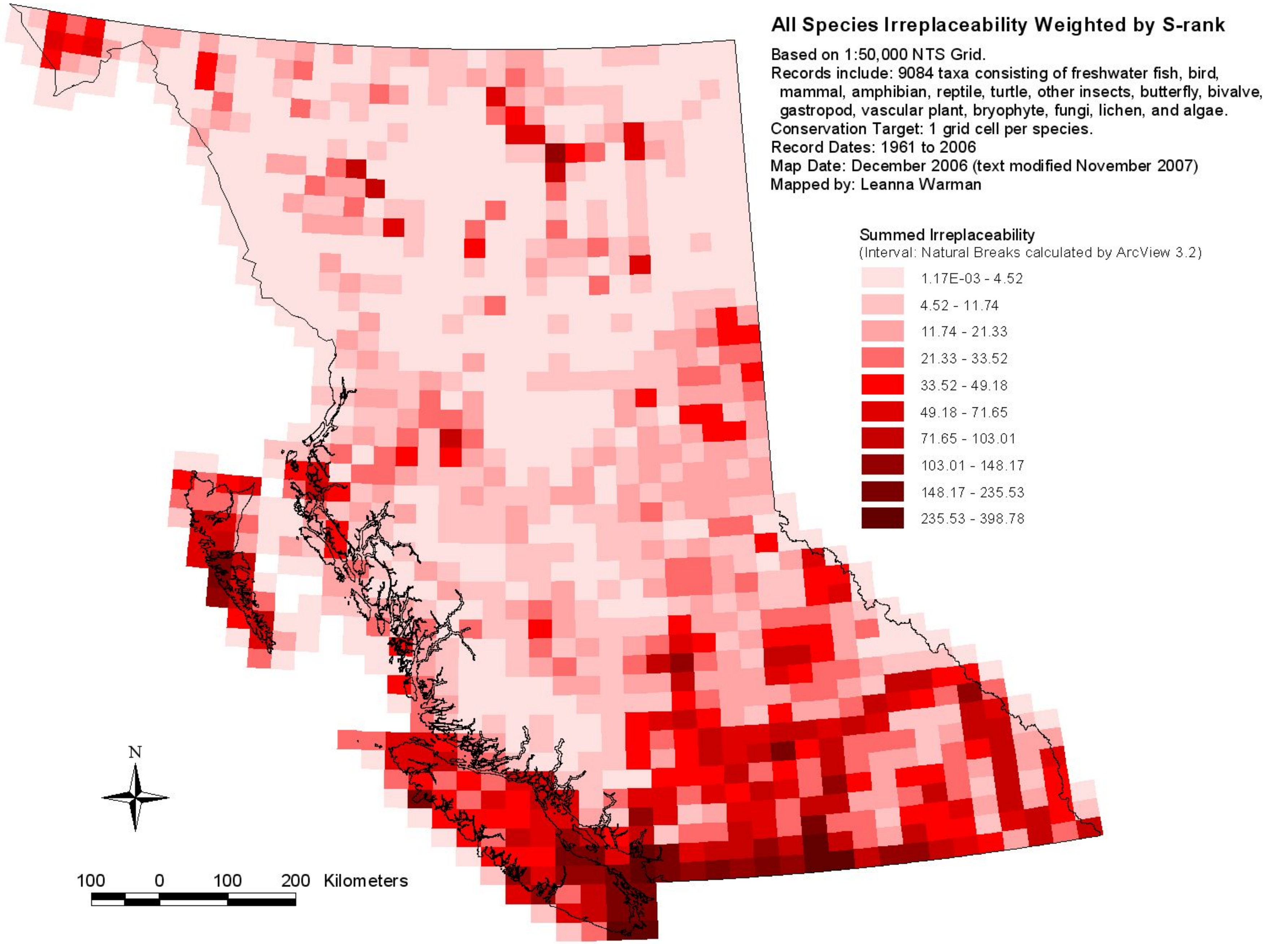
Appendix IVd. Map of summed irreplaceability for all species weighted by G-rank with records from 1961 to 2006 with a target of one grid cell for each species.



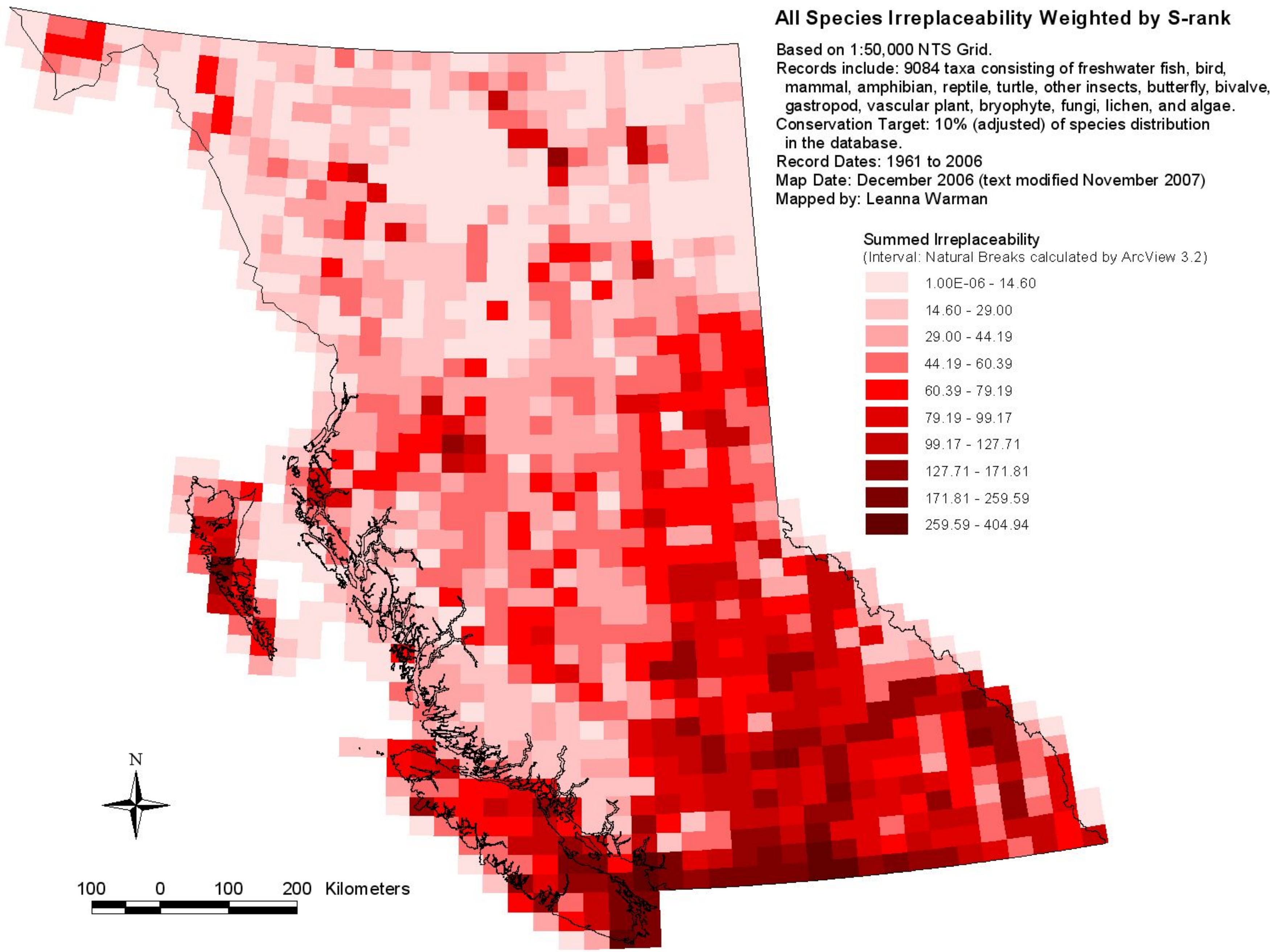
Appendix IVe. Map of summed irreplaceability for all species weighted by G-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



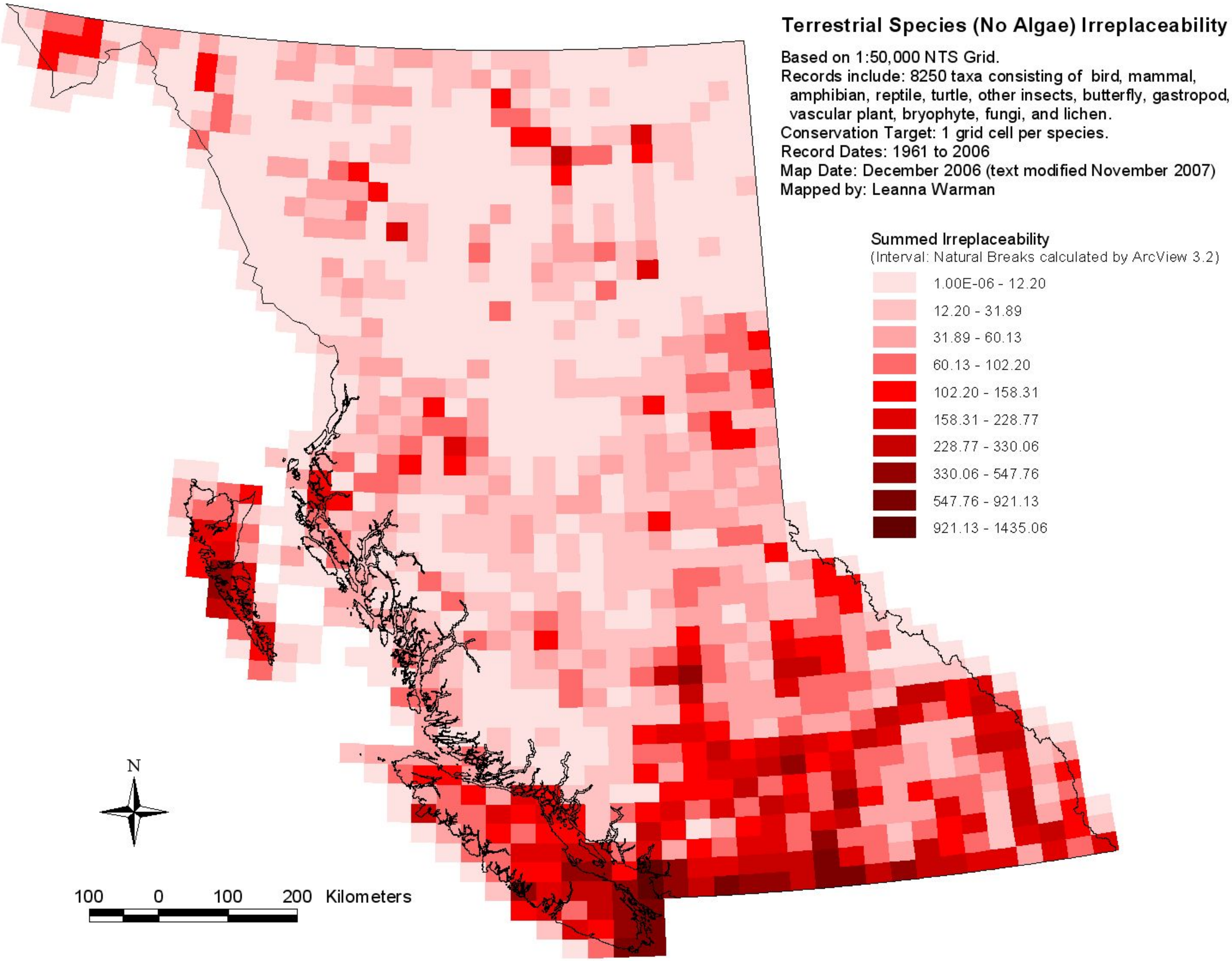
Appendix IVf. Map of summed irreplaceability for all species weighted by S-rank with records from 1961 to 2006 with a target of one grid cell for each species.



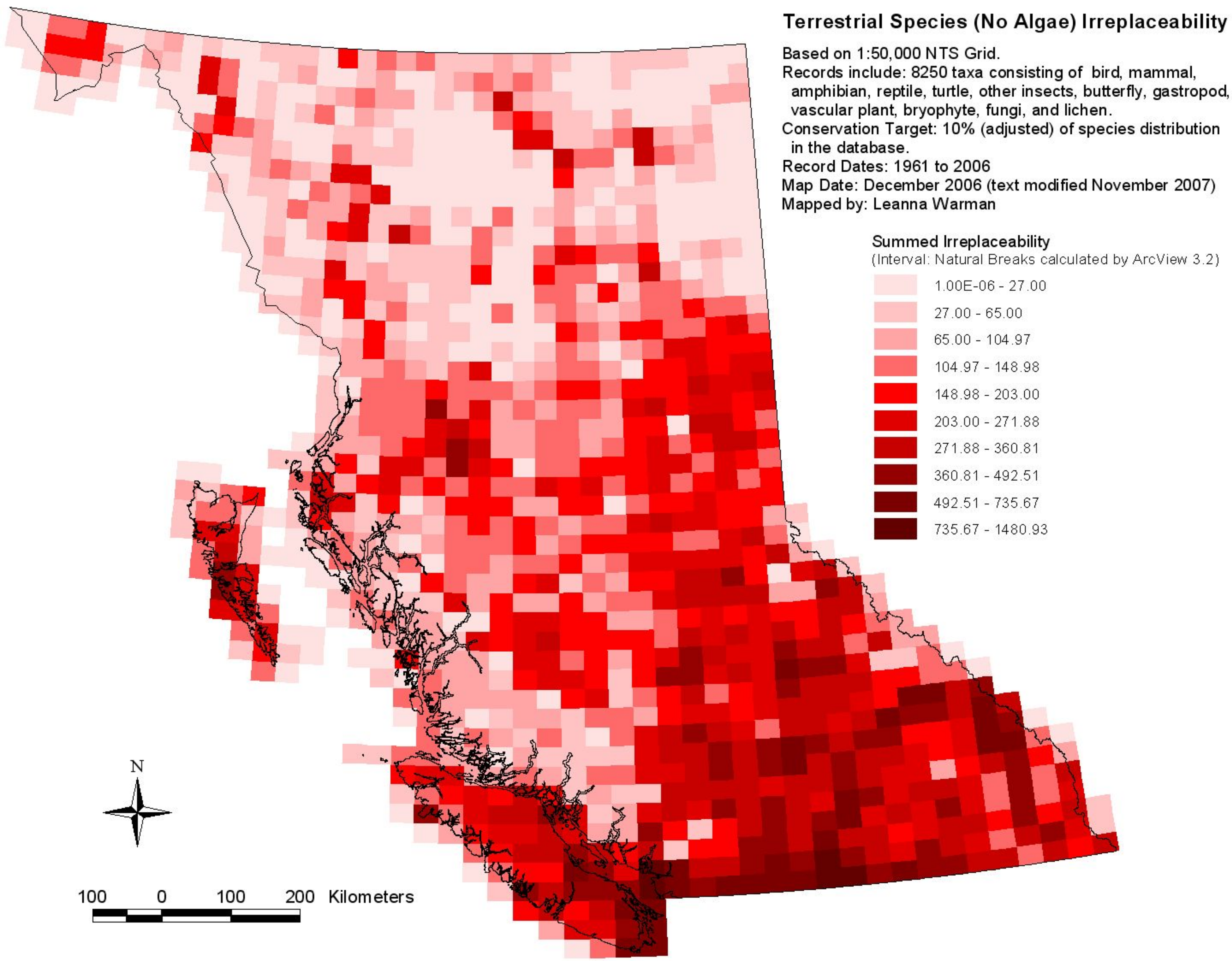
Appendix IVg. Map of summed irreplaceability for all species weighted by S-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



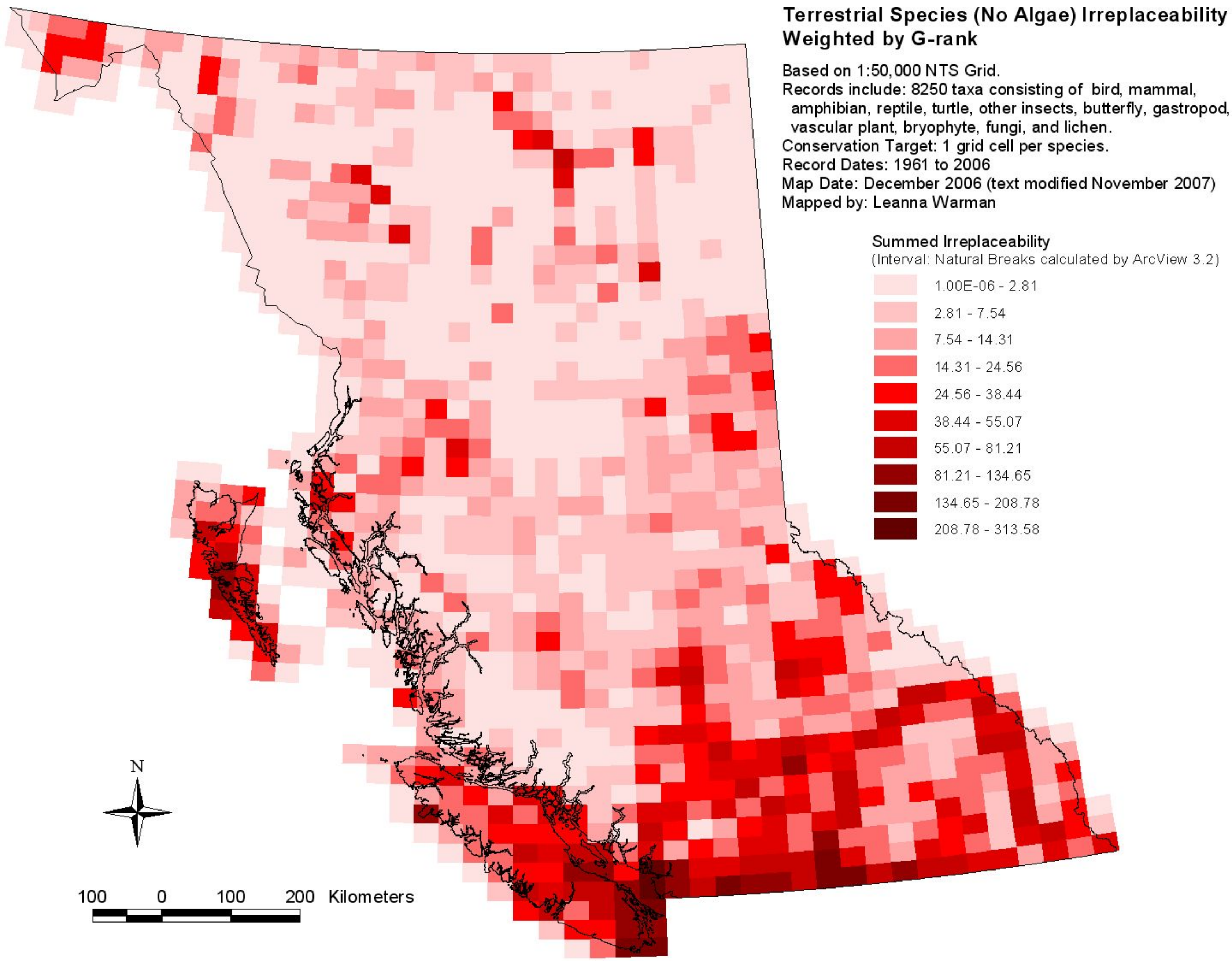
Appendix IVh. Map of summed irreplaceability for terrestrial species with records from 1961 to 2006 with a target of one grid cell for each species.



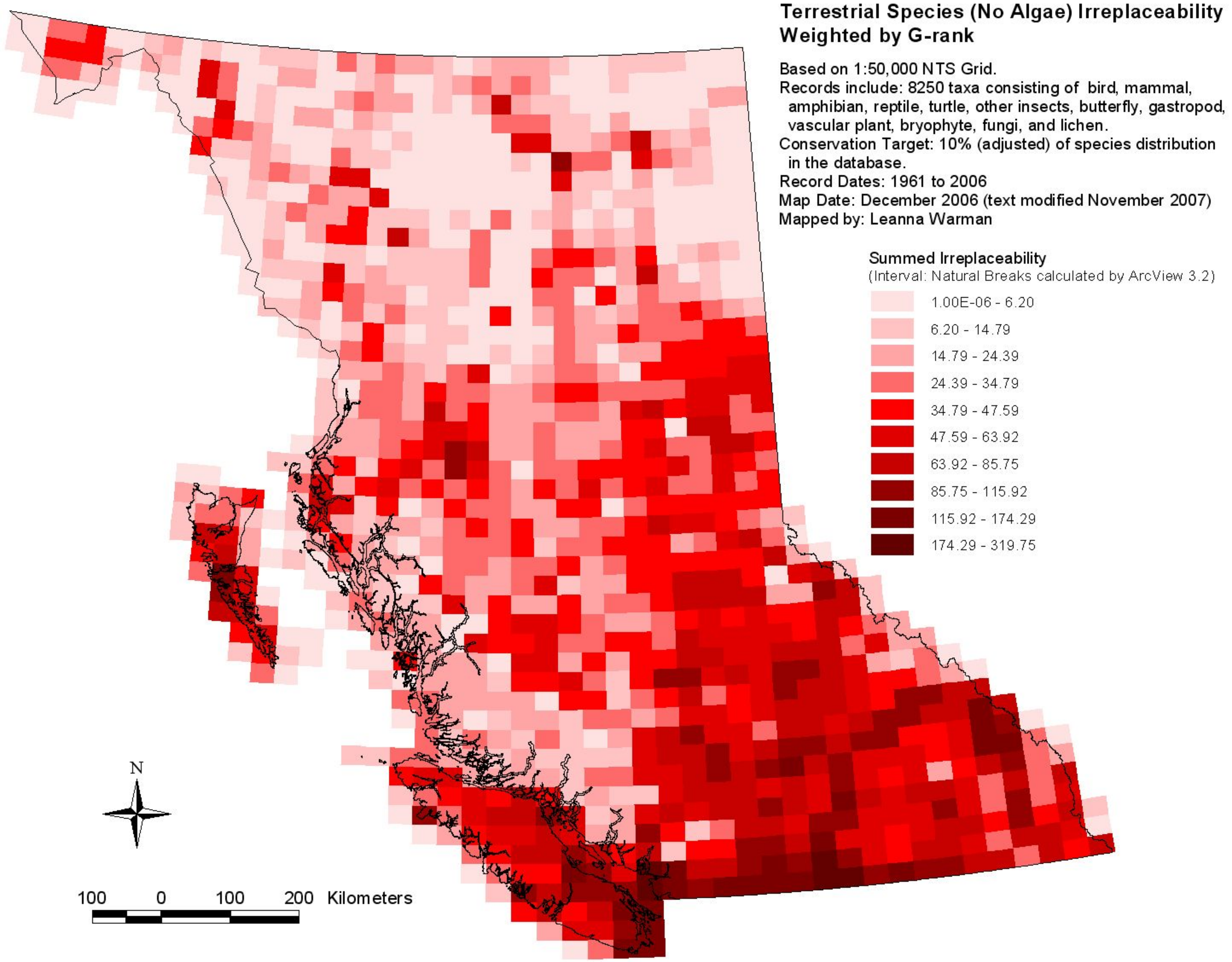
Appendix IVi. Map of summed irreplaceability for terrestrial species excluding algae with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



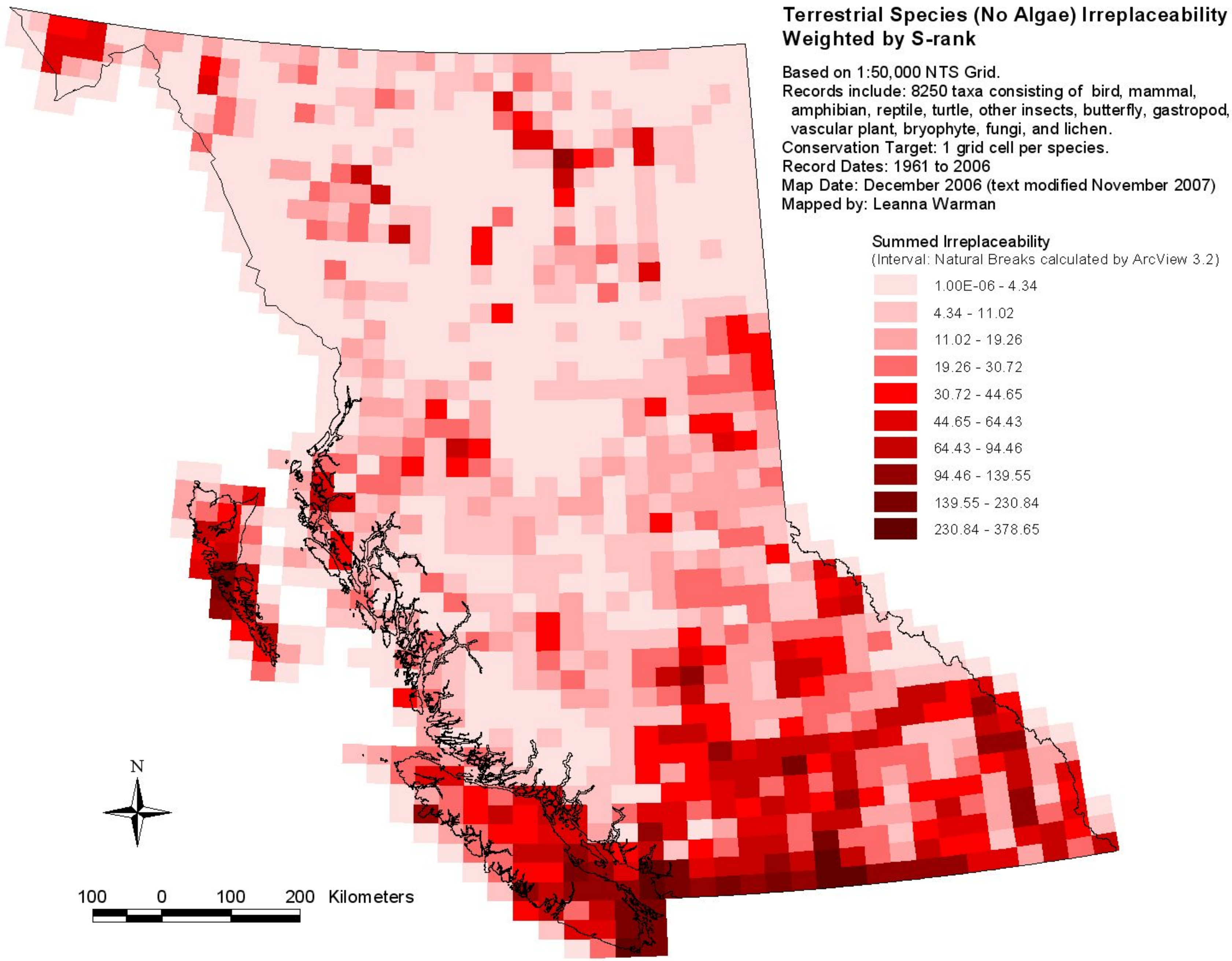
Appendix IVj. Map of summed irreplaceability for terrestrial species excluding algae weighted by G-rank with records from 1961 to 2006 with a target of one grid cell for each species.



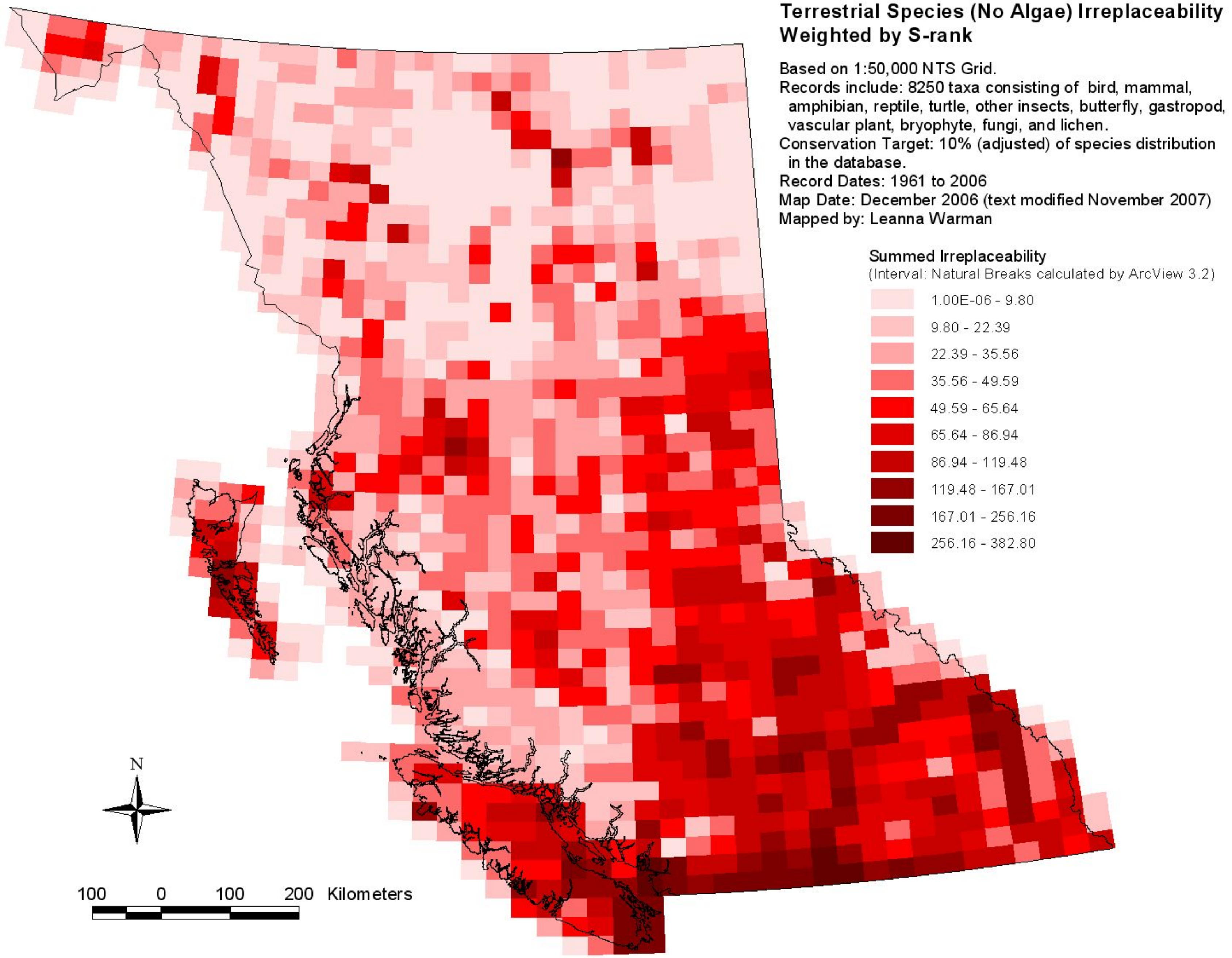
Appendix IVk. Map of summed irreplaceability for terrestrial species excluding algae weighted by G-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



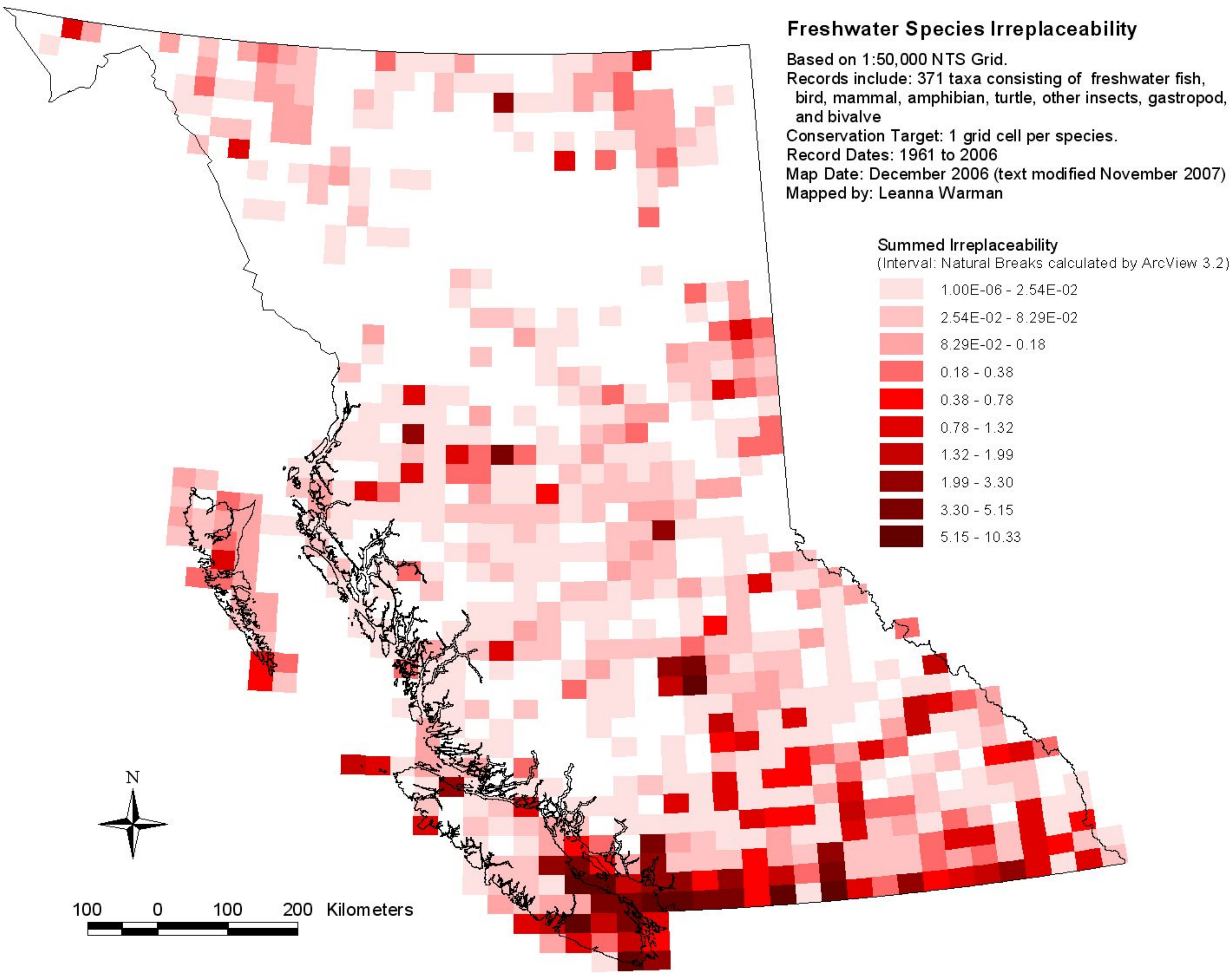
Appendix IVI. Map of summed irreplaceability for terrestrial species excluding algae weighted by S-rank with records from 1961 to 2006 with a target of one grid cell for each species.



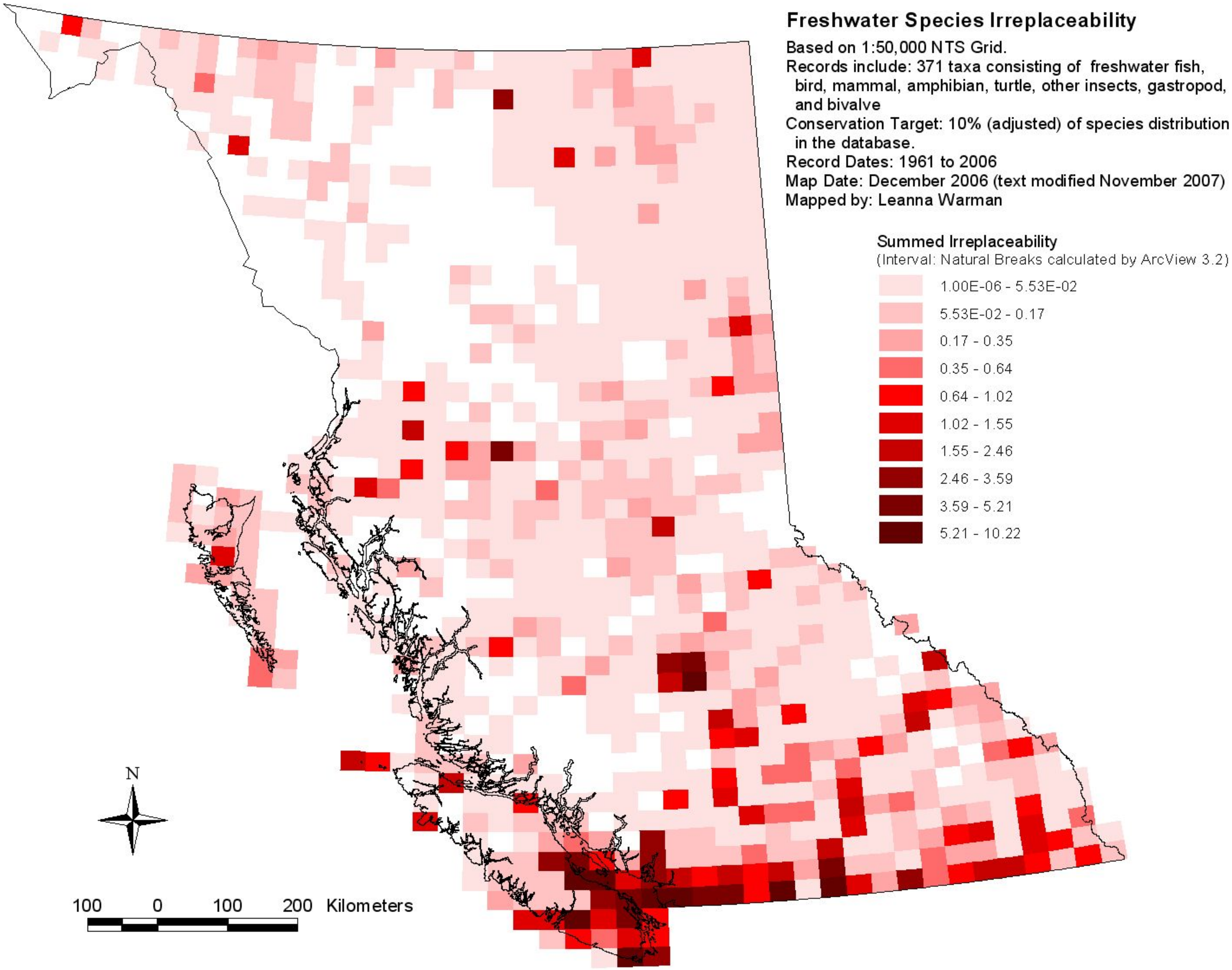
Appendix IVm. Map of summed irreplaceability for terrestrial species excluding algae weighted by S-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



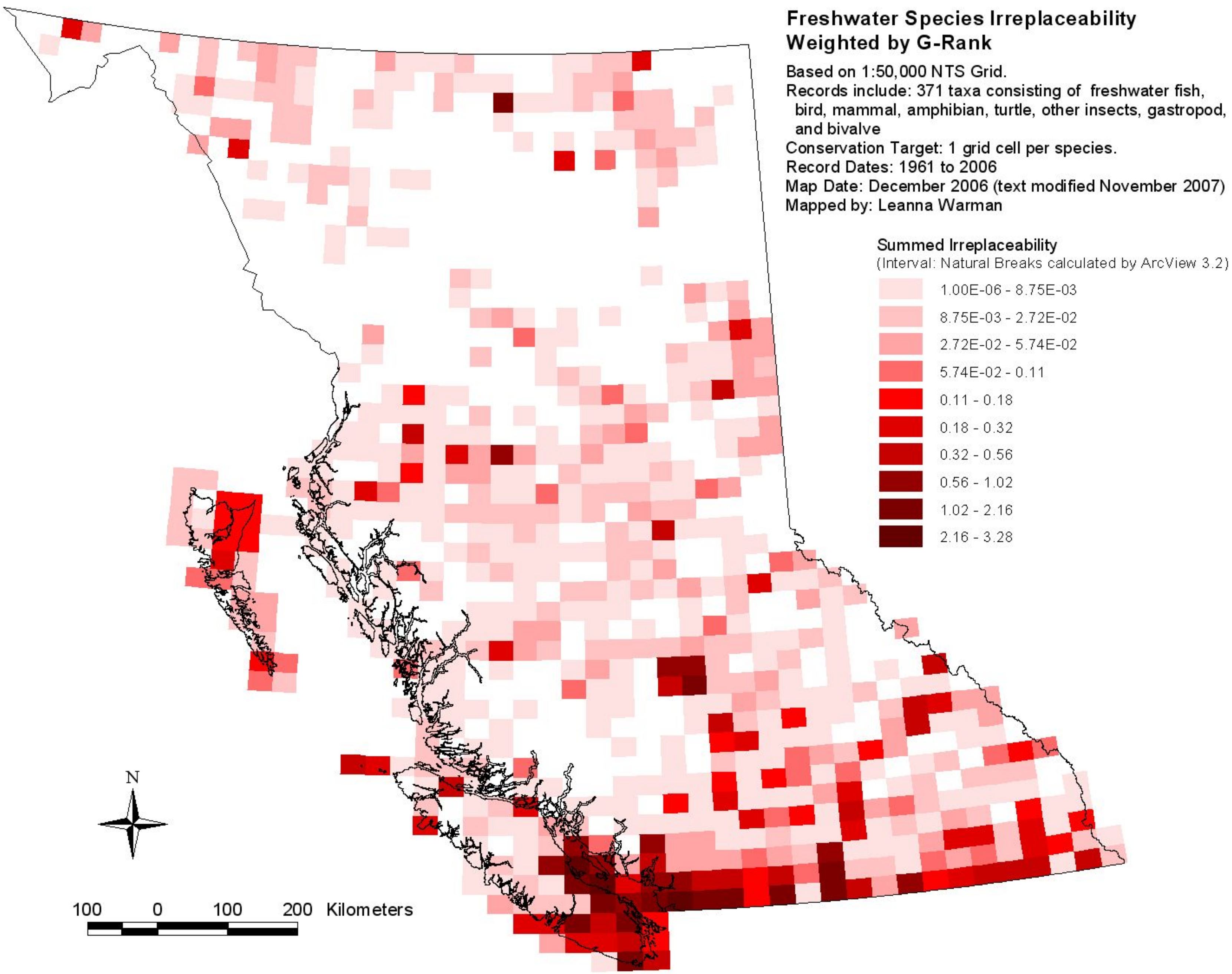
Appendix IVn. Map of summed irreplaceability for freshwater species with records from 1961 to 2006 with a target of one grid cell for each species.



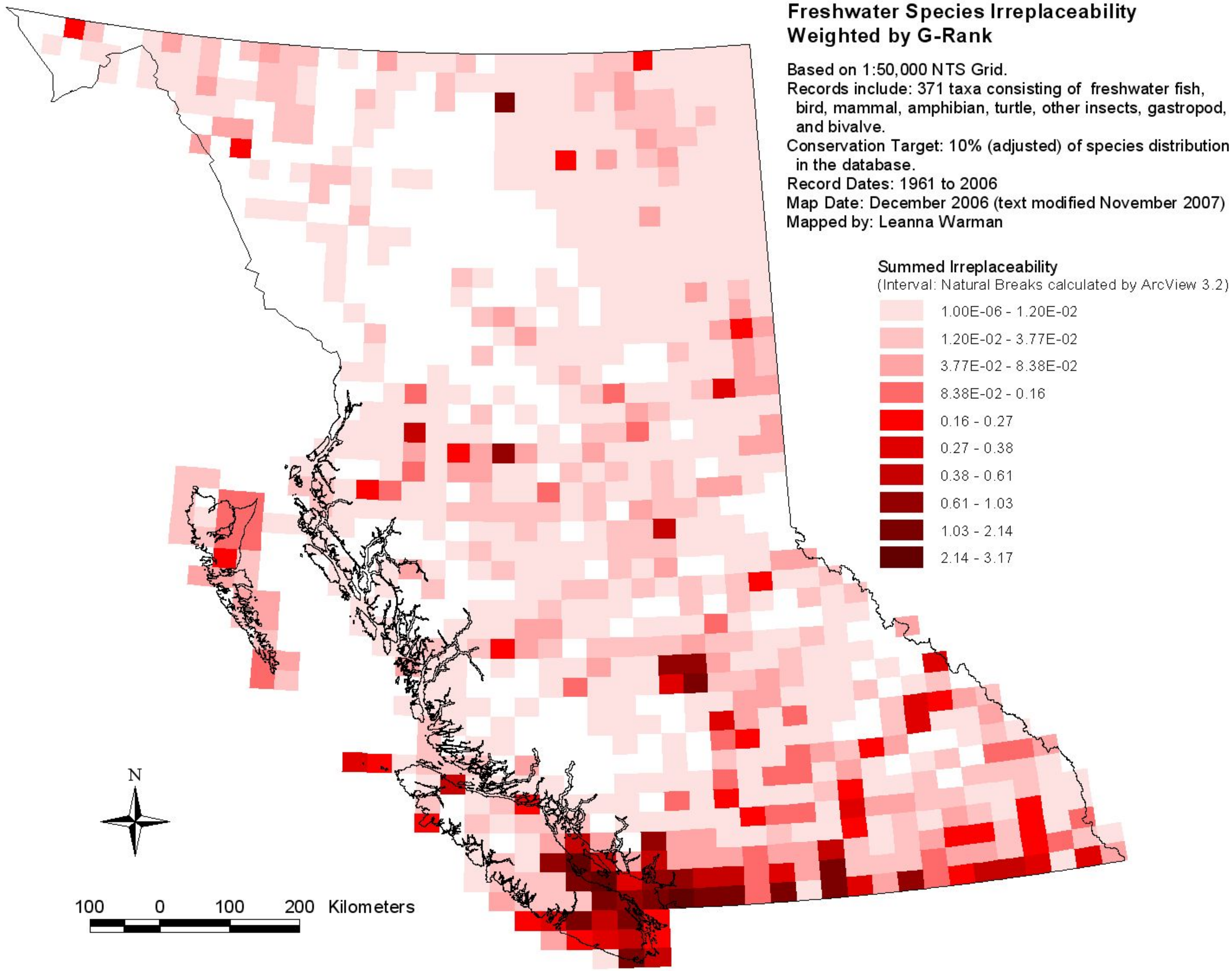
Appendix IVo. Map of summed irreplaceability for freshwater species with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



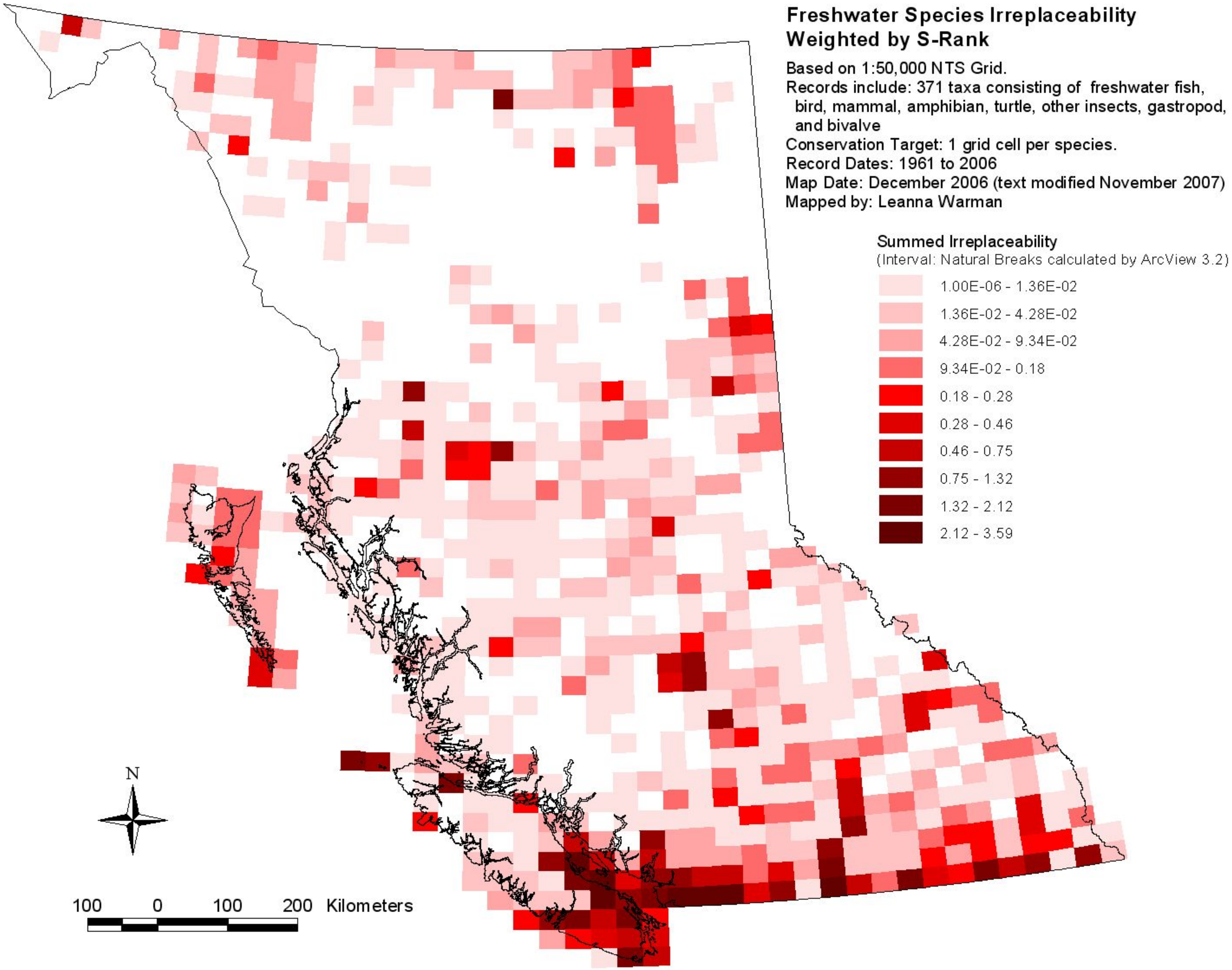
Appendix IVp. Map of summed irreplaceability for freshwater species weighted by G-rank with records from 1961 to 2006 with a target of one grid cell for each species.



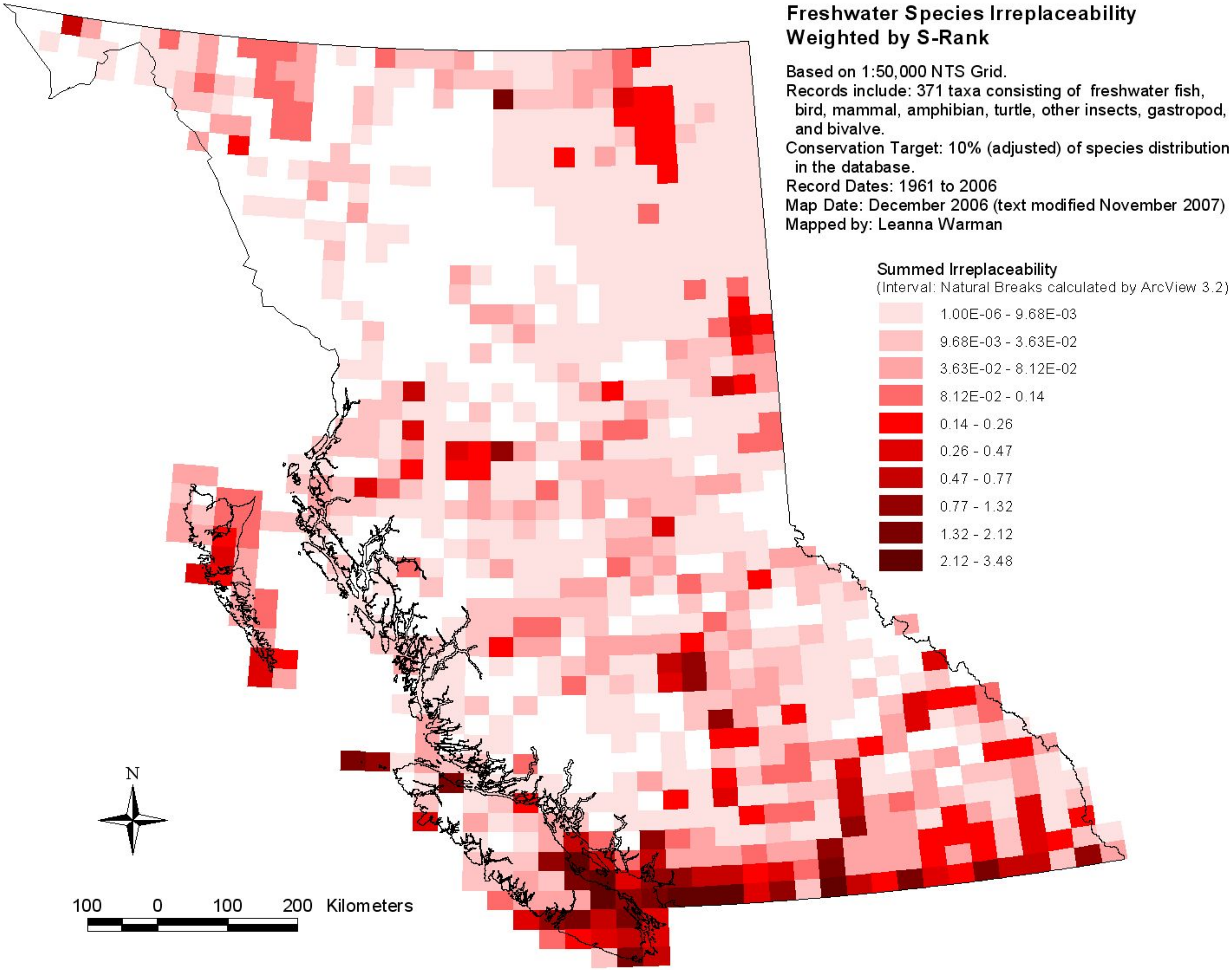
Appendix IVq. Map of summed irreplaceability for freshwater species weighted by G-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



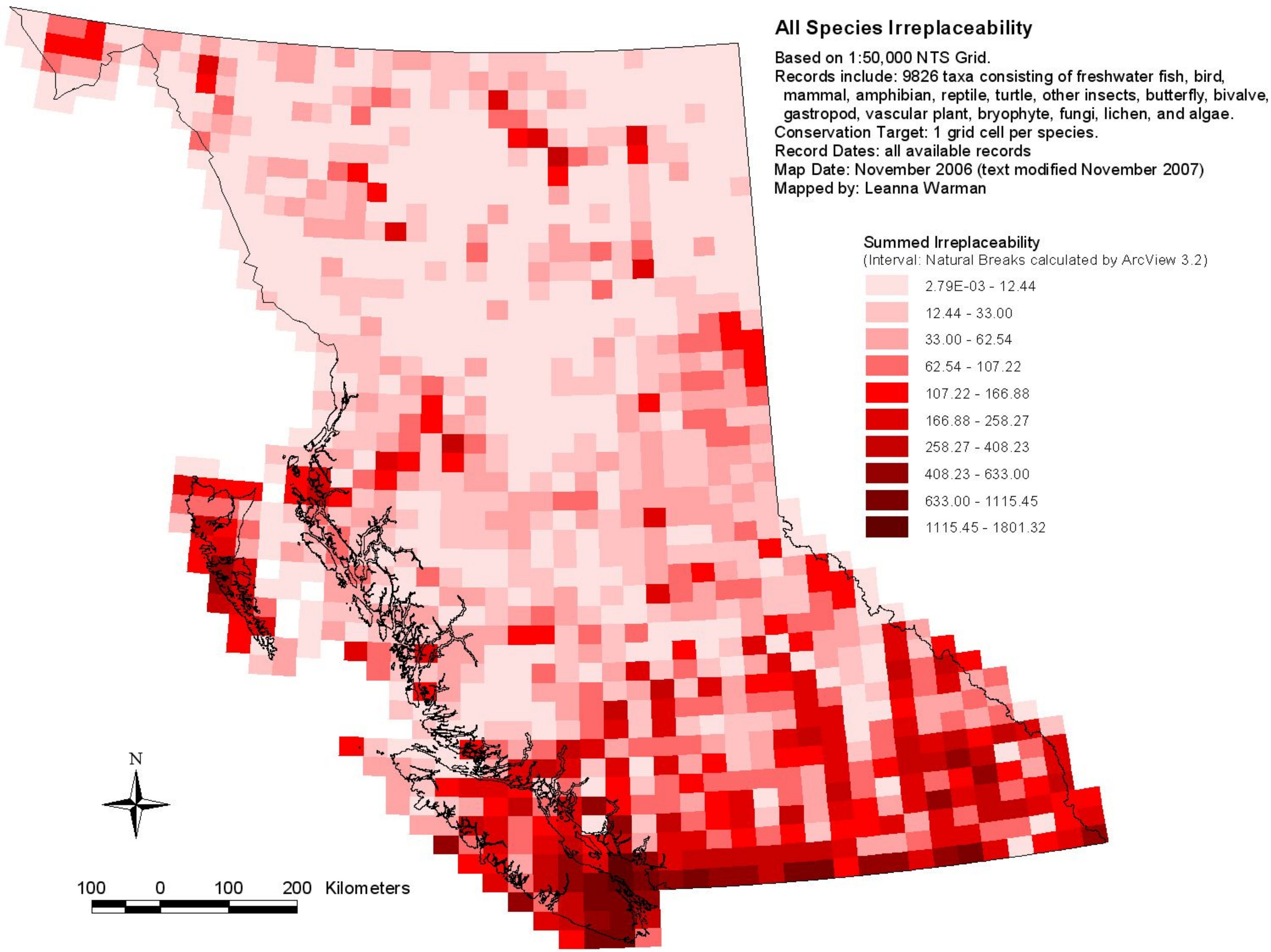
Appendix IVr. Map of summed irreplaceability for freshwater species weighted by S-rank with records from 1961 to 2006 with a target of one grid cell for each species.



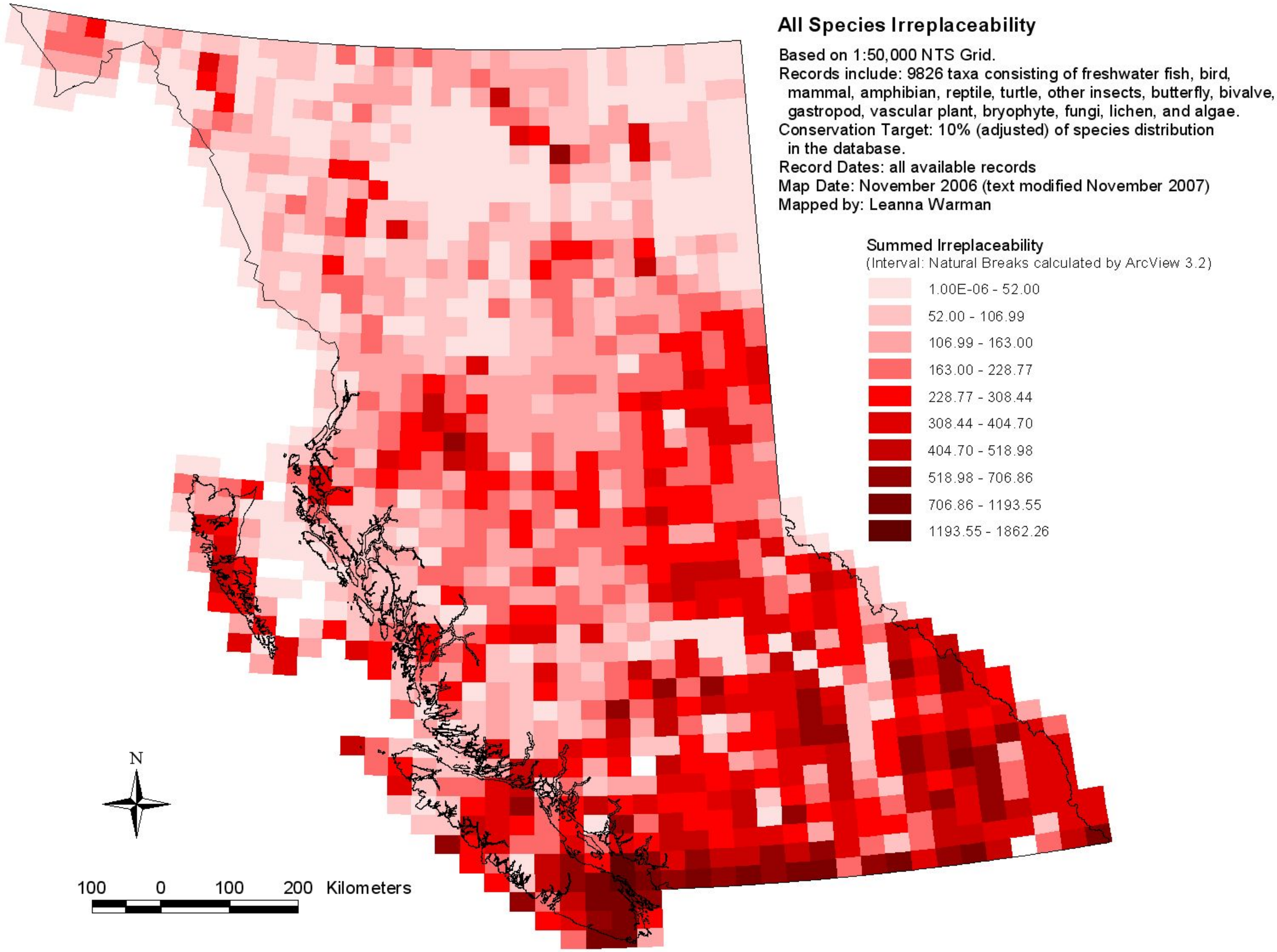
Appendix IVs. Map of summed irreplaceability for freshwater species weighted by S-rank with records from 1961 to 2006 with a target of 10% (adjusted) of each species' extent in the database.



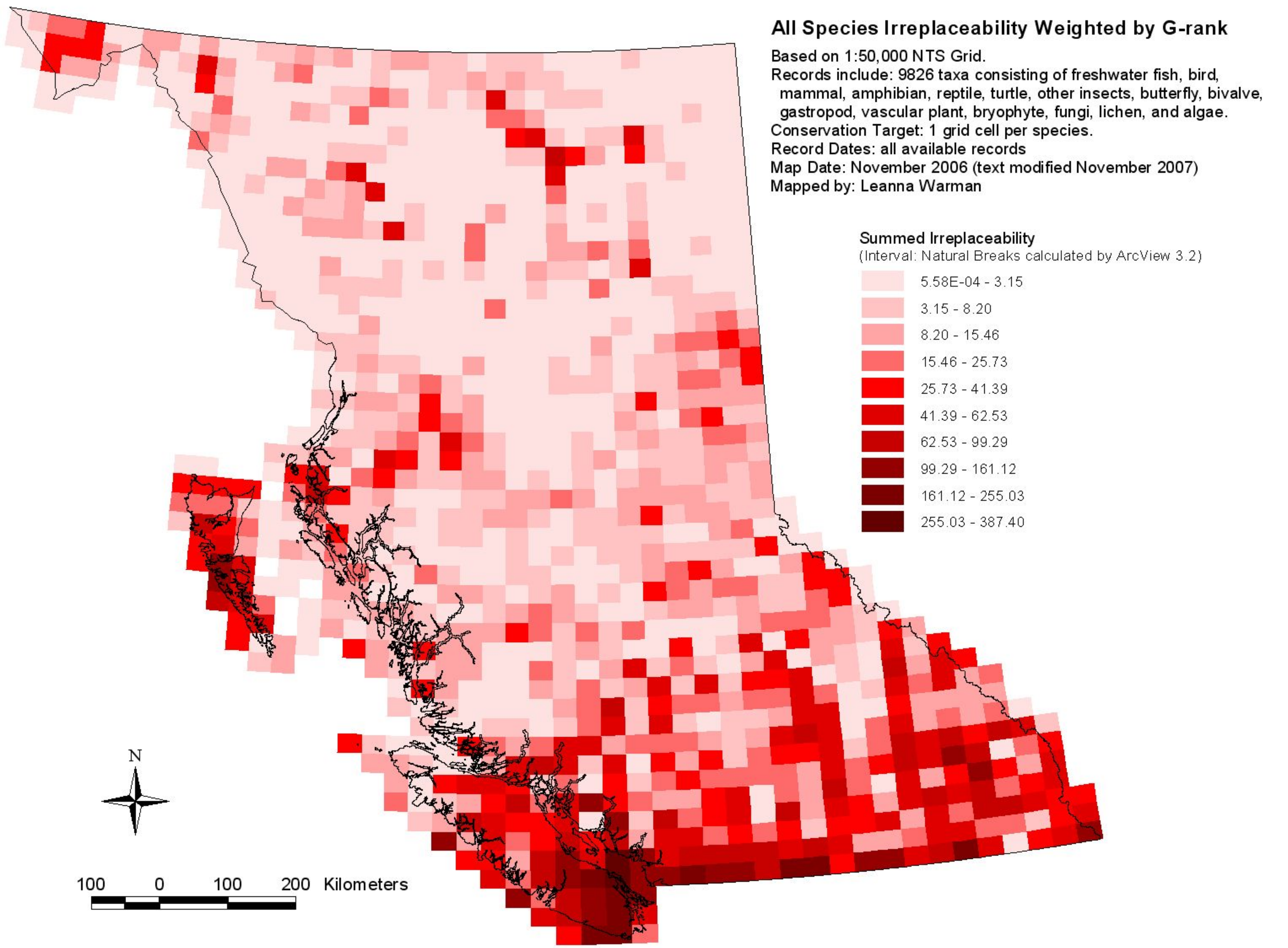
Appendix Va. Map of summed irreplaceability for all species with all records (i.e. all dates) with a target of one grid cell for each species.



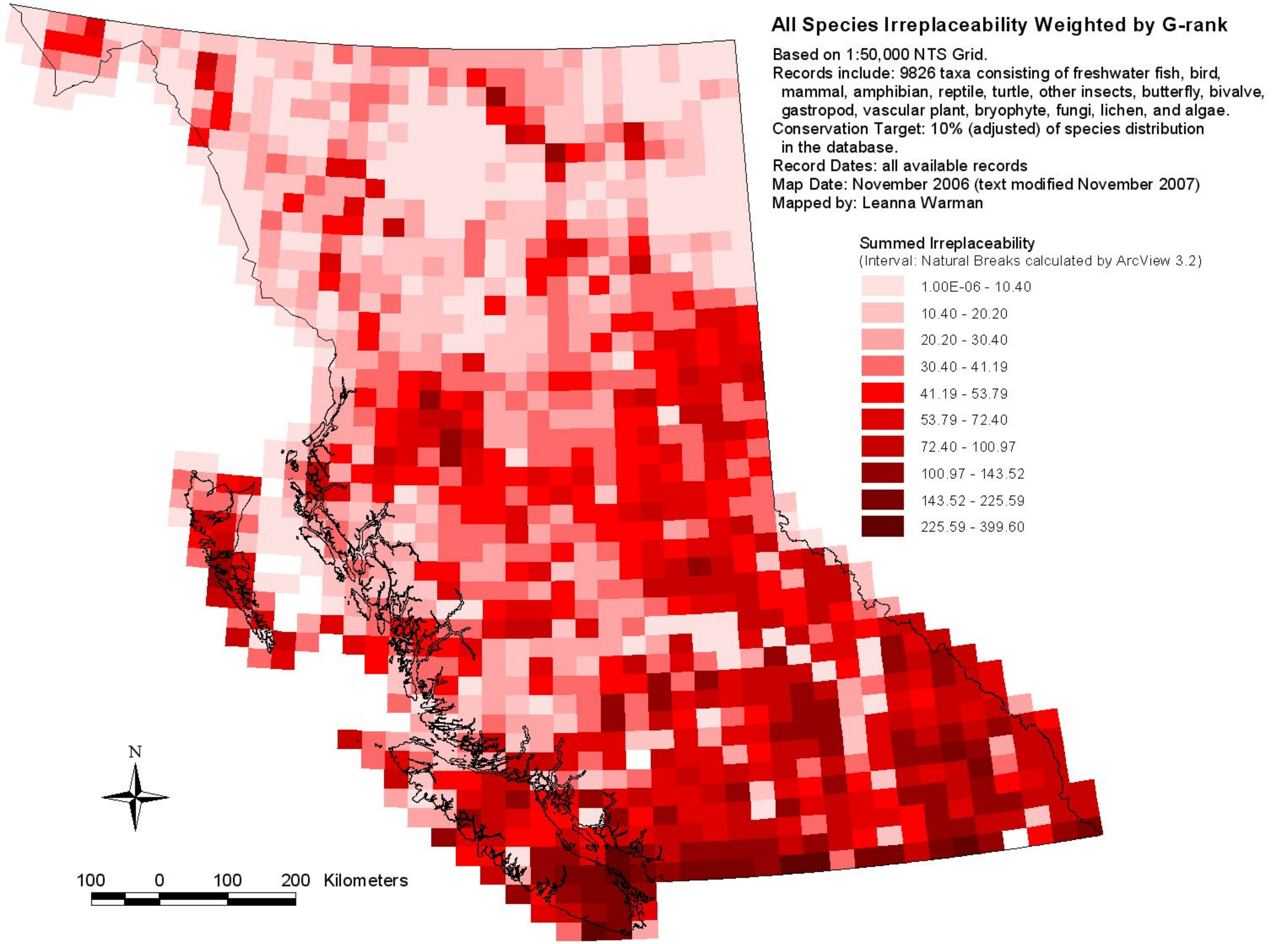
Appendix Vb. Map of summed irreplaceability for all species with all records (i.e. all dates) with a target of 10% (adjusted) of each species' extent in the database.



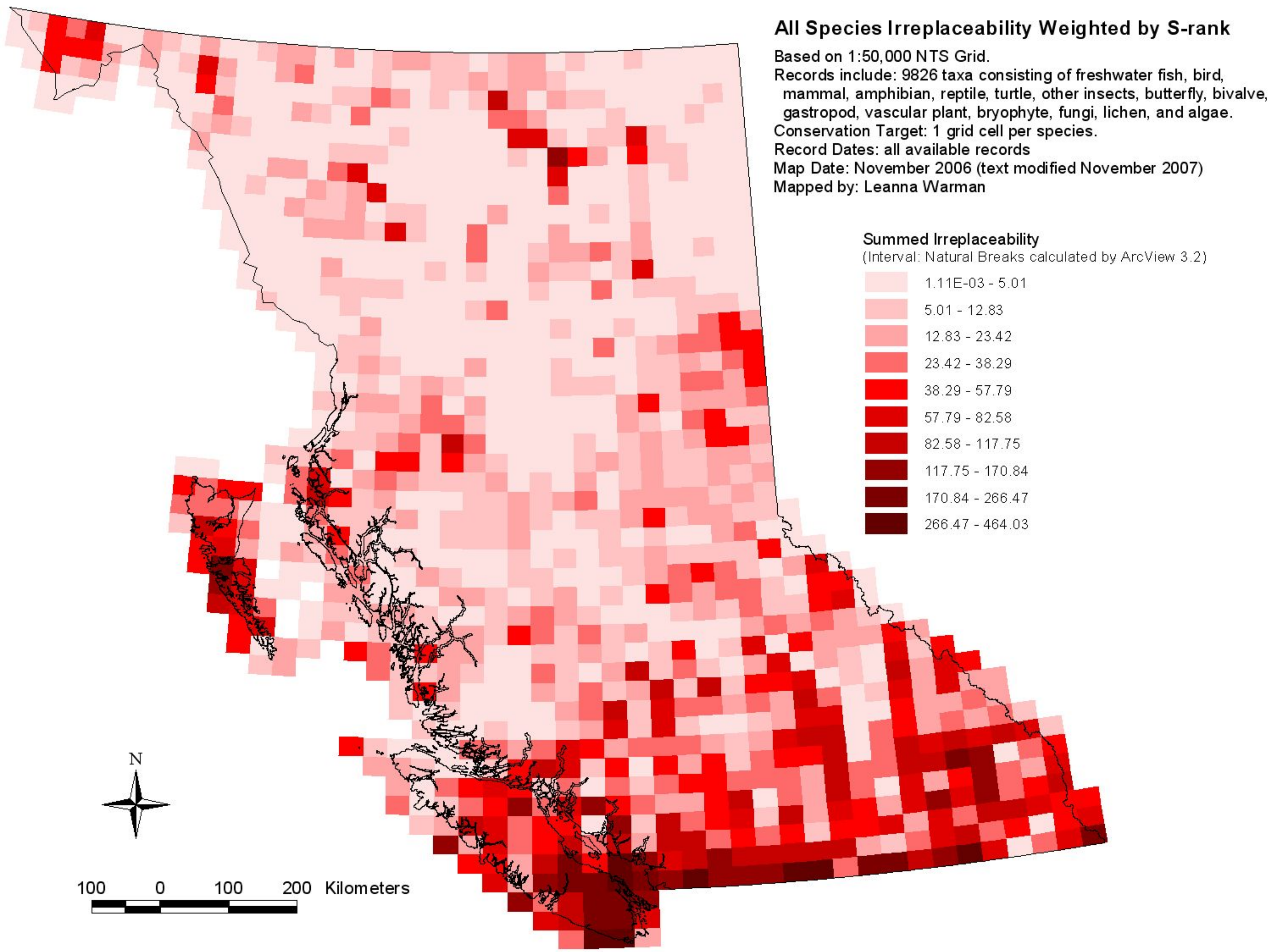
Appendix Vc. Map of summed irreplaceability for all species weighted by G-rank with all records (i.e. all dates) with a target of one grid cell for each species.



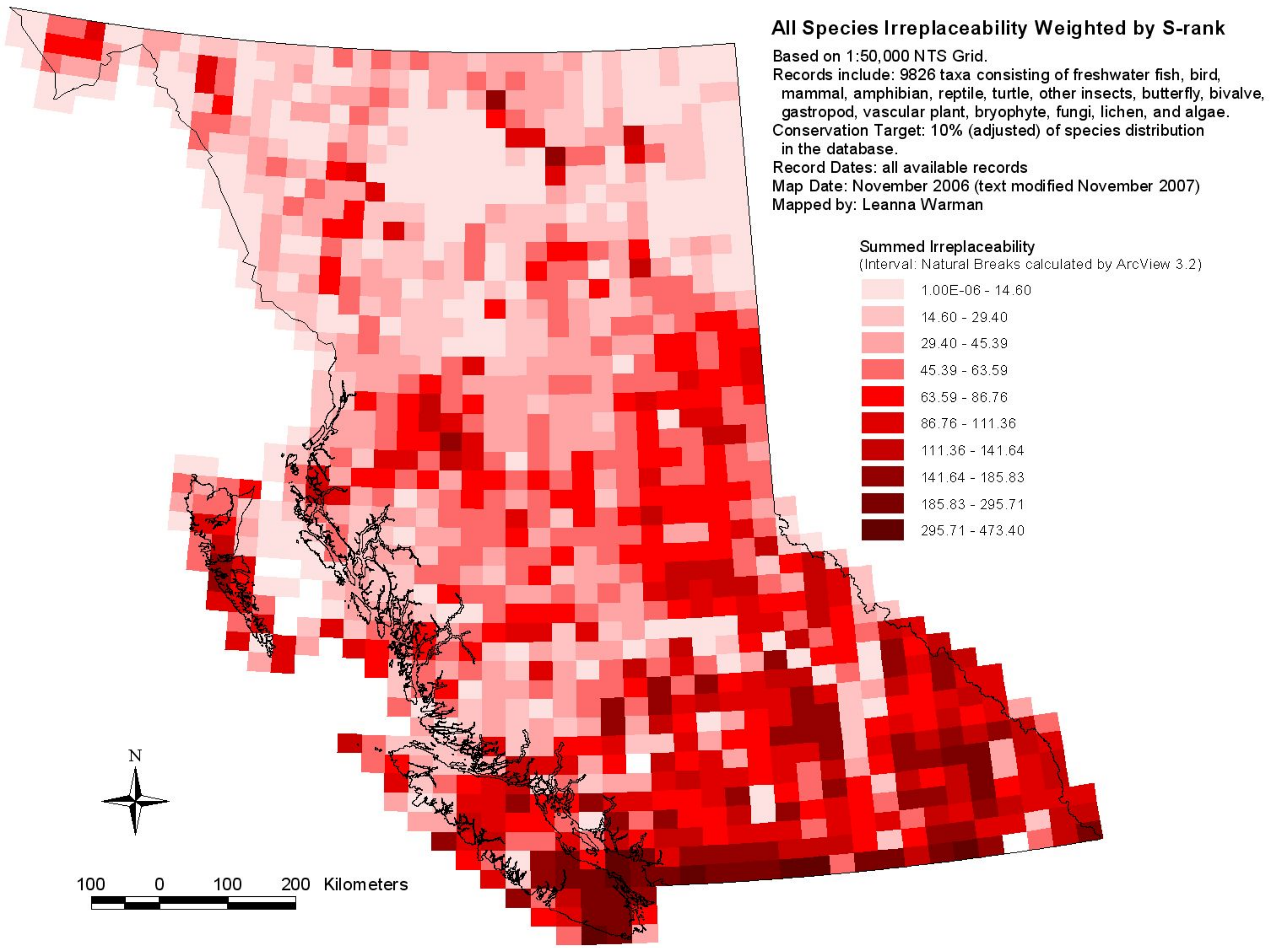
Appendix Vd. Map of summed irreplaceability for all species weighted by G-rank with all records (i.e. all dates) with a target of 10% (adjusted) of each species' extent in the database.



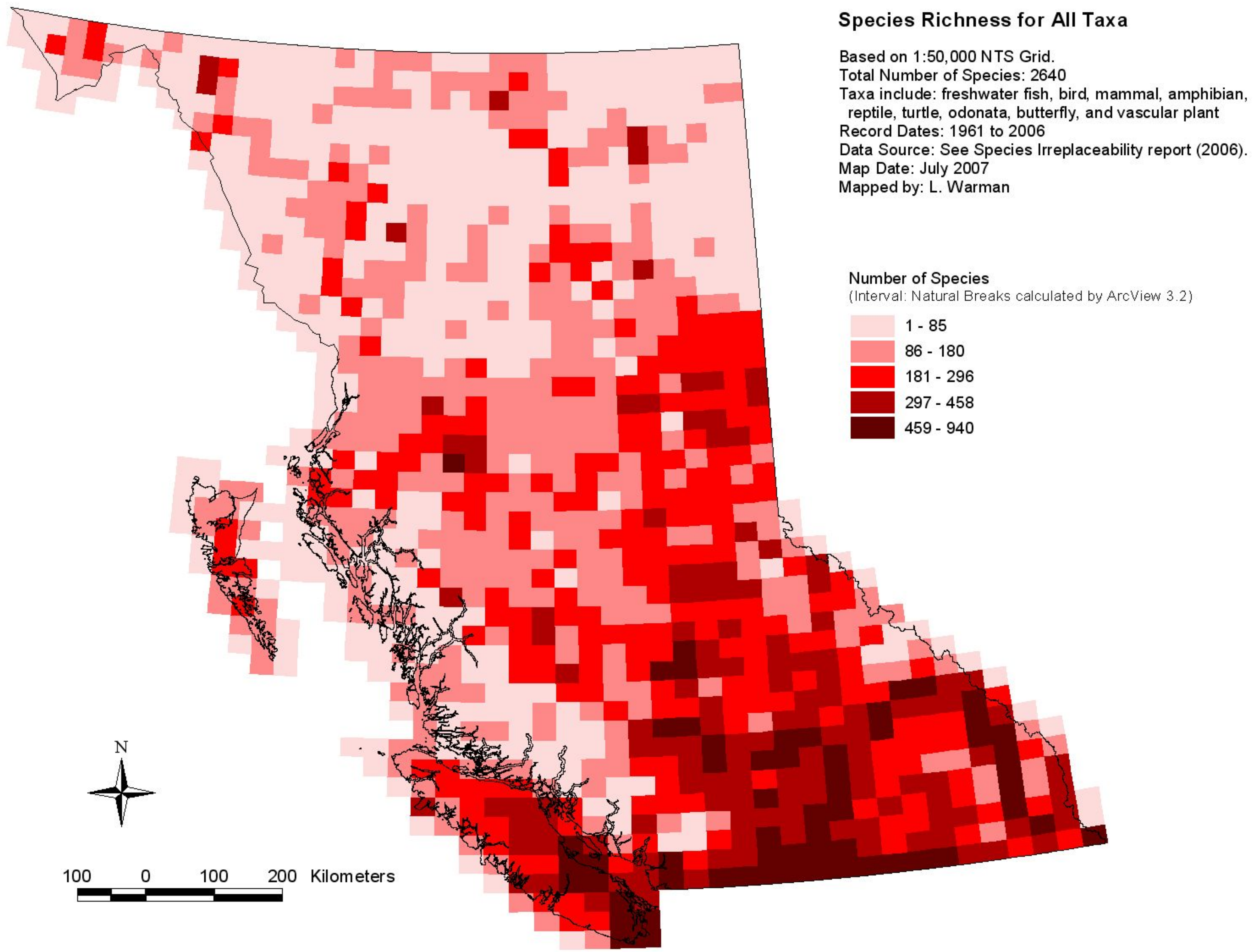
Appendix Ve. Map of summed irreplaceability for all species weighted by S-rank with all records (i.e. all dates) with a target of one grid cell for each species.



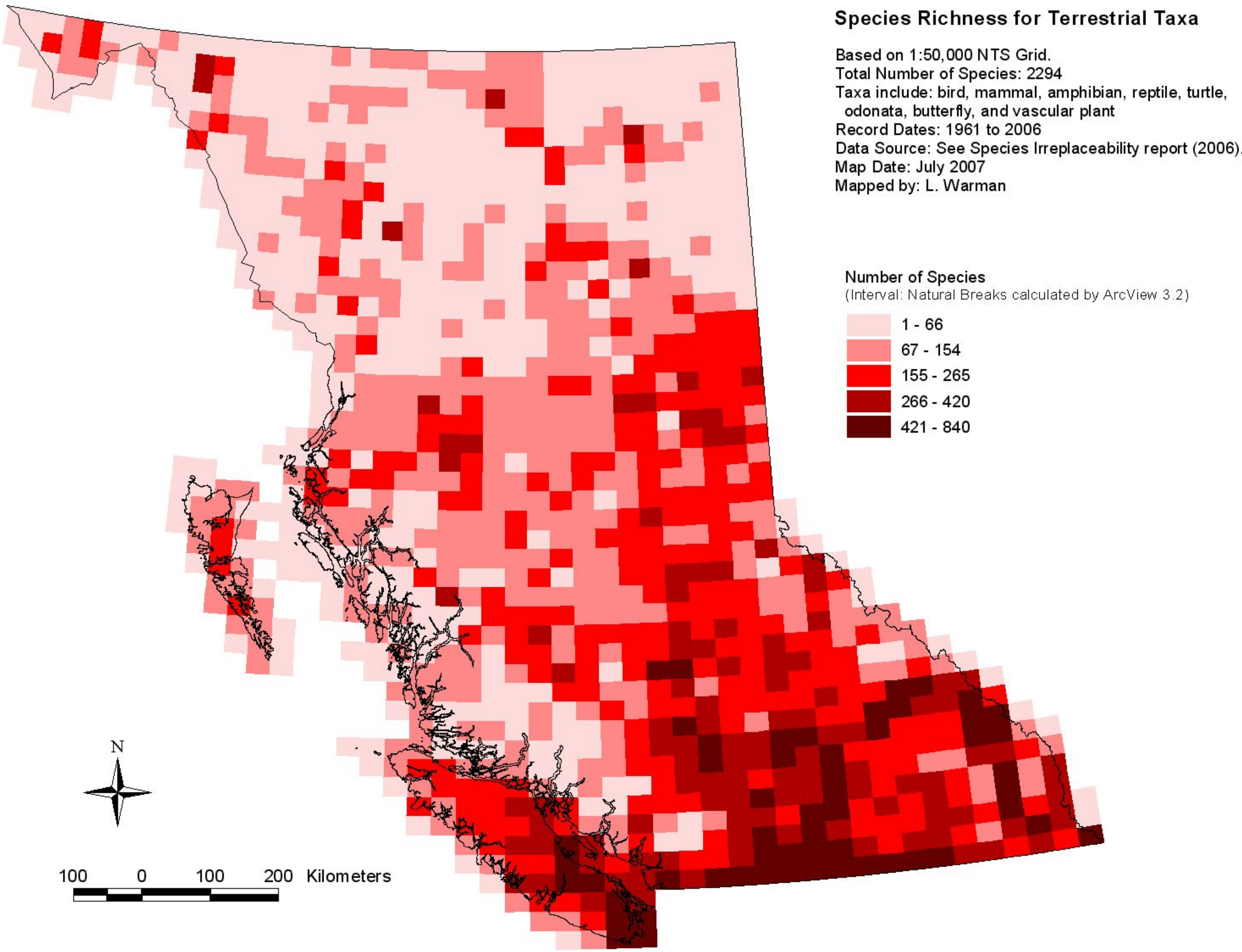
Appendix Vf. Map of summed irreplaceability for all species weighted by S-rank with all records (i.e. all dates) with a target of 10% (adjusted) of each species' extent in the database.



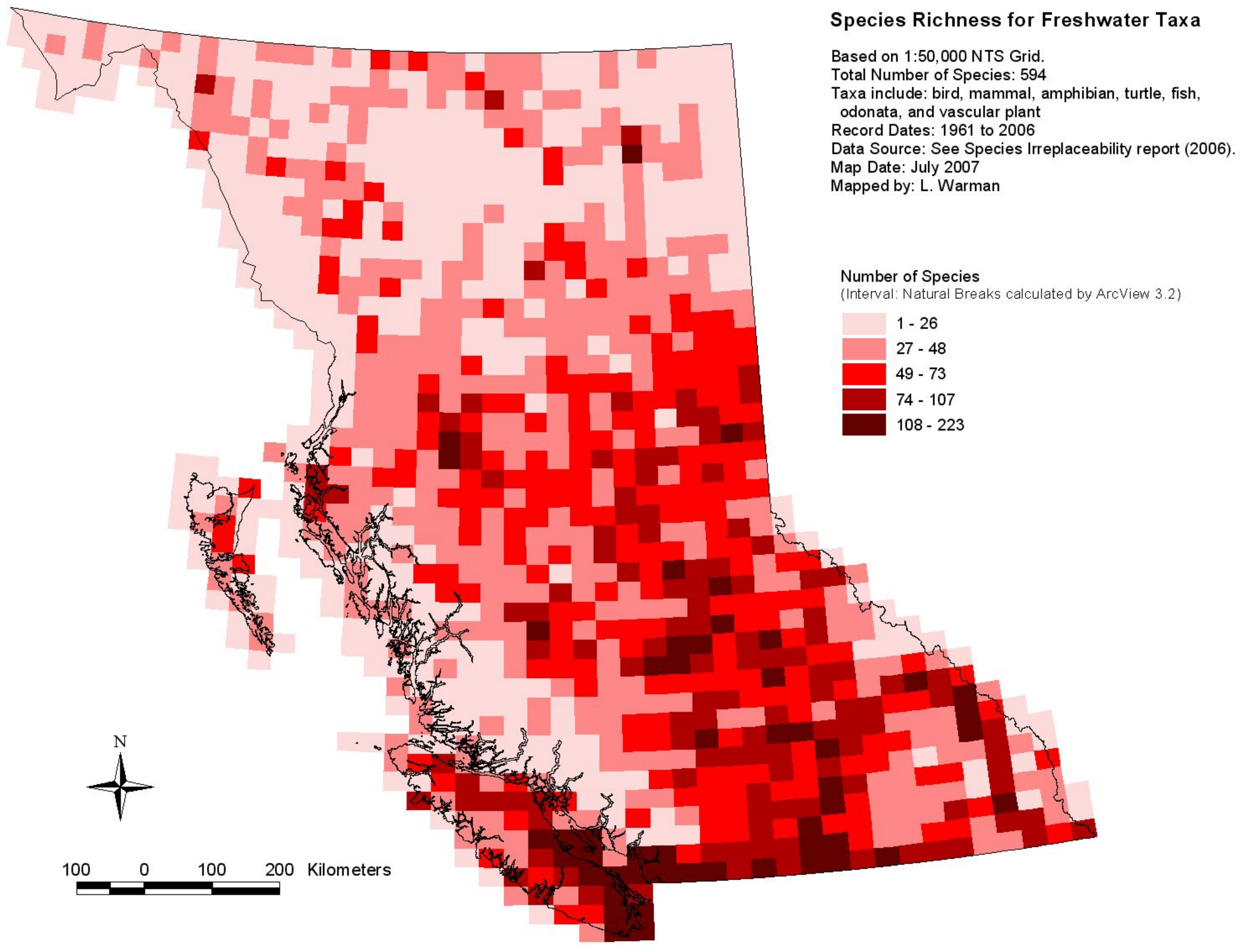
Appendix VIa. Species richness for all taxa in select species groups.



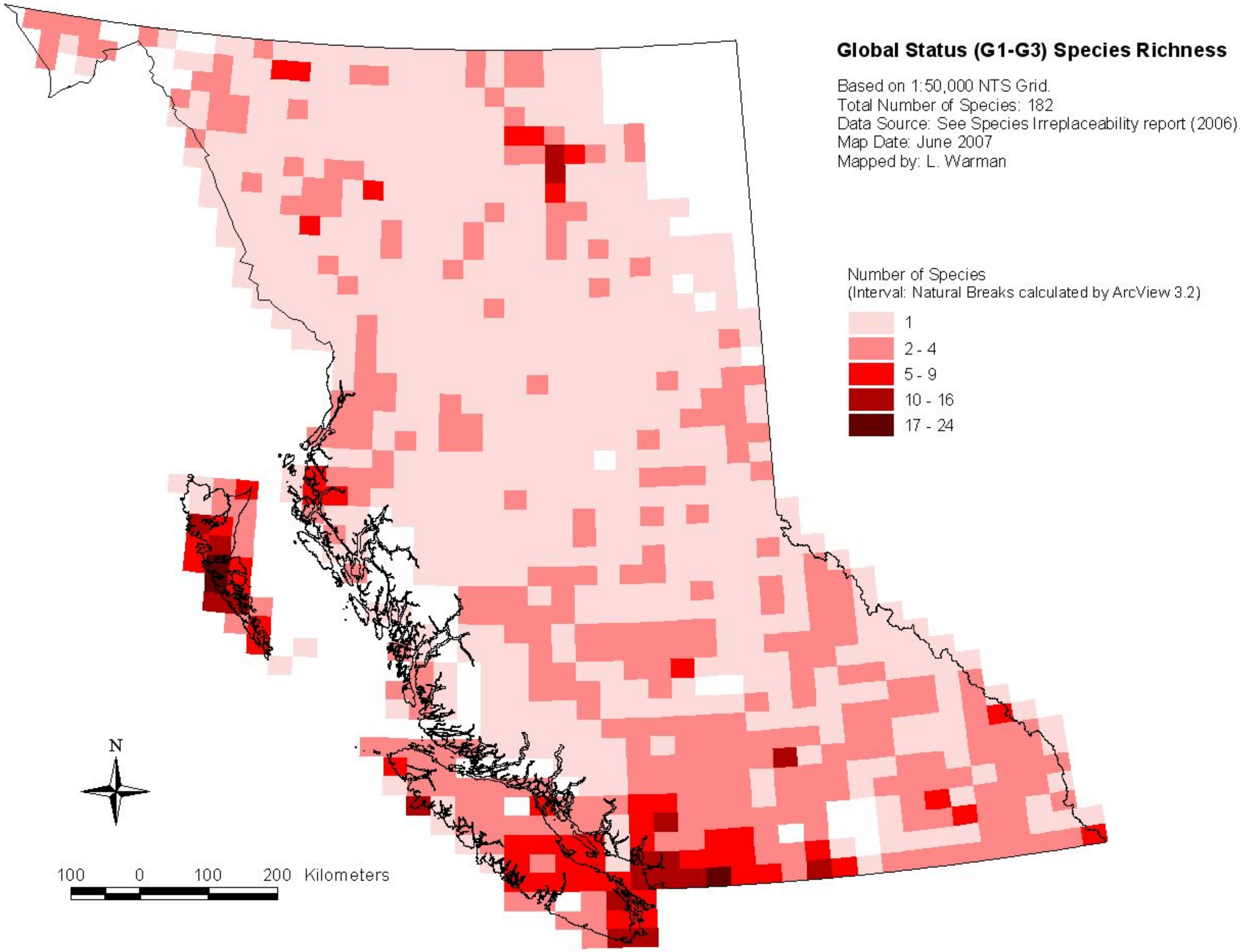
Appendix VIb. Species richness for terrestrial taxa from select species groups.



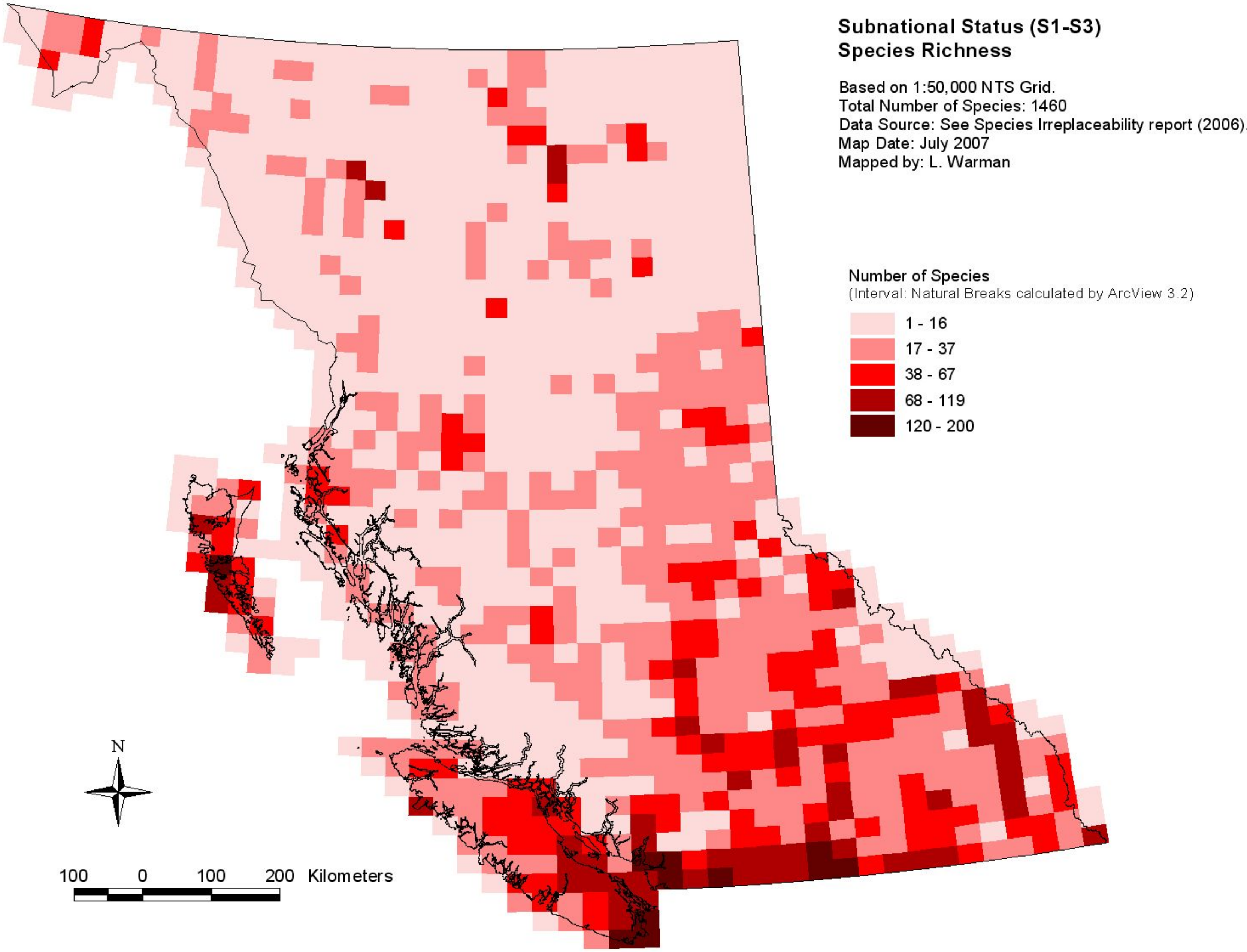
Appendix VIc. Species richness for freshwater taxa from select species groups.



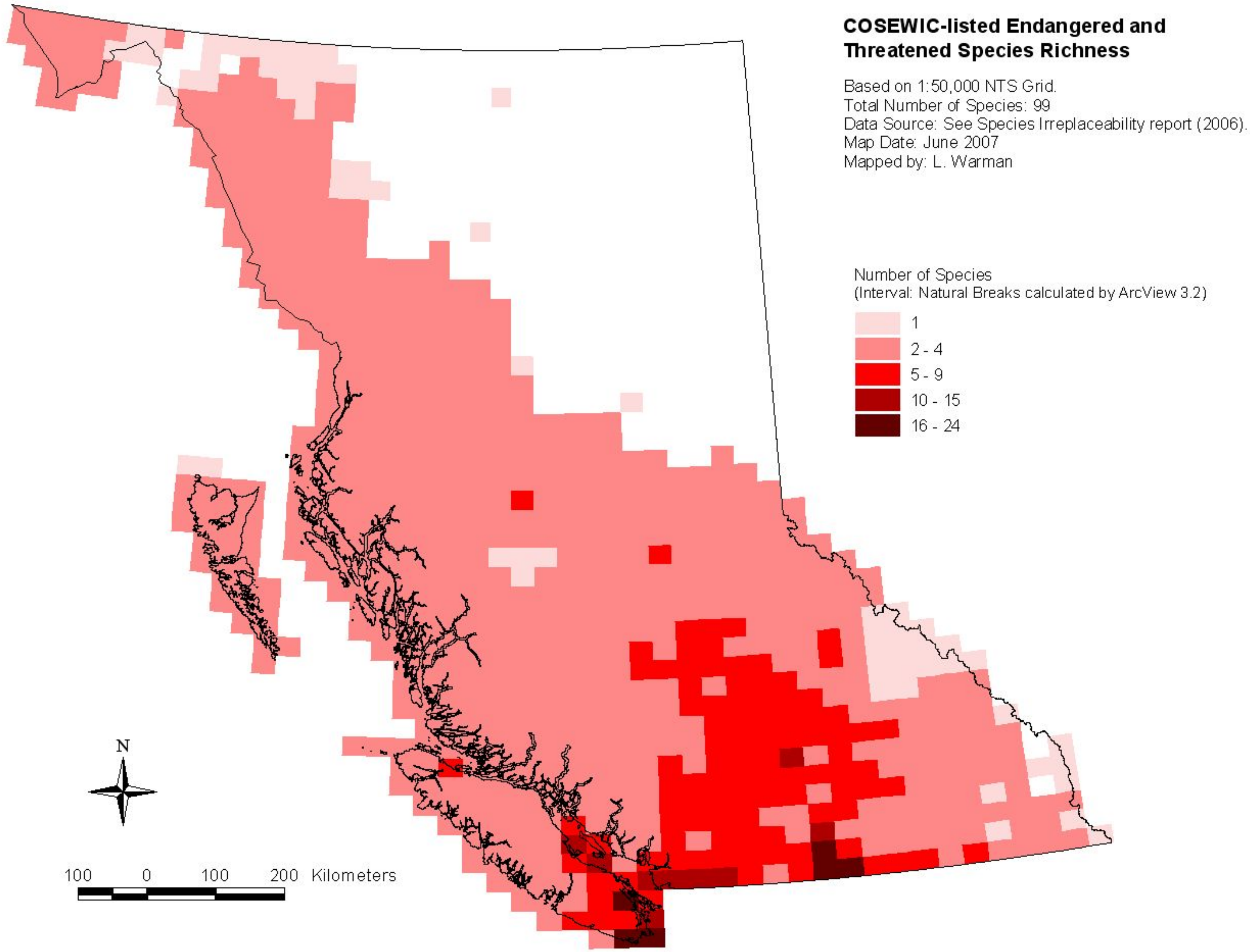
Appendix VId. Species richness for taxa with global ranks of G1, G2, or G3.



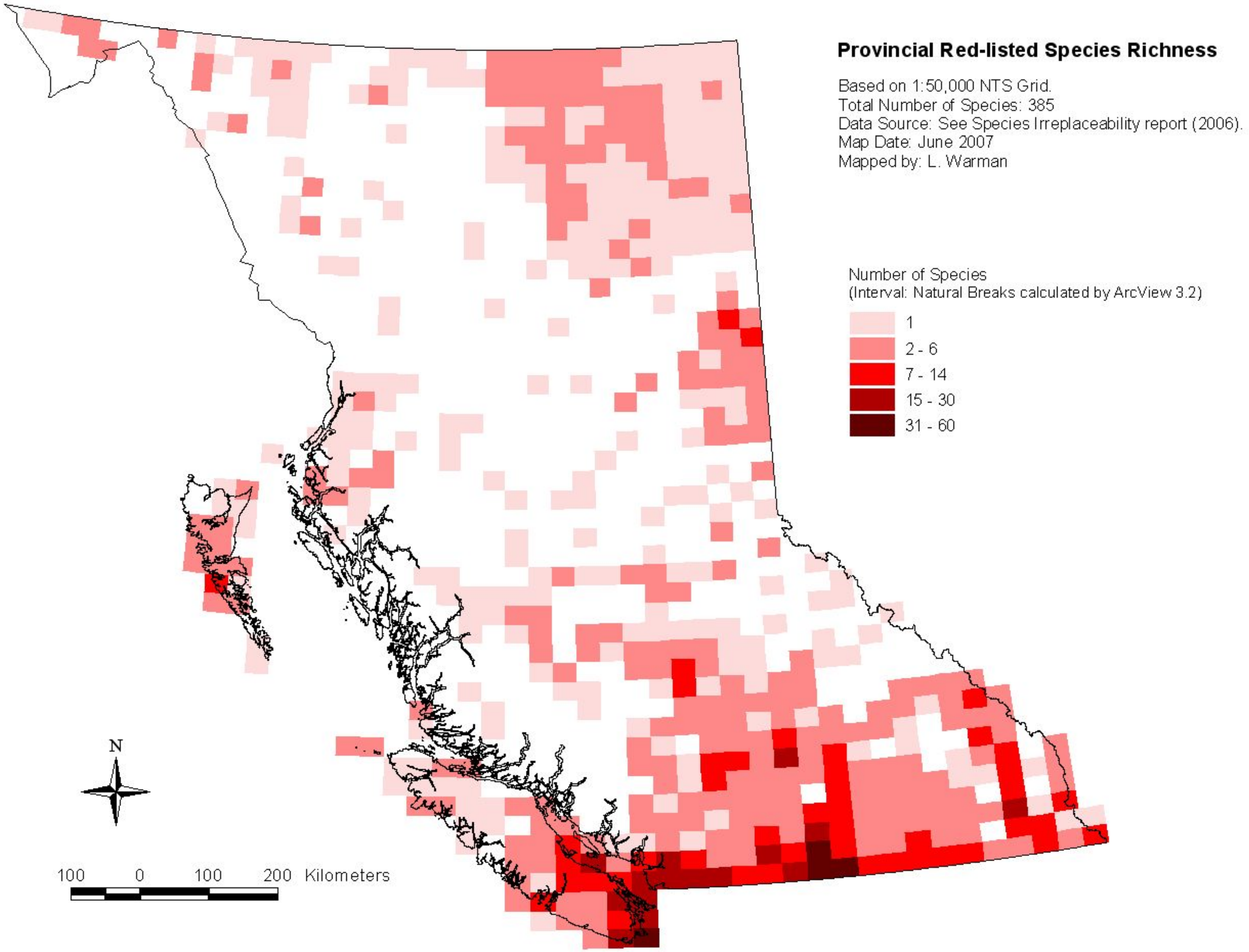
Appendix VIe. Species richness for taxa with sub-national (provincial) ranks of S1, S2, or S3.



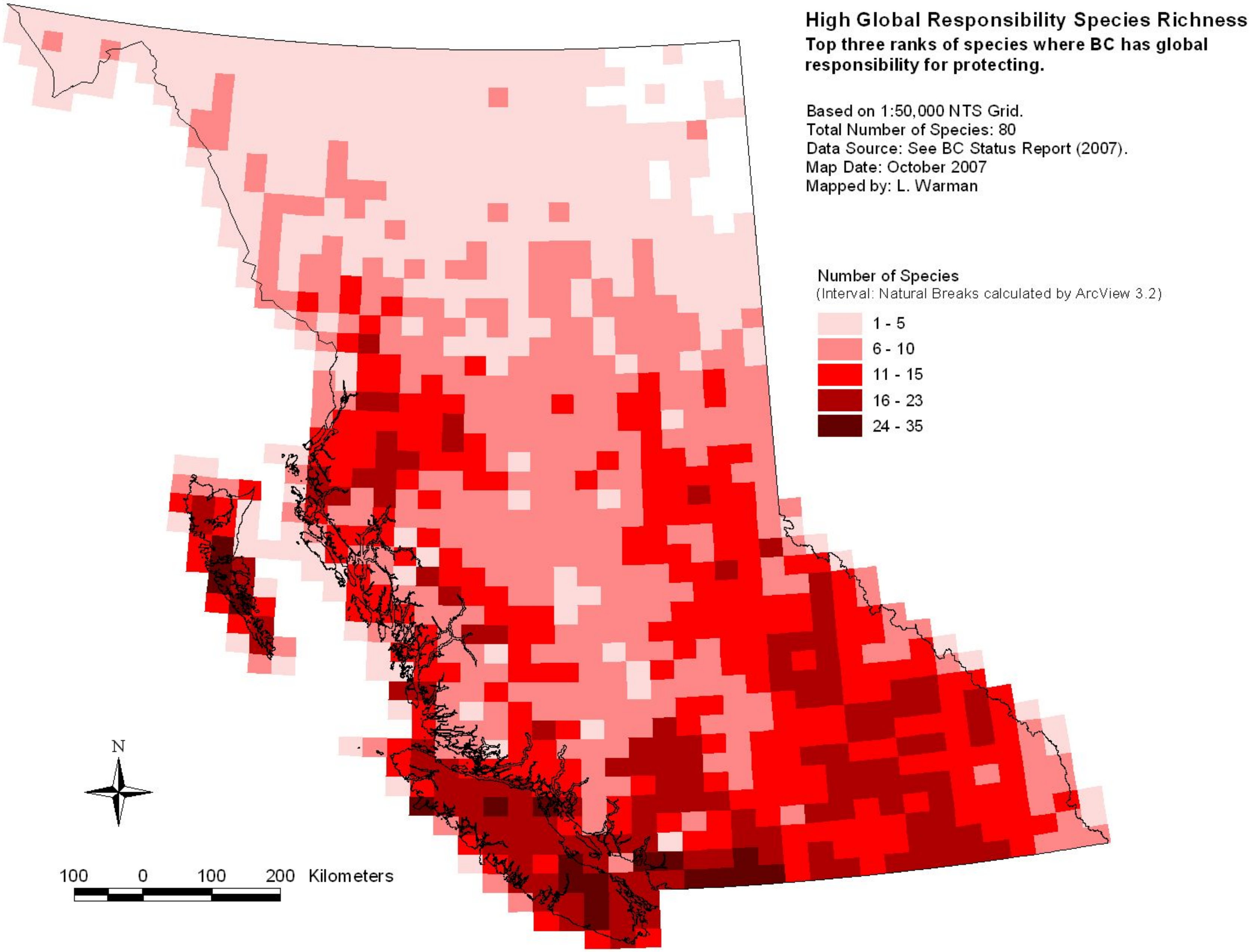
Appendix VIf. Species richness for taxa listed as endangered or threatened by COSEWIC.



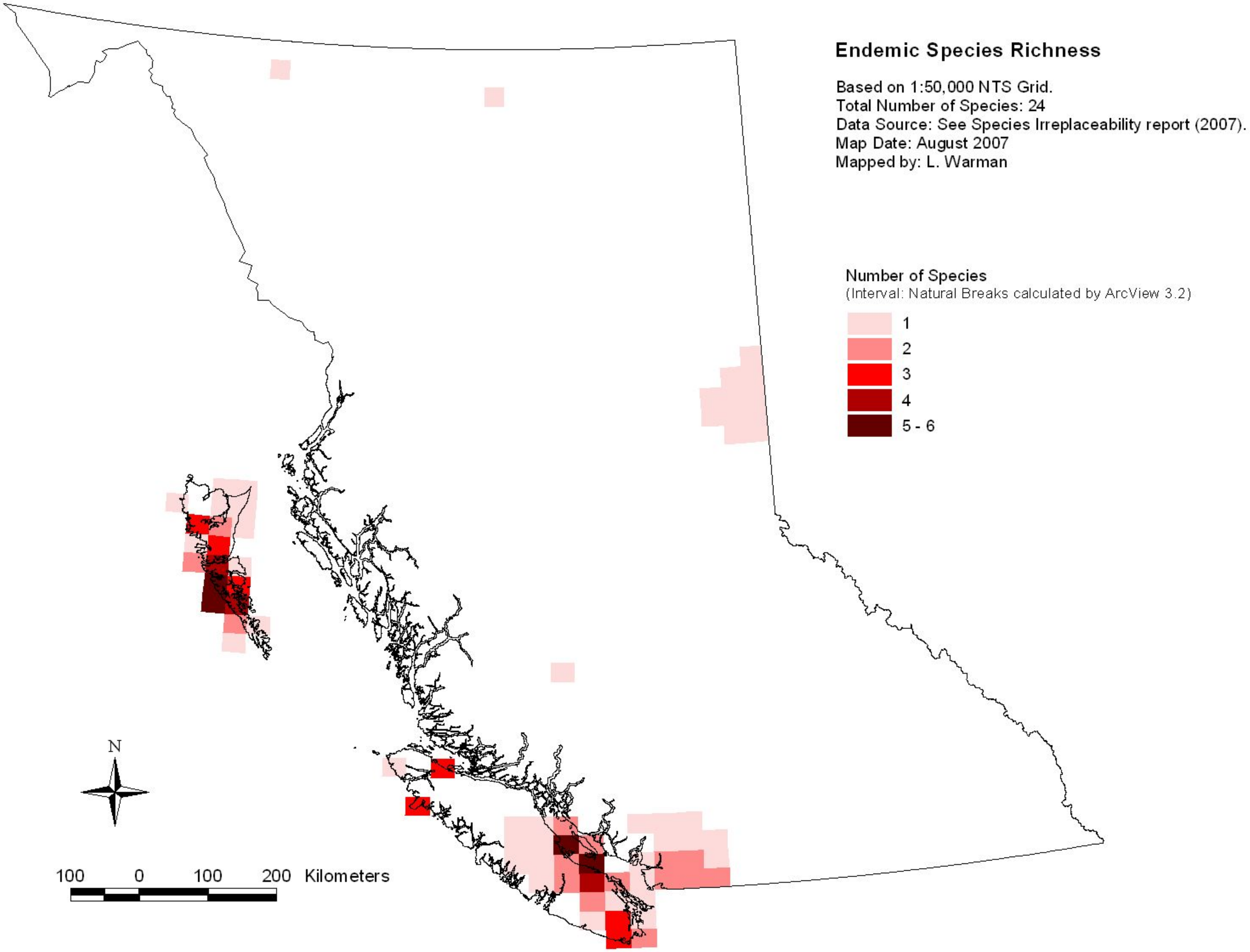
Appendix VIg. Species richness for taxa ranked as red listed in British Columbia.



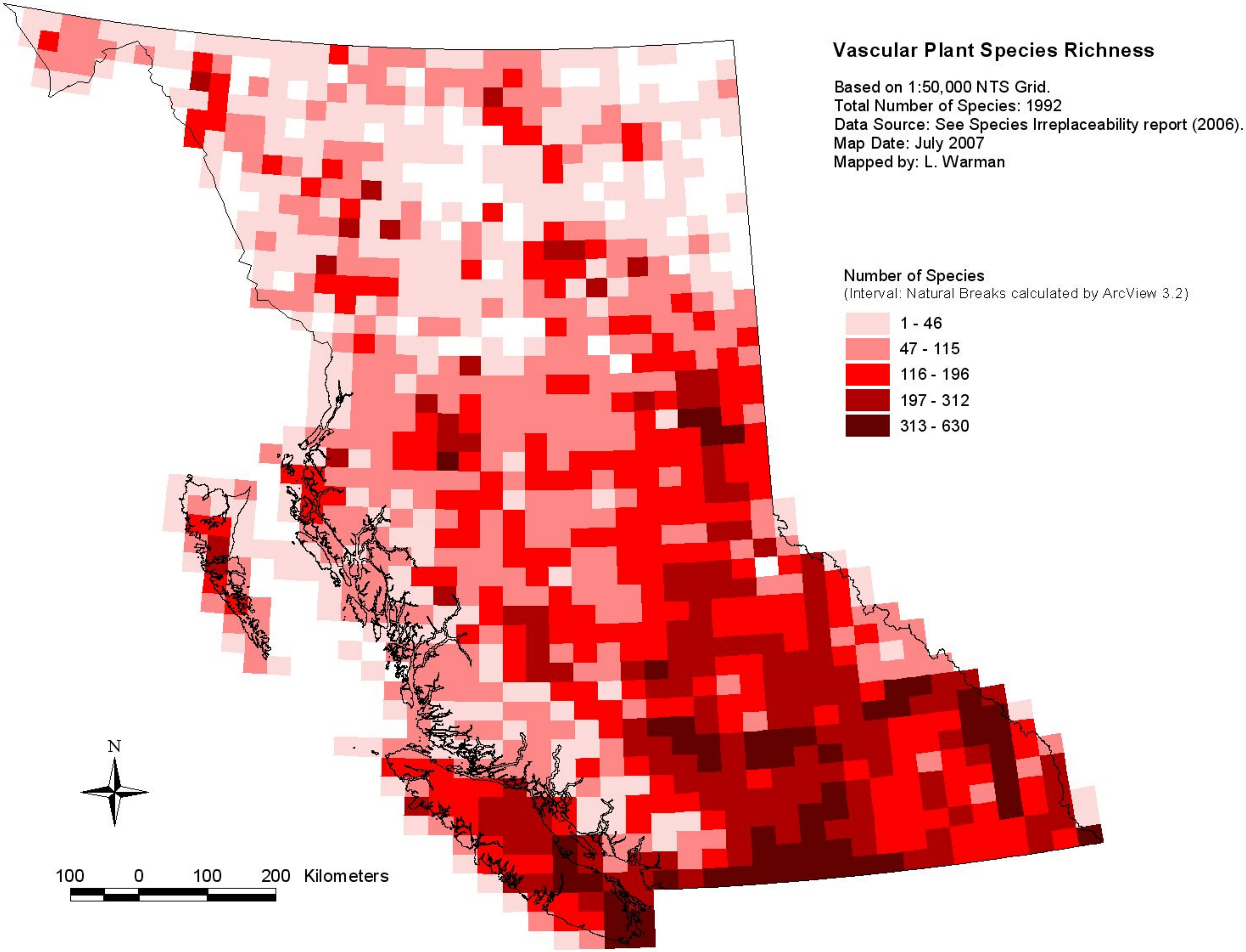
Appendix VIh. Species richness for taxa where British Columbia has high global responsibility (ranks of 1 to 3).



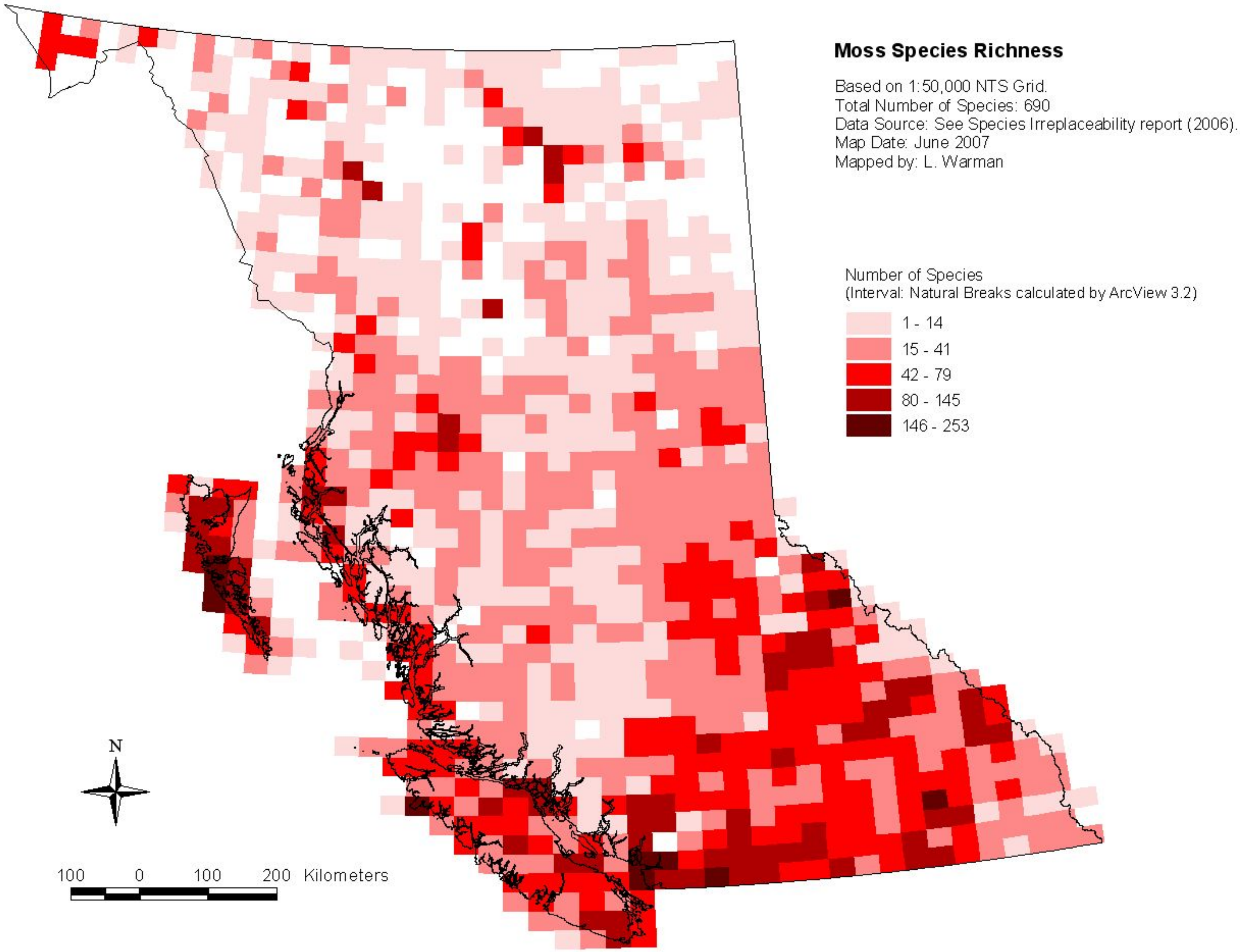
Appendix VIi. Species richness for taxa endemic to British Columbia.



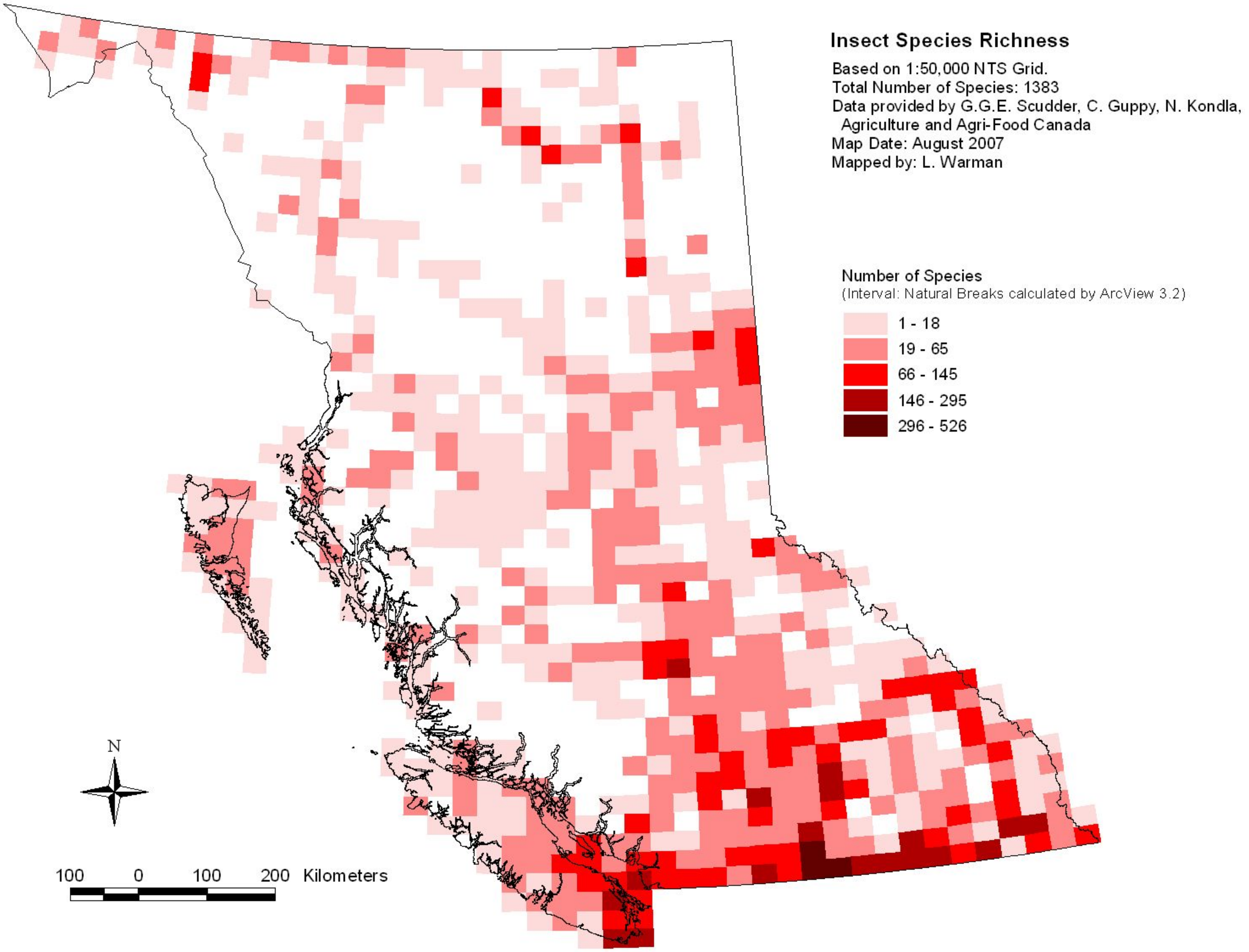
Appendix VIj. Species richness for vascular plant taxa.



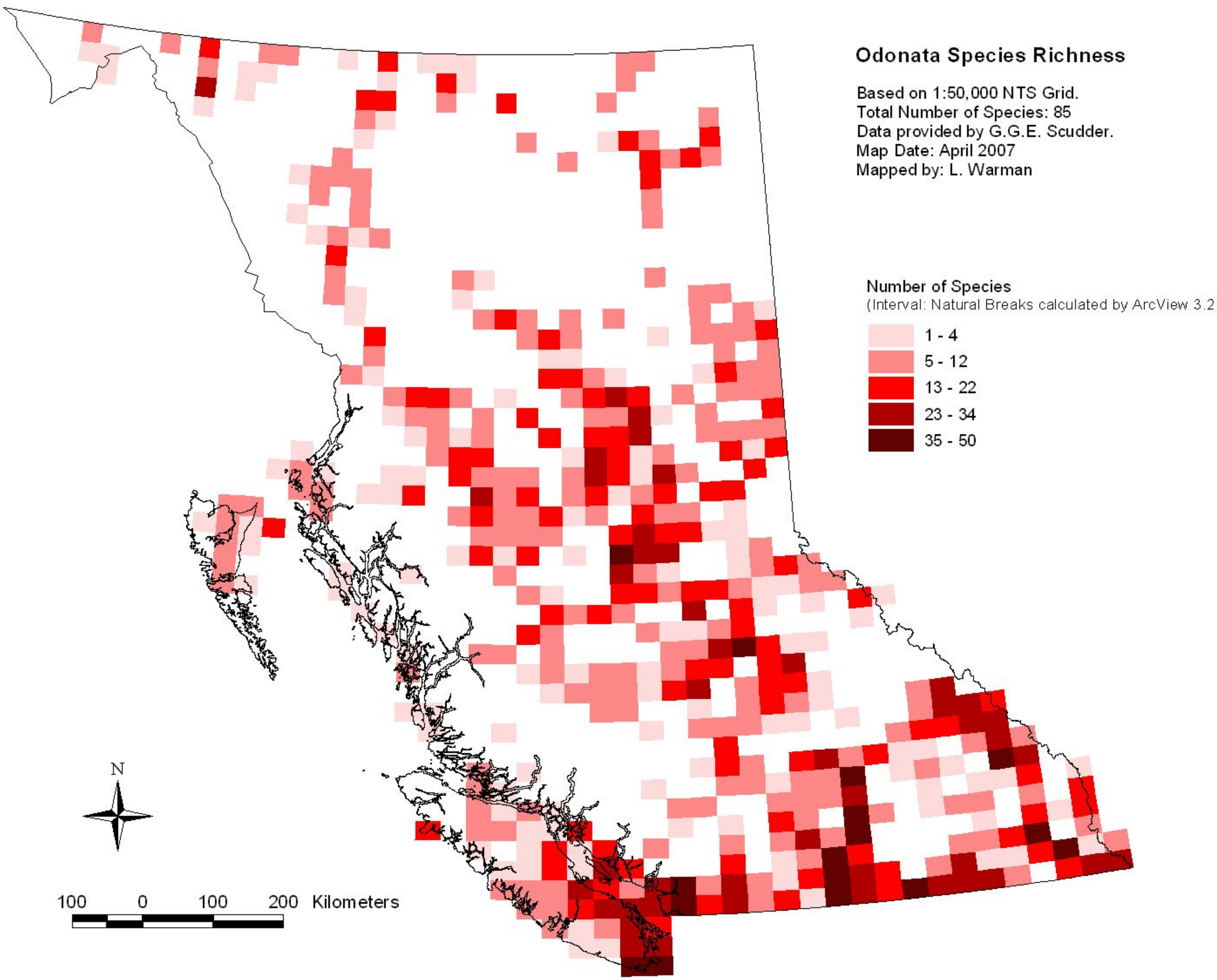
Appendix VIk. Species richness for moss taxa.



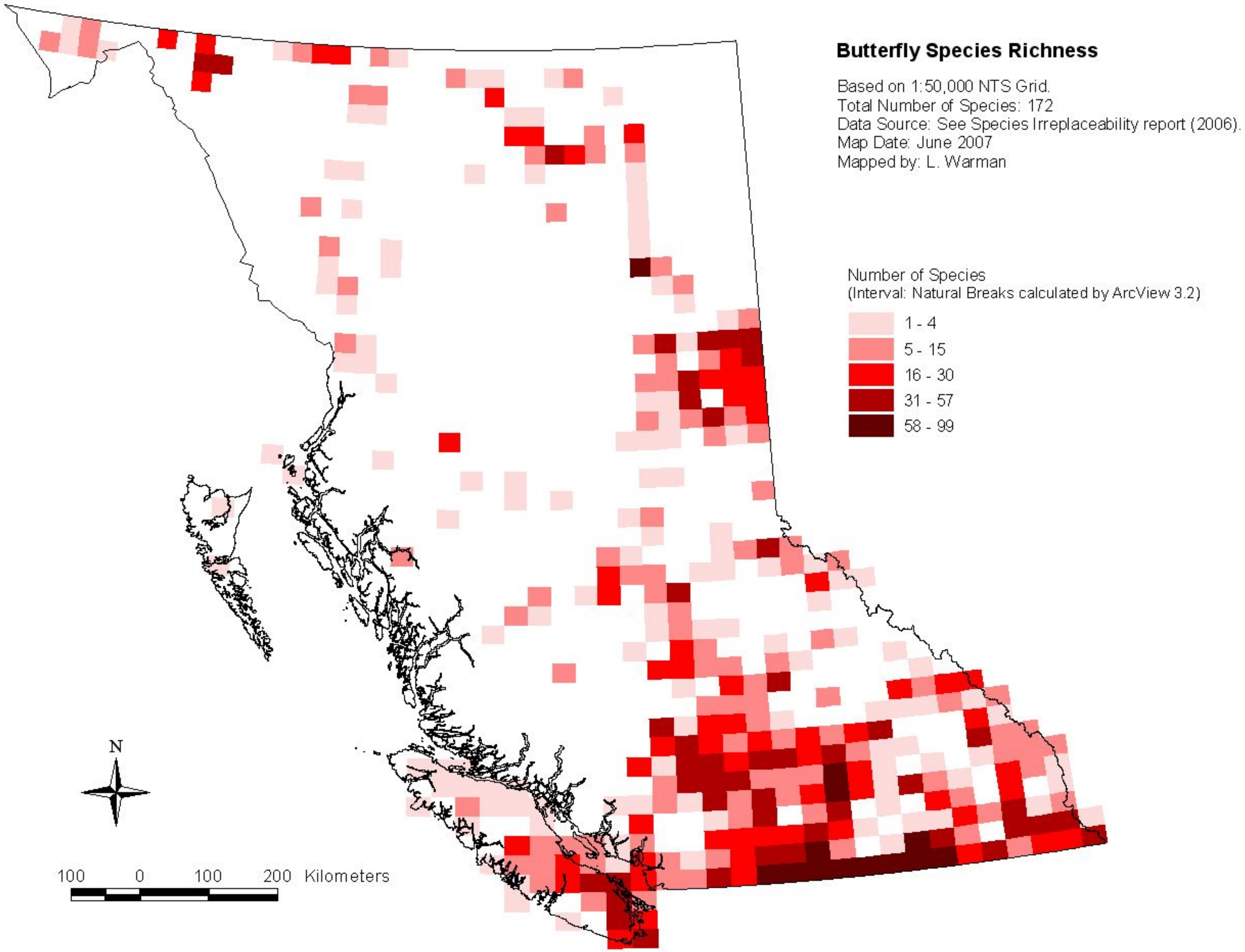
Appendix VII. Species richness for select insect (i.e. neuropteroids, plecoptera, carabidae, heteroptera, odonata and butterfly) taxonomic groups.



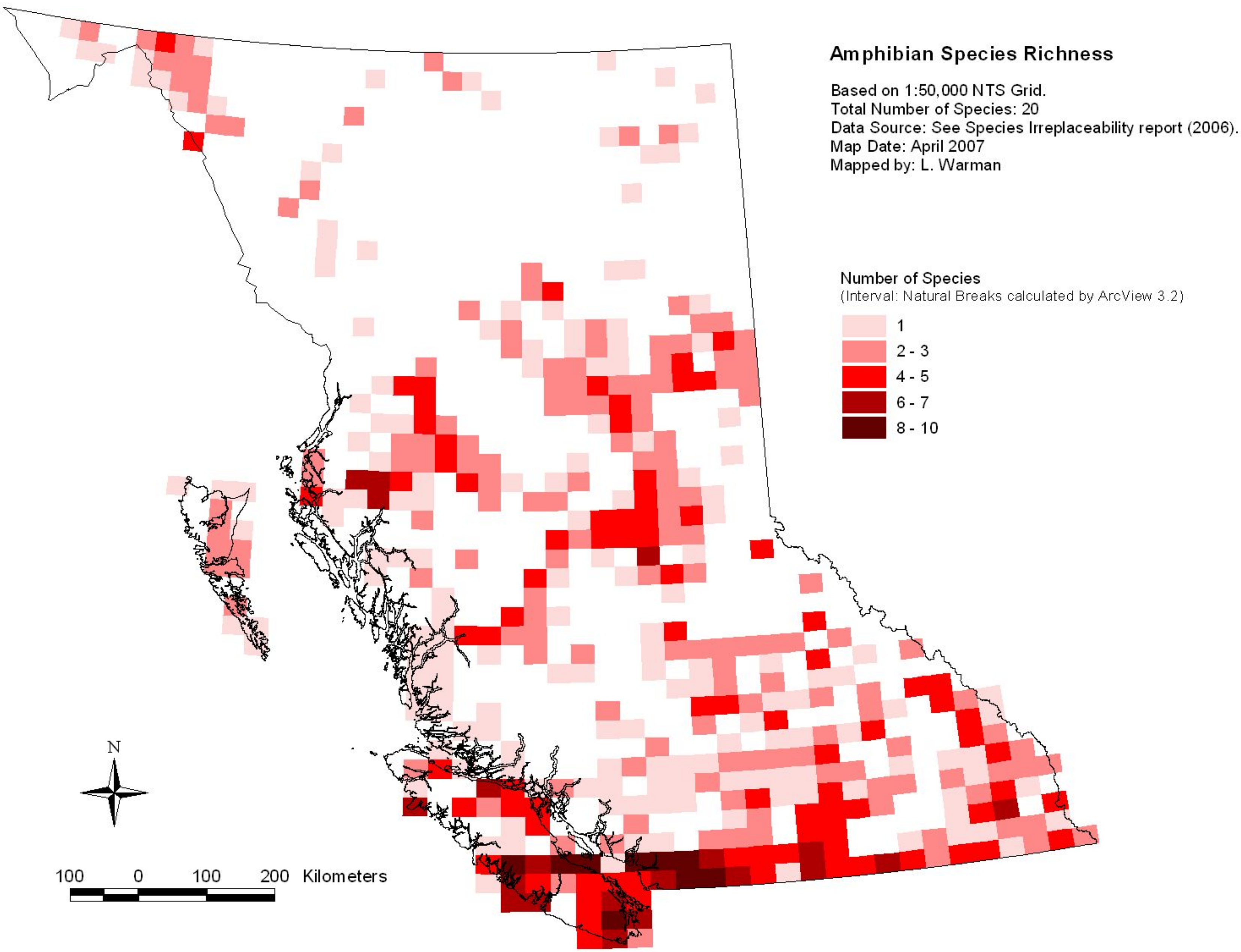
Appendix VIm. Species richness for odonata taxa.



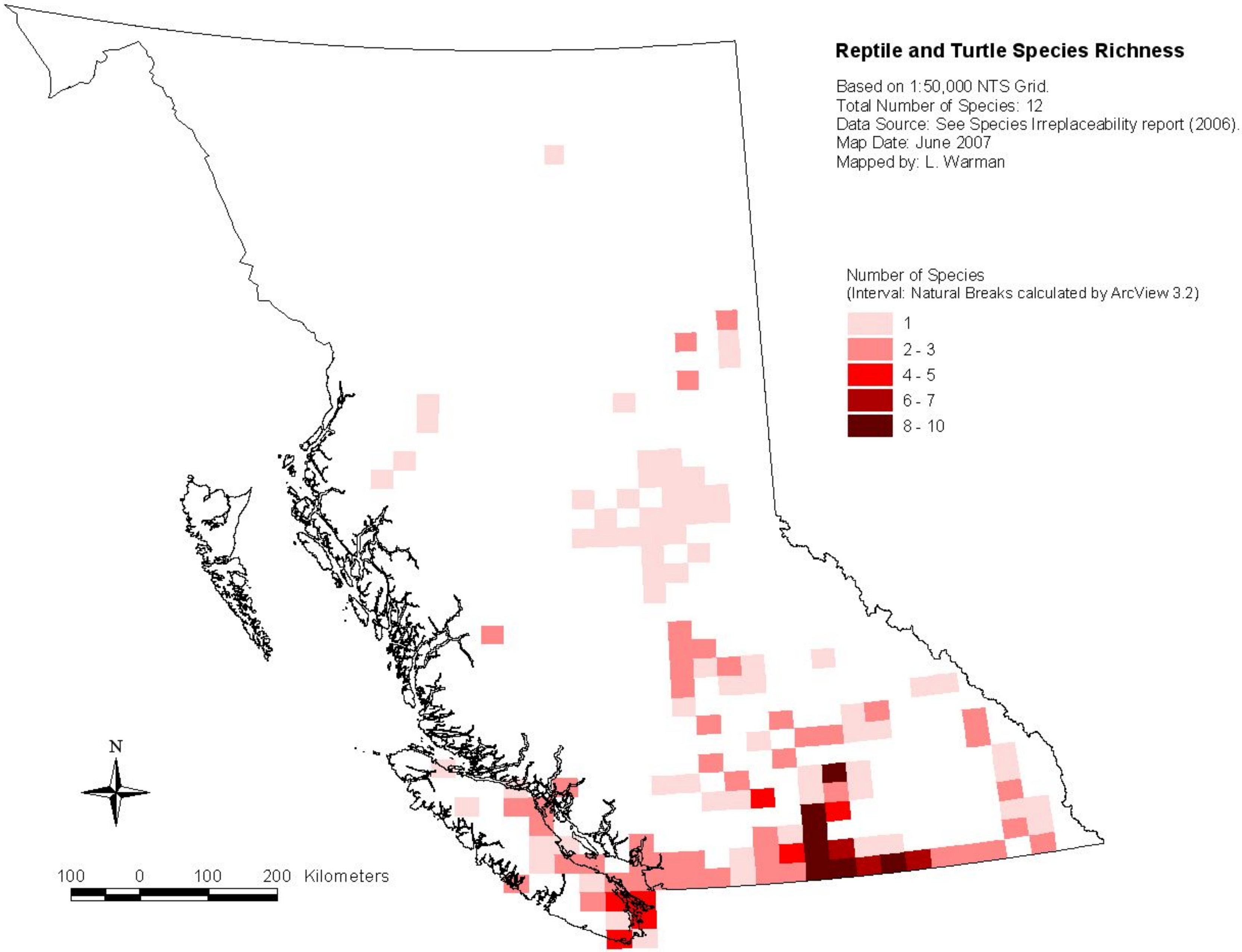
Appendix VIn. Species richness for butterfly taxa.



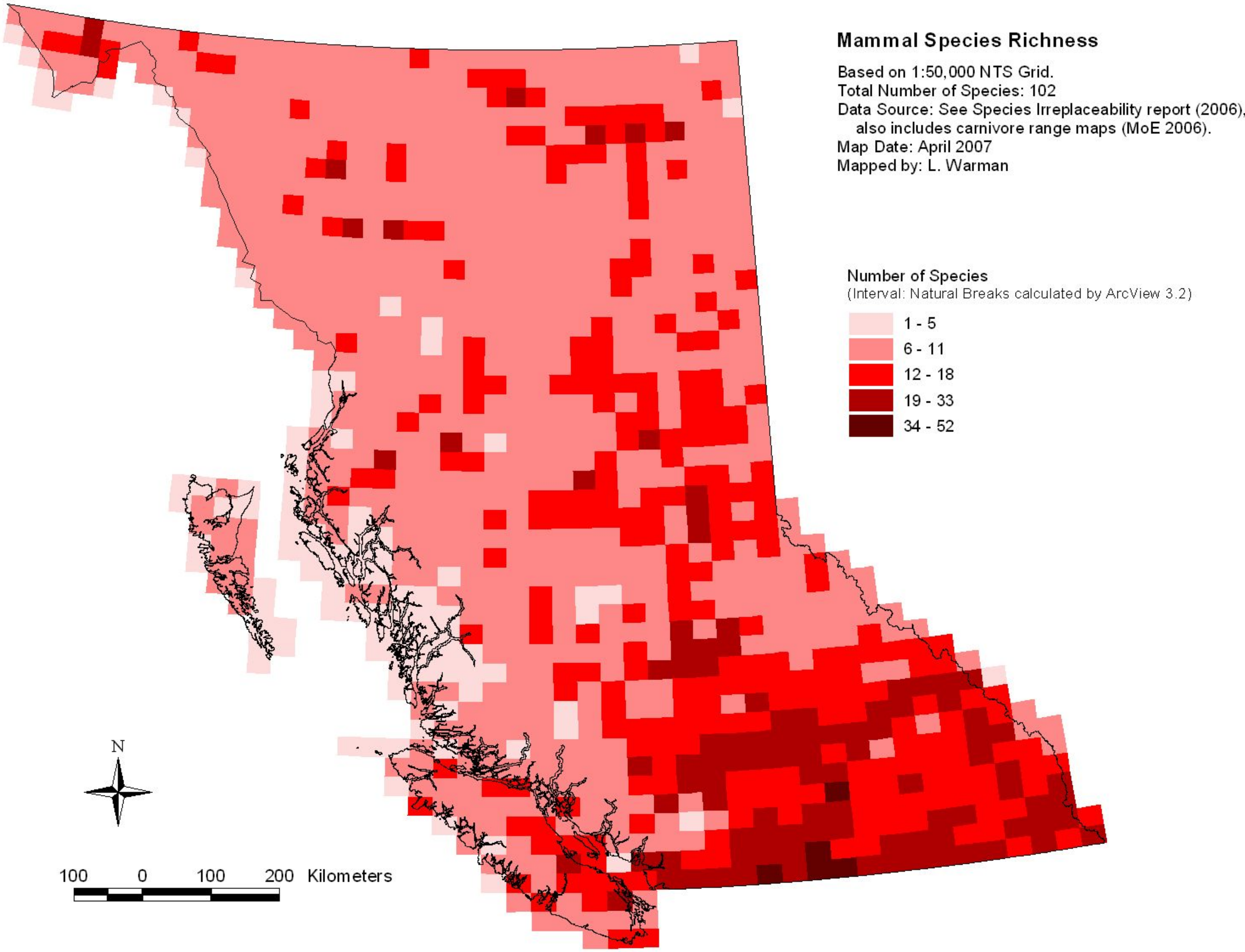
Appendix VIo. Species richness for amphibian taxa.



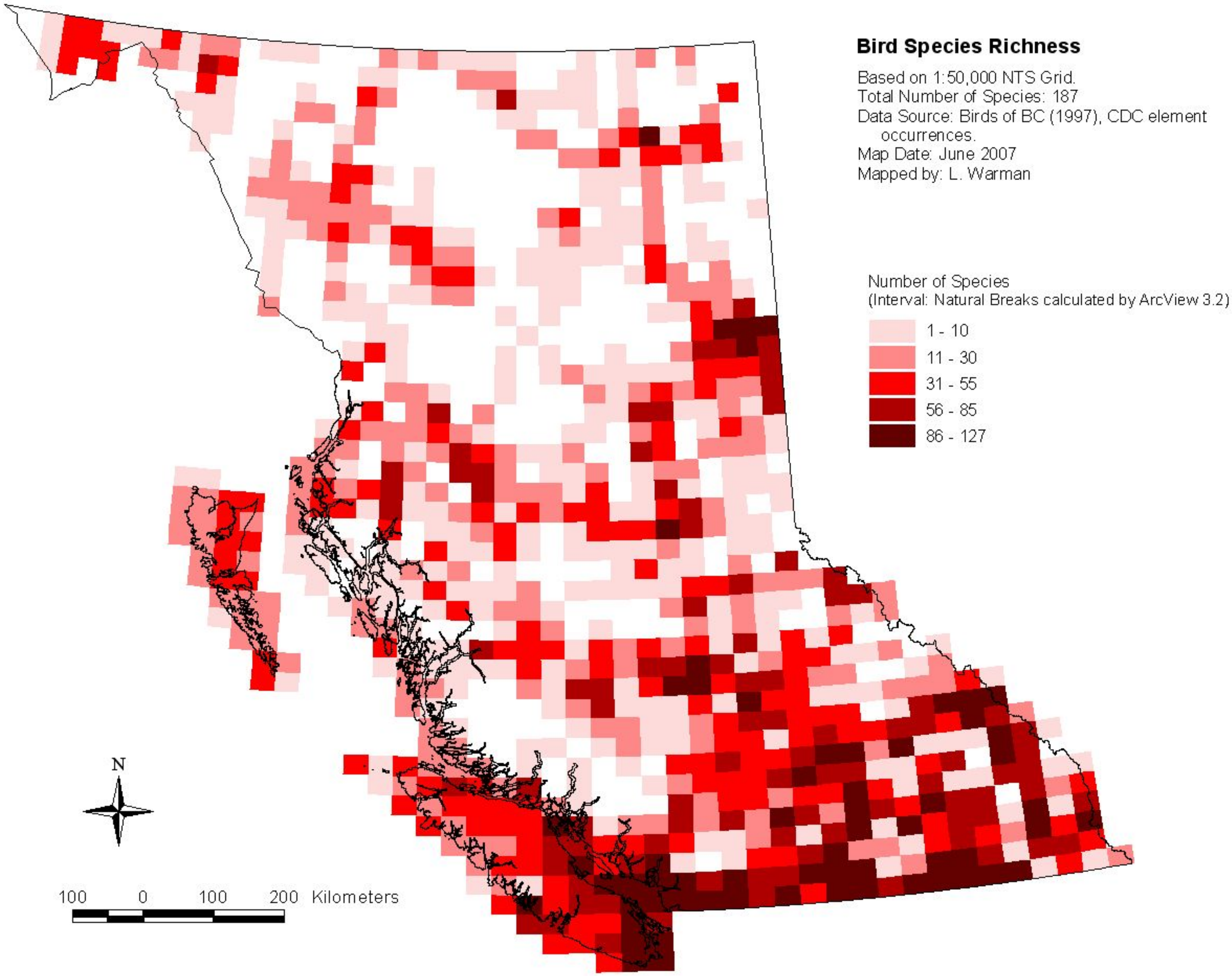
Appendix VIp. Species richness for reptile and turtle taxa.



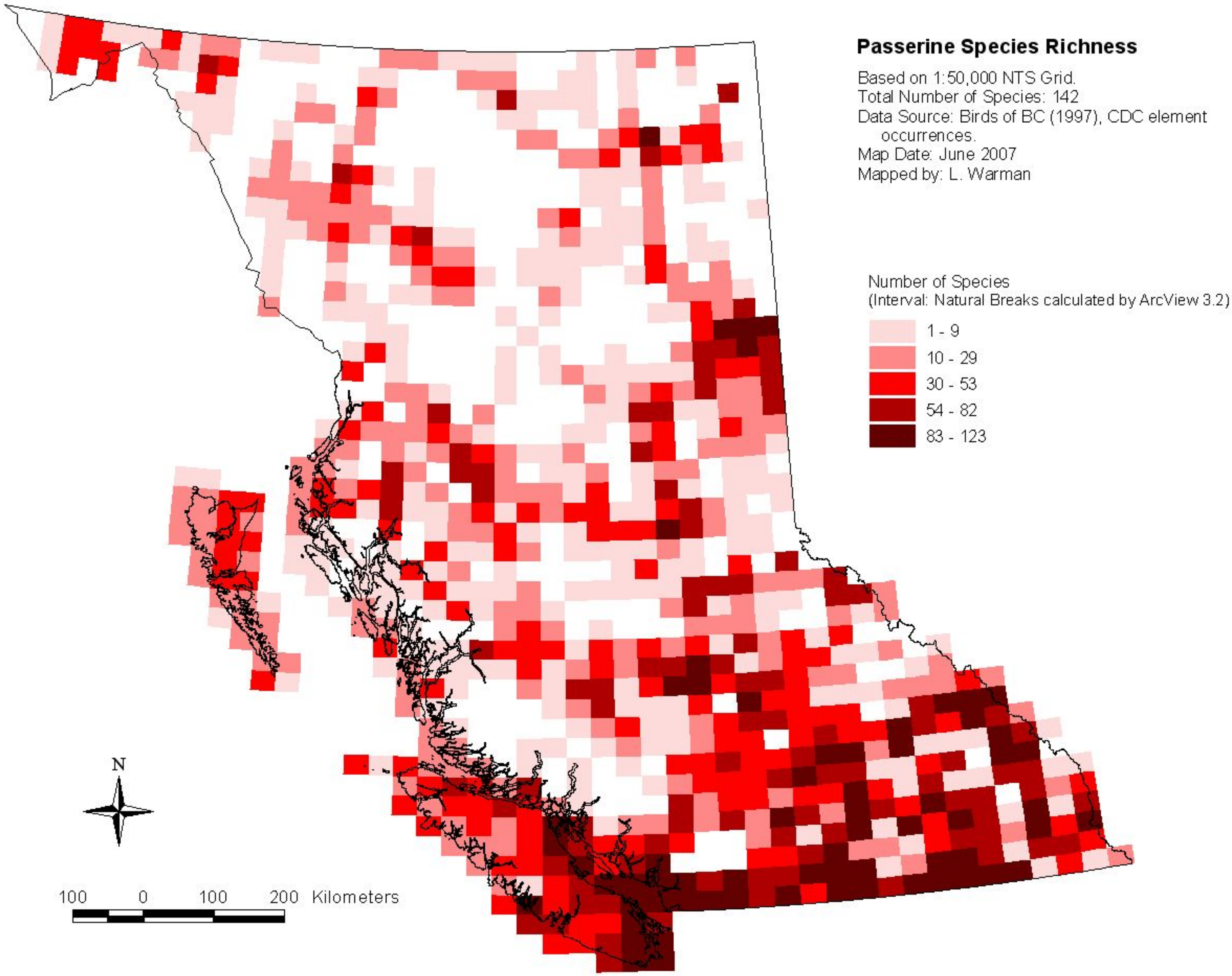
Appendix VIq. Species richness for mammal taxa.



Appendix VIr. Species richness for bird taxa.



Appendix VIs. Species richness for passerine taxa (also included in the bird map).



Appendix VIt. Species richness for freshwater fish taxa.