Section V. Landscape Intactness

Chapter 29. Landscape Intactness

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Introduction

Ecological integrity has become a guiding principle for ecosystem management (Andreasen and others, 2001; Noss, 1990) and has been defined as "the ability of an ecological system to support and maintain a community of organisms that has the species composition, diversity, and functional organization comparable to those of natural habitats within a region" (Parrish and others, 2003, p. 852). Land use, such as development, can negatively affect ecological integrity by altering landscape composition (such as changes in the proportion of native vegetation), structure (such as patch sizes and connectivity), and function (such as disturbance regimes), and it can lead to a loss in the resistance and resilience of ecological systems following natural and anthropogenic perturbations (Peterson and others, 1998; Gunderson, 2000; Wiens, 2002). There are challenges, however, in evaluating ecological integrity at the ecoregional level, due in part to the inherent complexity of multiple interacting biological and physical factors, as well as the lack of information on components of ecological integrity over a range of spatial scales (Andreasen and others, 2001). A more operational concept to guide management decisions at the ecoregion level is that of landscape intactness, which has been defined by the Bureau of Land Management (BLM) as a quantifiable estimate of naturalness measured on a gradient of anthropogenic influence and based on available spatial data (David Wood, Bureau of Land Management, oral commun., September 2014). Landscape intactness addresses how human activities at multiple spatial scales affect landscape-level composition and structure.

By representing the gradient of anthropogenic influence, the Terrestrial Development Index (TDI) and the Aquatic Development Index (ADI) can be used as indicators of landscape intactness for terrestrial and aquatic systems, respectively. Additional information is also needed to evaluate condition, including grazing intensity, presence of invasive species, or levels of human activity, which were not available regionwide but may be available locally. Therefore, to fully evaluate landscape intactness, multiple scales of information (such as regional and local scale) are often necessary.

We used TDI and ADI to quantify attributes of landscape structure (size and connectivity of relatively undeveloped areas). This is based on the assumption that larger, well-connected areas with lower development levels have greater potential for resistance and resilience of populations and communities from natural and anthropogenic disturbances. We also evaluated how well relatively undeveloped areas for the entire project area represent species and communities, and we included the protection status and agencies responsible for these areas. Finally, we explored how the potential for shifts in the distribution of ecological communities projected by particular climate scenarios could alter (1) the potential distribution of ecological communities in relatively undeveloped areas and (2) the viewsheds of historic trails.

Methods Overview

To evaluate landscape intactness (table 29–1) and associated Management Questions (table 29–2), we used the TDI and ADI, as described in Chapter 2—Assessment Framework. To identify areas with the greatest potential terrestrial landscape intactness, we included relatively undeveloped areas (TDI score ≤1 percent). Although TDI represents a gradient of landscape intactness, the use of relatively undeveloped areas to evaluate landscape structure was based on the assumption that the risk posed by human modifications is relatively low in these areas. Although other thresholds in TDI scores for defining landscape intactness could be selected, this threshold is most appropriate for the distribution of TDI scores for the Wyoming Basin. Relatively undeveloped areas represent 28.6 percent of the total project area (figs. 29–3 and 29–4). In contrast, only a small fraction (2.6 percent) of the project area has a TDI score of 0, and much of this area occurs at high elevations; consequently, a TDI of 0 was too

limiting for identifying intact areas in the Wyoming Basin. We also considered TDI thresholds greater than 1 percent, but these thresholds were rejected because they included too much area to be useful for identifying areas with the greatest conservation potential. For example, TDI thresholds of 2 percent or 3 percent include 55.9 percent and 68.0 percent of the project area, respectively (fig. 4–2). Furthermore, a small increase of only 1–2 percent in the TDI score represents a much greater degree of fragmentation than a TDI score ≤1 percent (fig. 2–5). See Selection of Terrestrial Development Index Breakpoints in the Appendix for additional discussion of how breakpoints for TDI scores were established.

We mapped the structural connectivity of relatively undeveloped areas at three interpatch distances based on connectivity analyses at local (1.18 kilometers [km]; 1.12 miles [mi]), landscape (2.25 km [1.4 mi]), and regional (3.51 km [2.18 mi]) scales. Areas that may function as barriers or corridors were identified by overlaying relatively undeveloped patches on the TDI map. Lower TDI scores (for example, <2 percent) may represent potential corridors for species' movements among undeveloped patches, whereas higher TDI scores (for example, >5 percent) may represent barriers to movements. The particular TDI scores that represent actual barriers or corridors will depend on the sensitivity of a particular species to development and landscape context (for example, the amount of sagebrush present for sagebrush-associated species). Collectively, the structural connectivity of relatively undeveloped patches and the TDI scores of the intervening matrix provide an index of the connectedness of these patches for the Wyoming Basin project area.

We used a similar approach to assess landscape intactness for aquatic systems. We defined relatively undeveloped catchments as having an ADI score <20 (fig. A–10). For potential alteration of flow regime, fragmentation, and loss of structural connectivity of streams, we summarized the number of dams and potential barriers (the number of diversion points and stream-road crossings in streams and rivers) by sixth-level watershed. The degree to which potential barriers affect functional connectivity of streams and rivers varies among species.

For both terrestrial and aquatic systems, we evaluated how well relatively undeveloped areas at the ecoregion level represent the ecological communities and species addressed by the REA. We compared the distribution of communities and species within the relatively undeveloped areas to their distribution for the entire project area. We synthesized the conservation potential for terrestrial species evaluated as Conservation Elements by displaying the townships with at least one species that was ranked as having very high conservation potential. Likewise, to synthesize the conservation potential for the aquatic species evaluated as Conservation Elements, we included fifth-level watersheds with at least one species or community that was ranked as having very high conservation potential. Because rankings are very sensitive to the input data used and the criteria used to develop the ranking thresholds, they are not intended as stand-alone maps. Rather, they are best used as an initial screening tool to compare regional rankings in conjunction with the geospatial data for Core Management Questions and information on local conditions that cannot be determined from regional REA maps (see Section III—Communities and Section IV—Species and Species Assemblages for ranks of conservation potential for individual species and communities).

To explore the potential consequences of climate change for terrestrial ecological communities, we used available models of bioclimatic conditions (also called bioclimatic envelopes) suitable for ecological communities developed by Rehfeldt and others (2012) (fig. 2–18). We used a 6.4-km (4-mi) buffer on either side of historic trails to examine how changes in bioclimatic envelopes for communities could affect trail viewsheds under climate scenario I (Canadian Centre for Climate Modeling and Analysis Coupled Global Model, ver. 3, emissions scenario A2) (Chapter 2—Assessment Framework). We also evaluated how potential shifts in the distribution of bioclimatic envelopes could affect the community composition of relatively undeveloped areas for climate scenario I.

Table 29–1. Attributes and associated indicators of landscape intactness for the Wyoming Basin Rapid Ecoregional Assessment.

[km, kilometer; mi, mile]

Attributes	Variables[1]	Indicators[1]
Amount and distribution	Total area and patch size distribution	Distribution of relatively undeveloped areas.
Landscape structure	Structural connectivity[2]	Interpatch distances that provide an index of connectivity among relatively undeveloped areas at local (1.8 km; 1.12 mi), landscape (2.25 km; 1.4 mi), and regional (3.51 km; 2.18 mi) levels
	Barriers and corridors	High Terrestrial Development Index (TDI) scores represent potential barriers to movement and low TDI scores represent potential corridors.

[1] Relatively undeveloped areas are defined as having a Terrestrial Development Index score ≤1 percent.

[2] Structural connectivity refers to the proximity of patches at local, landscape, and regional levels, but does not reflect functional connectivity. See Chapter 2—Assessment Framework and the Appendix.

Table 29–2. Management Questions addressed for ecological intactness for the Wyoming Basin Rapid Ecological Assessment.

Core Management Questions	Results
Where are the relatively undeveloped terrestrial areas?	Figure 29–1
Where are the largest relatively undeveloped patches?	Figure 29–2
Where are relatively undeveloped areas with high structural connectivity, and which areas may function as stepping stones that connect large, relatively undeveloped areas?	Figure 29–3
Where does development pose potential barriers to animal movements among relatively undeveloped areas?	Figure 29–4
What is the distribution and percent of each terrestrial ecological community within relatively undeveloped areas?	Figures 29–5 and 29–6
Where are the relatively undeveloped watersheds?	Figure 29–7
Where has development fragmented streams and rivers, altered flows, and decreased connectivity?	Figure 29–8
What is the ownership or jurisdiction and protected status of relatively undeveloped areas?	Figure 29–9, Table 29–3
Where are the potential changes in the distribution of terrestrial communities for the Wyoming Basin Rapid Ecoregional Assessment project area and historic trails?	Figure 29–10
Where are the projected changes in distribution of terrestrial communities for relatively undeveloped areas?	Figure 29–11
Integrated Management Questions	**Results**
How well do relatively undeveloped areas represent terrestrial species evaluated as Conservation Elements?	Figure 29–12
Where are the townships with the highest conservation potential for terrestrial species evaluated as Conservation Elements?	Figure 29–13, Table 29–4
Where are the watersheds with the highest conservation potential for aquatic species evaluated as Conservation Elements?	Figure 29–14, Table 29–5

Key Findings for Management Questions

Where are the relatively undeveloped terrestrial areas (fig. 29–1)?

- A total of 28.6 percent of the Wyoming Basin REA project area is relatively undeveloped, whereas 23.7 percent of the ecoregion proper (not including the project area buffer) is relatively undeveloped.

Where are the largest relatively undeveloped patches (fig. 29–2)?

- The largest patches of relatively undeveloped areas are located at high elevations and in the Bighorn and Great Divide Basins.

Where are relatively undeveloped areas with high structural connectivity, and which areas may function as stepping stones that connect large, relatively undeveloped areas (fig. 29–3)?

Where does development pose potential barriers to animal movements among relatively undeveloped areas (fig. 29–4)?

- Although the relatively undeveloped patches >100 km^2 are important to local and landscape connectivity, areas <100 km^2 may contribute to regional connectivity (fig. 29–3).
- Areas with high development levels (such as TDI scores >5 percent) represent potential barriers to movement among many of the largest relatively undeveloped patches (fig. 29–4). The actual TDI scores that represent actual barriers or corridors depend on the sensitivity of species to development and landscape context (for example, the amount of sagebrush present for sagebrush-associated species).

What is the distribution and percent of each terrestrial ecological community within relatively undeveloped areas (figs. 29–5 and 29–6)?

- Most of the relatively undeveloped areas are at high elevations and include montane and (or) subalpine forests and foothill shrublands and woodlands. There is a greater proportion of these community types in relatively undeveloped areas compared to their proportional area in the Wyoming Basin project area (figs. 29–5 and 29–6).
- At lower elevations, desert shrublands have a greater proportional area in relatively undeveloped areas compared to the project area.
- Sagebrush steppe is the only ecological community that has a much greater proportional area (51 percent) in the project area compared to relatively undeveloped areas (14 percent), indicating this community is underrepresented in relatively undeveloped areas (fig. 29–6).

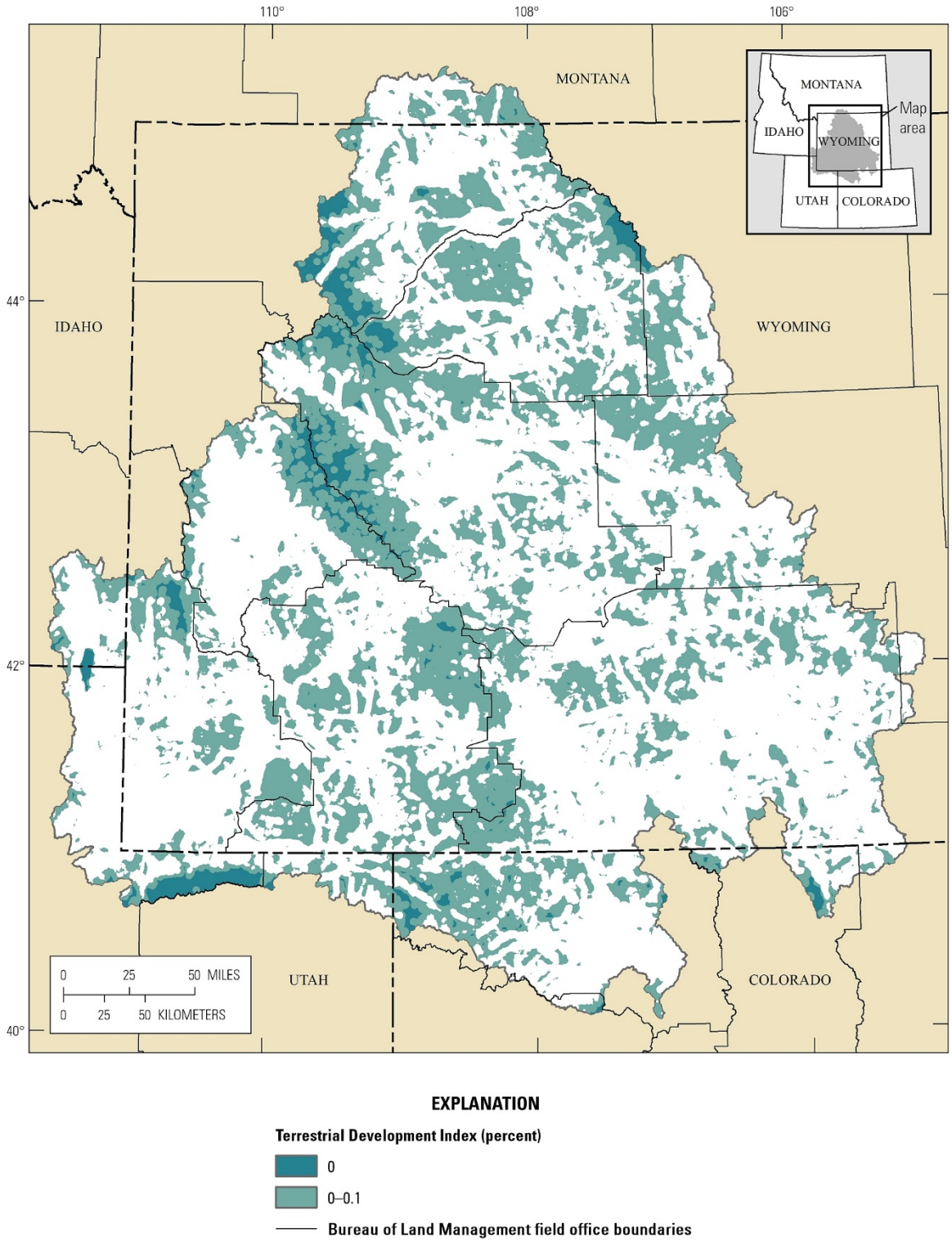

Figure 29–1. Relatively undeveloped terrestrial areas (Terrestrial Development Index scores ≤1 percent) in the Wyoming Basin Rapid Ecoregional Assessment project area.

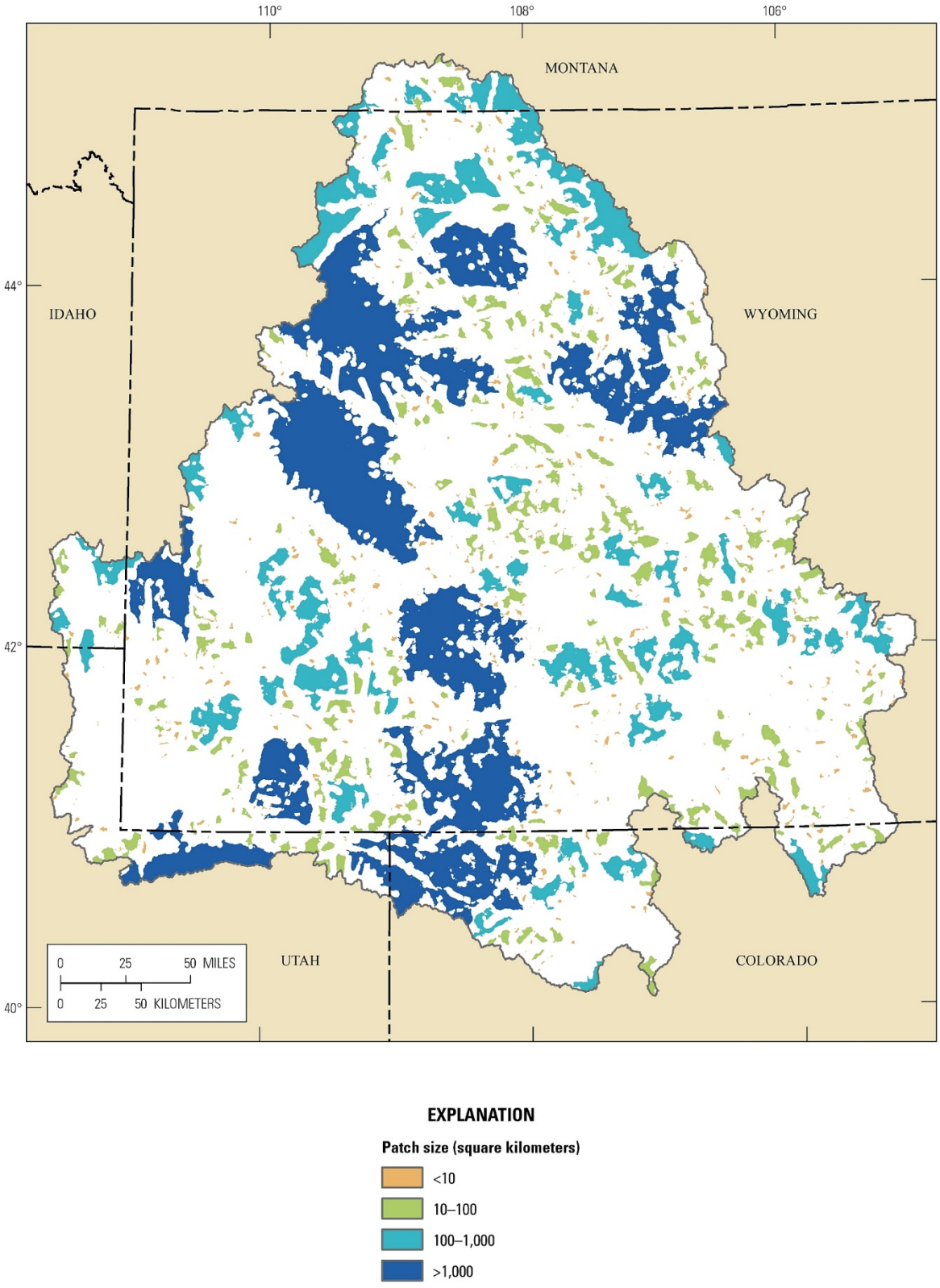

Figure 29–2. Patch sizes of relatively undeveloped terrestrial areas in the Wyoming Basin Rapid Ecoregional Assessment project area.

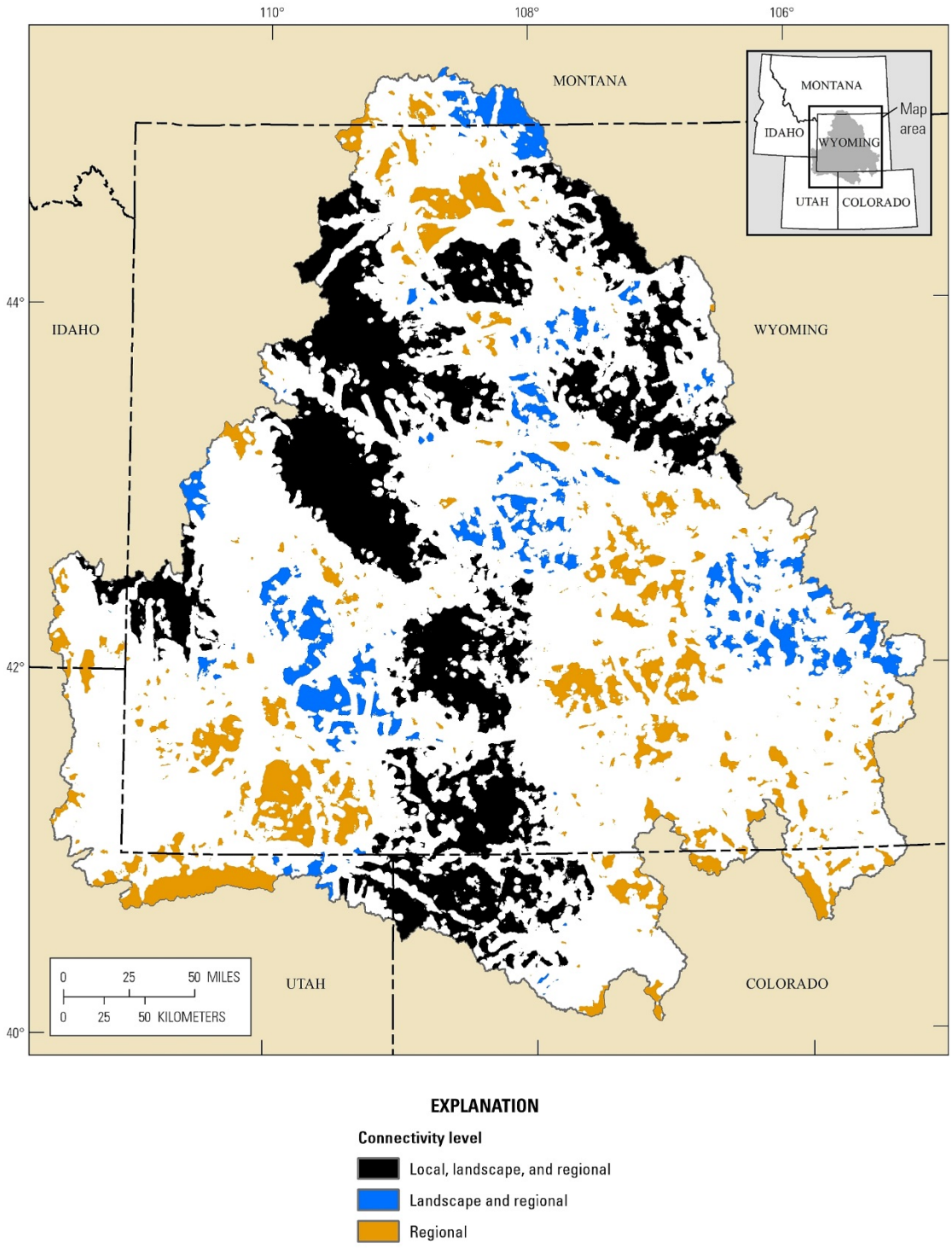

Figure 29–3. Physical connectivity of relatively undeveloped patches in the Wyoming Basin Rapid Ecoregional Assessment project area. Black polygons represent large and highly connected patches. Blue polygons represent patches that contribute to both landscape and regional connectivity. Orange polygons represent isolated clusters of patches surrounded by developed areas that may represent stepping stones across areas with high levels of development.

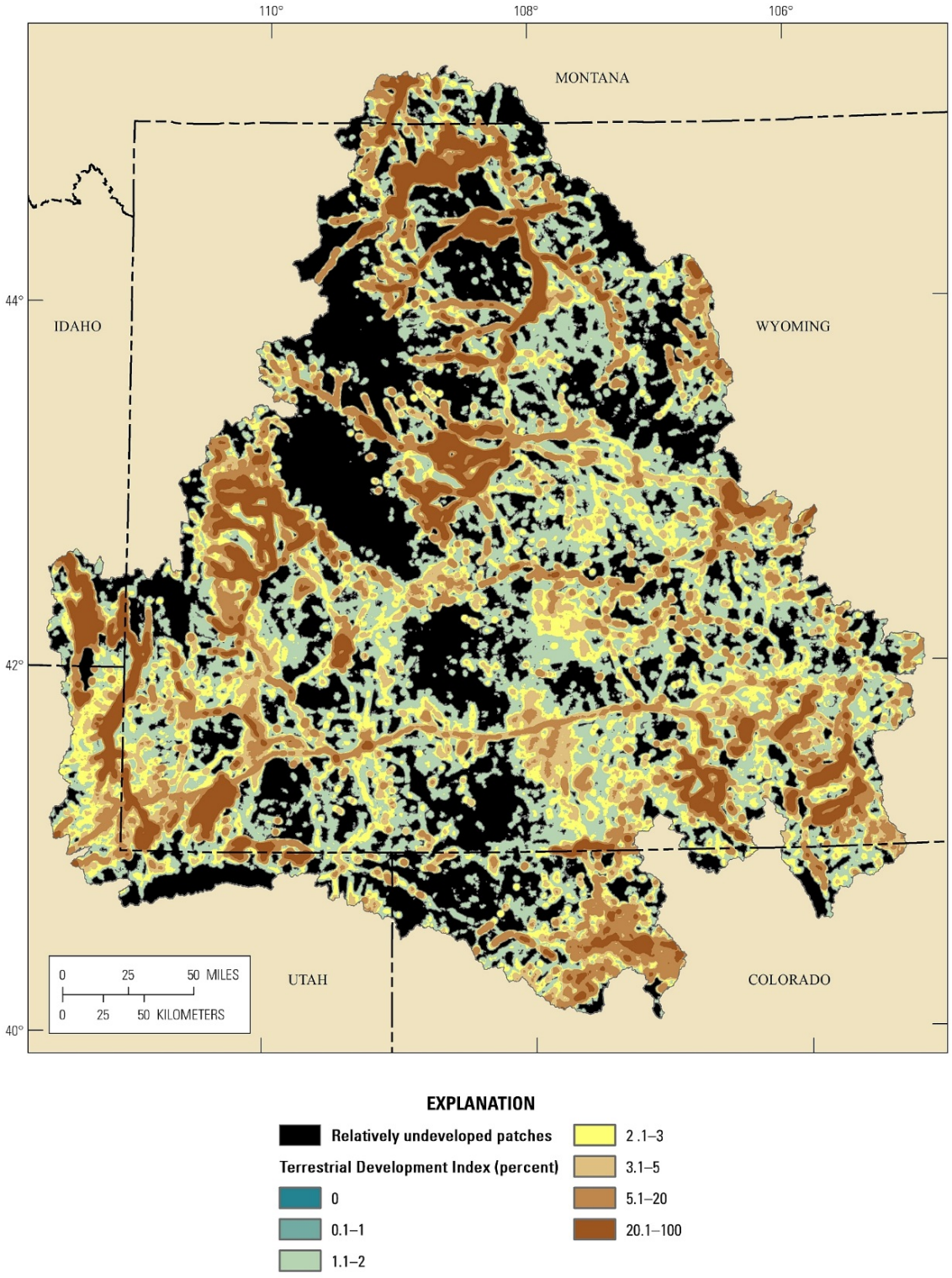

Figure 29–4. Potential barriers and corridors as a function of the Terrestrial Development Index (TDI) scores for lands surrounding relatively undeveloped areas. Higher TDI scores (for example, >5 percent) represent potential barriers to movement among relatively undeveloped patches. Lower TDI scores (for example, <2 percent) represent potential corridors for movements among patches.

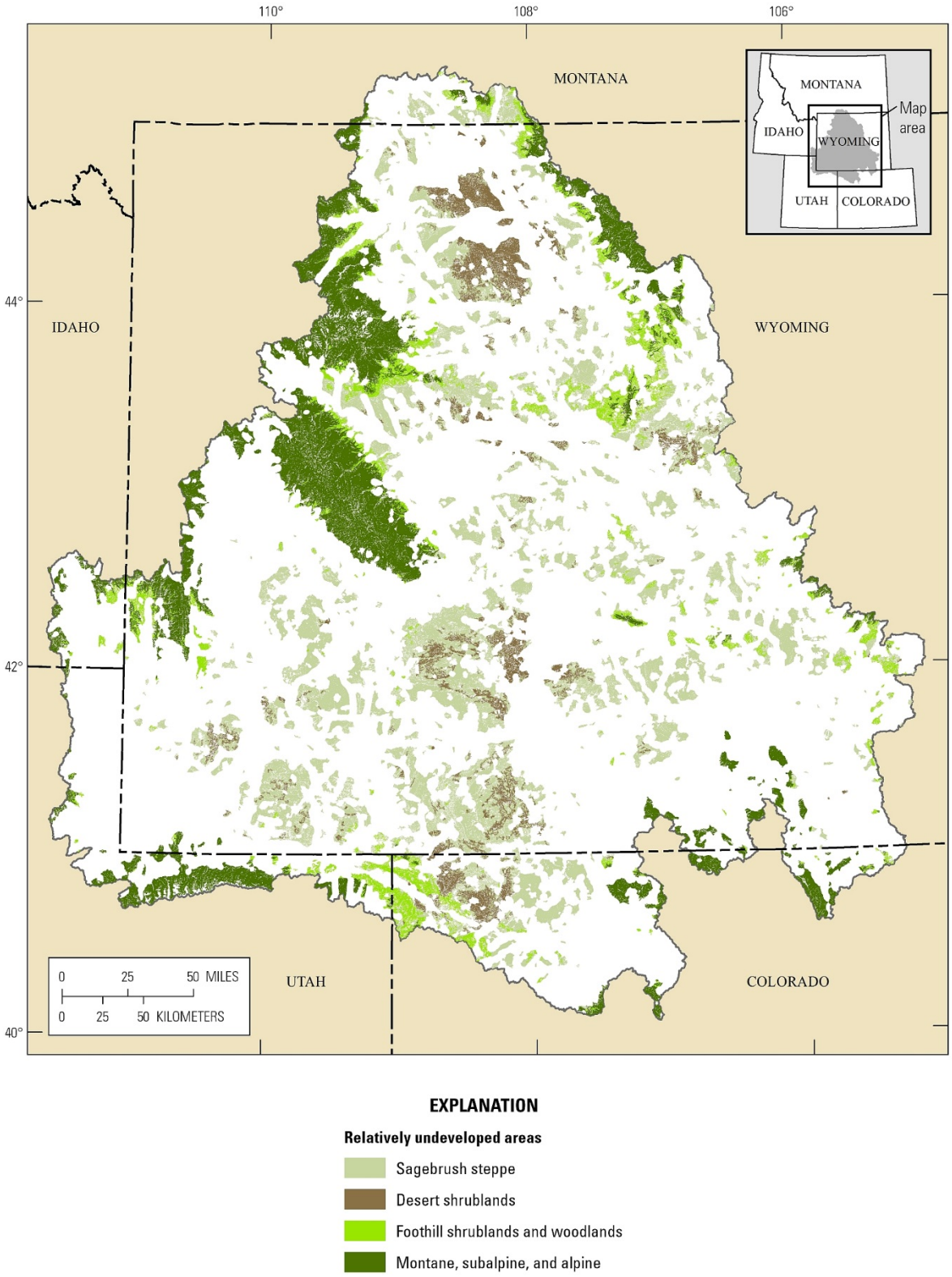

Figure 29–5. Distribution of terrestrial ecological communities within relatively undeveloped areas in the Wyoming Basin Rapid Ecoregional Assessment project area. See figure 29–6 for the percent of each terrestrial community in relatively undeveloped areas.

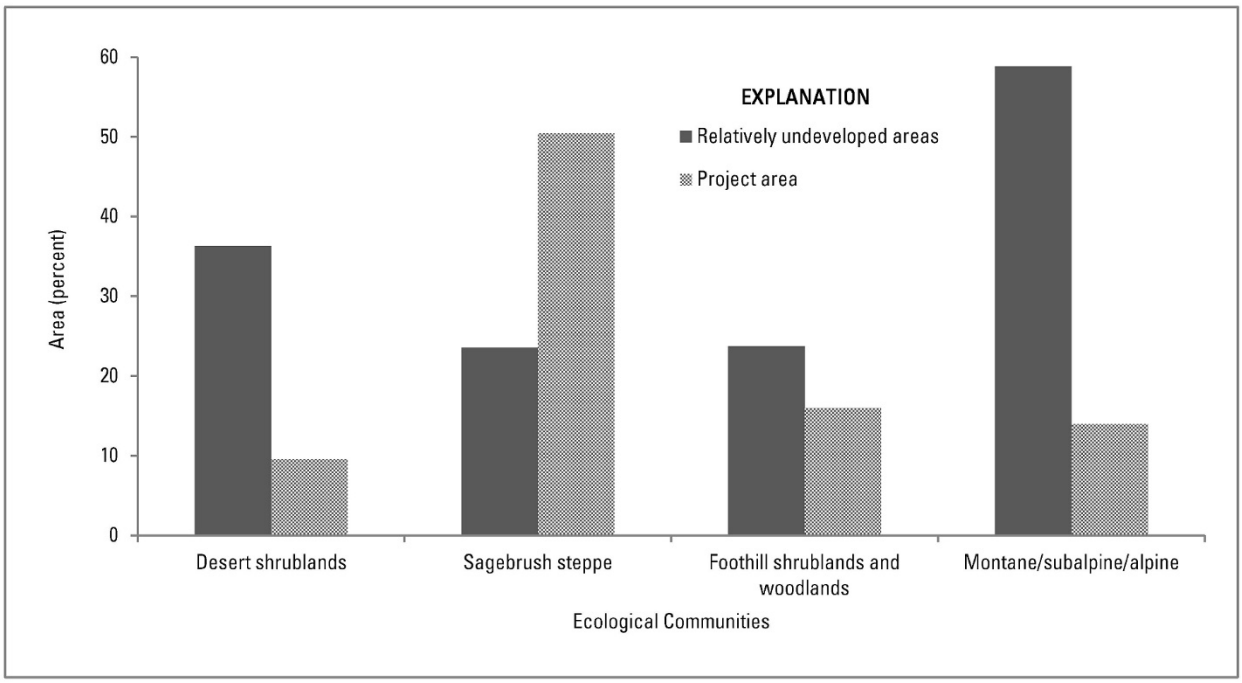

Figure 29–6. Proportional area of each terrestrial ecological community that is relatively undeveloped in relation to the proportional area of each community in the Wyoming Basin Rapid Ecoregional Assessment project area.

Where are the relatively undeveloped watersheds (fig. 29–7)?

- Relatively undeveloped watersheds tend to occur at the highest elevations. The largest areas of undeveloped watersheds generally correspond to the relatively undeveloped areas for terrestrial systems (figs. 29–1 and 29–7).
- A total of 29 percent of the ecoregion falls within watersheds that are relatively undeveloped.

Where has development fragmented streams and rivers, altered flows, and decreased connectivity (fig. 29–8)?

- Few perennial streams lack potential barriers posed by dams, diversions, and stream crossings, except at the highest elevations.
- Approximately 71 percent of the watersheds contain more than 11 potential barriers and 46 percent contain 11–50 barriers.

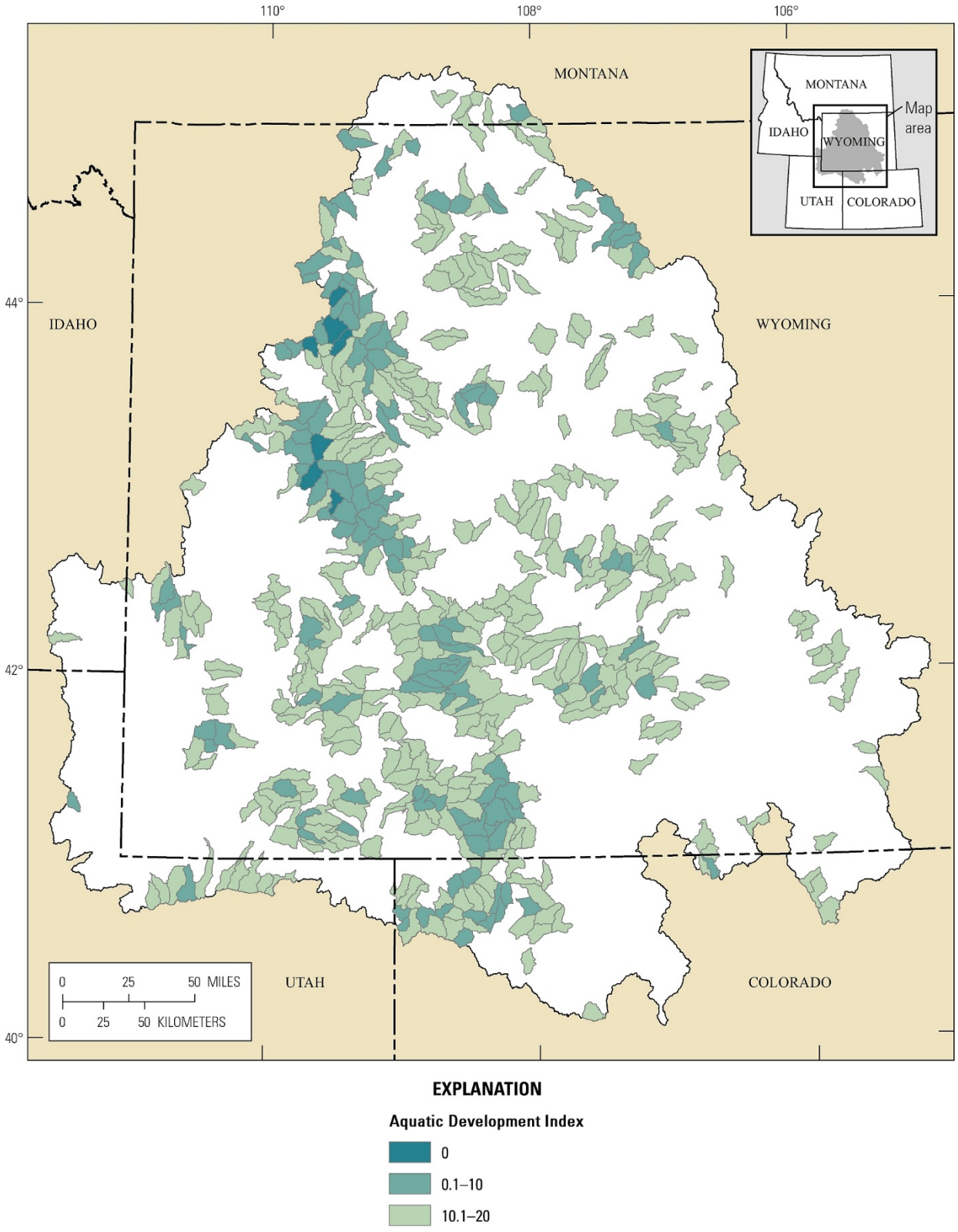

Figure 29–7. Relatively undeveloped aquatic areas (Aquatic Development Index scores <20), summarized by sixth-level watershed, in the Wyoming Basin Rapid Ecoregional Assessment project area.

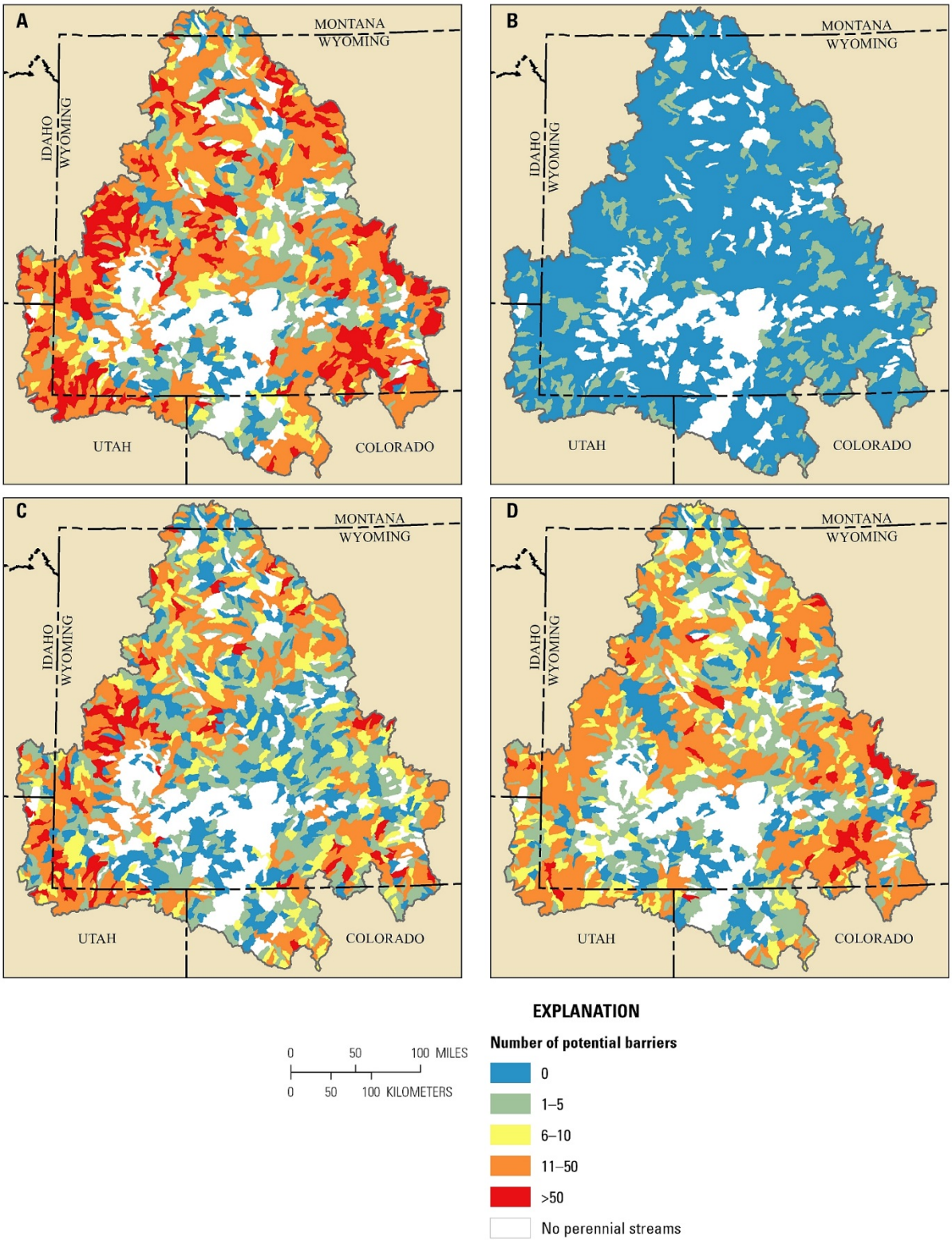

Figure 29–8. Potential barriers in perennial streams and rivers, summarized by sixth-level watershed. (*A*) All potential barriers, (*B*) number of dams, (*C*) points of diversion, and (*D*) stream/road crossings. Watersheds without any perennial streams or rivers are white

What is the ownership and protected status of relatively undeveloped terrestrial areas (table 29–3, fig. 29–9)?

- Collectively, Federal lands represent 70.7 percent of the relatively undeveloped areas (fig. 29–9), with 42.1 percent managed by the BLM (table 29–3).

Table 29–3. Area and percent of relatively undeveloped areas by land ownership or jurisdiction in the Wyoming Basin Rapid Ecoregional Assessment project area.

[km^2, square kilometer]

Ownership or jurisdiction	Area (km^2)	Percent of area
Bureau of Land Management	21,537	42.1
Forest Service[1]	13,737	26.8
Private	8,776	17.1
Tribal	3,698	7.2
State/County	2,235	4.4
Other Federal[2]	741	1.4
Private conservation	236	0.5
National Park Service	185	0.4

[1] U.S. Department of Agriculture Forest Service.
[2] Bureau of Reclamation, Department of Defense, Department of Energy, and U.S. Fish and Wildlife Service.

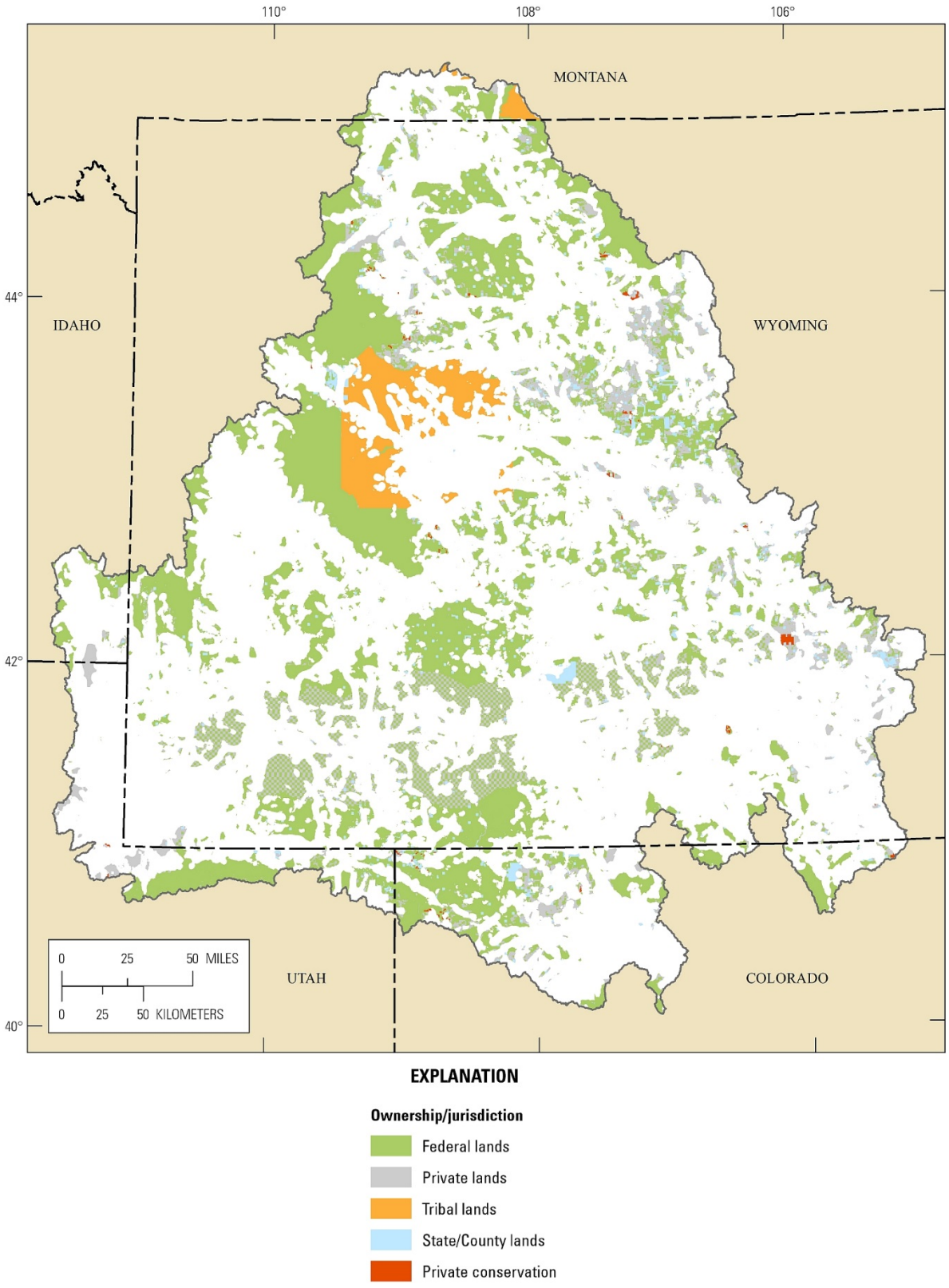

Figure 29–9. Land ownership or jurisdiction of relatively undeveloped terrestrial areas in the Wyoming Basin Rapid Ecoregional Assessment project area.

Where are the potential changes in the distribution of terrestrial communities for the Wyoming Basin REA project area and historic trails (fig. 29–10)?

Where are the projected changes in distribution of terrestrial communities for relatively undeveloped areas (fig. 29–11)?

- Projected distribution of bioclimatic conditions (envelope) indicates the potential for a decrease in the area of montane and subalpine forests, alpine zones, and sagebrush steppe under climate scenario I within the Wyoming Basin project area (fig 29–10*A*).
- Distribution of the bioclimatic envelope for foothill shrublands and woodlands is projected to initially shift upslope, but ultimately the projected distribution of the bioclimatic envelope for this community is projected to contract by 2090.
- The bioclimatic envelope for desert shrublands and grasslands is projected to expand.
- Potential changes in distribution of bioclimatic envelopes within viewsheds of historic trails are similar to those projected for the ecoregion, with the exception that alpine zones are not currently present in the viewsheds (fig. 29–10*B*).
- Desert shrublands are projected to have the greatest potential for expansion within the viewsheds under this climate scenario.
- Potential changes in distribution of bioclimatic envelopes within relatively undeveloped areas closely correspond to the projections at the project level (fig. 29–10*A*).
- Although the distribution of the current bioclimatic envelope for terrestrial communities (fig. 29–11A) differs somewhat from the current distribution map (fig. 29–5), the potential changes in the distribution of bioclimatic envelopes for projected climate changes in 2030 show where sagebrush steppe in relatively undeveloped areas may be more vulnerable to projected climate changes for climate scenario I (fig. 29–11).
- Although the climate projections and bioclimatic envelopes cannot reliably be used to predict future conditions, they nevertheless indicate potential future vulnerabilities under the climate scenarios evaluated for the REA. At lower elevations, sagebrush steppe is especially vulnerable to climate scenarios projecting decreased precipitation coupled with increased temperatures, which could lead to shifts from sagebrush steppe to desert shrublands or grasslands within the Wyoming Basin. Because sagebrush steppe is under-represented in relatively undeveloped areas, this could increase the vulnerability of this ecological community to changing climatic conditions. At higher elevations, subalpine forests and the alpine zone are especially vulnerable to projected increases in temperatures. This is particularly true for subalpine and alpine species of the Bighorn and Laramie Mountains due to the isolation of these mountain ranges from the northern Rocky Mountains, thereby decreasing the potential for these species to shift northward under a warming climate.

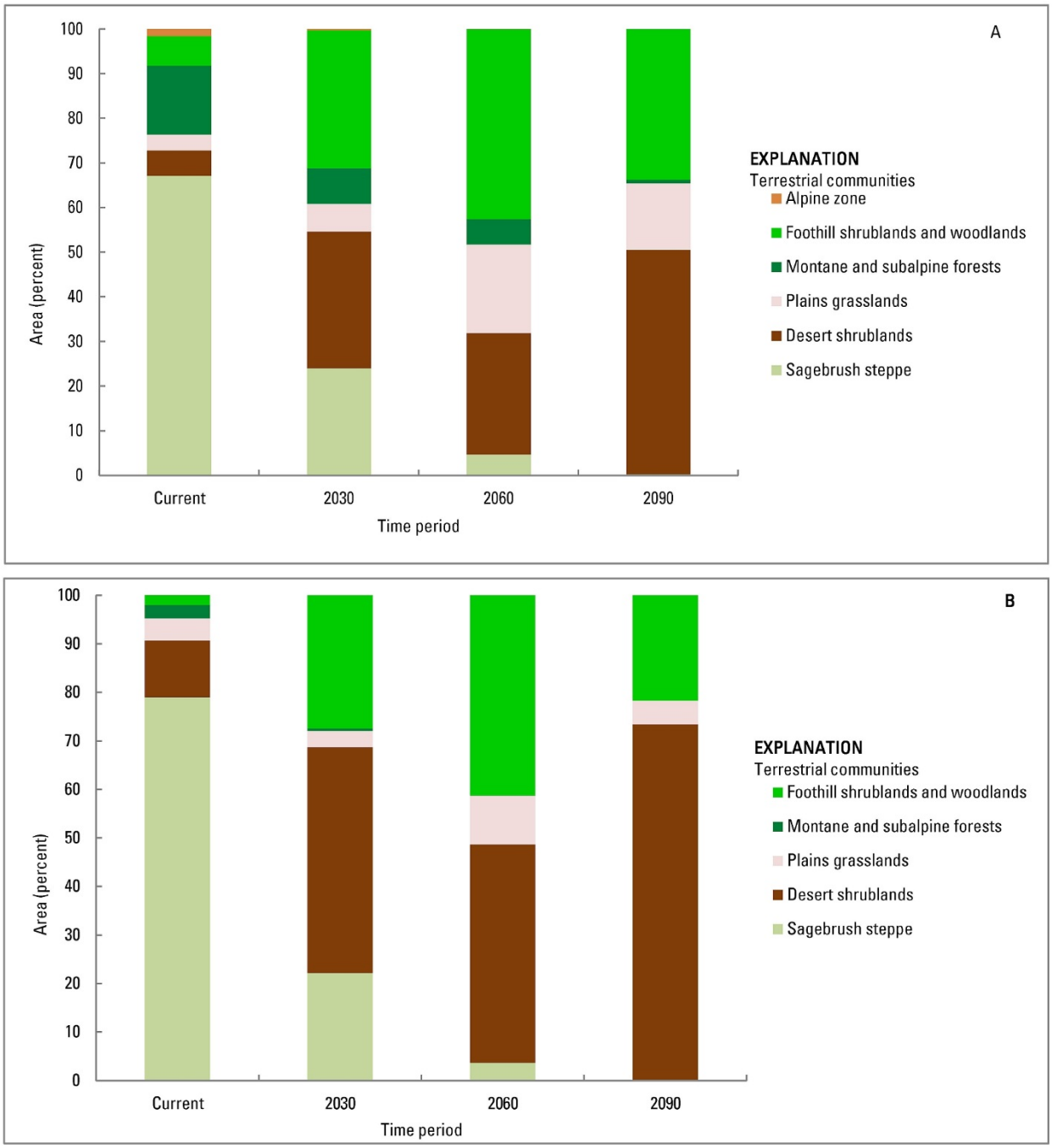

Figure 29–10. Potential changes in the proportional area of the projected bioclimatic envelopes for terrestrial communities (*A*) for the project area and (*B*) within viewsheds of historic trails in the Wyoming Basin Rapid Ecoregional Assessment project area. Current conditions and climate projections in 2030, 2060, and 2090 are based on bioclimatic envelopes developed by Rehfeldt and others (2012) using climate scenario I.

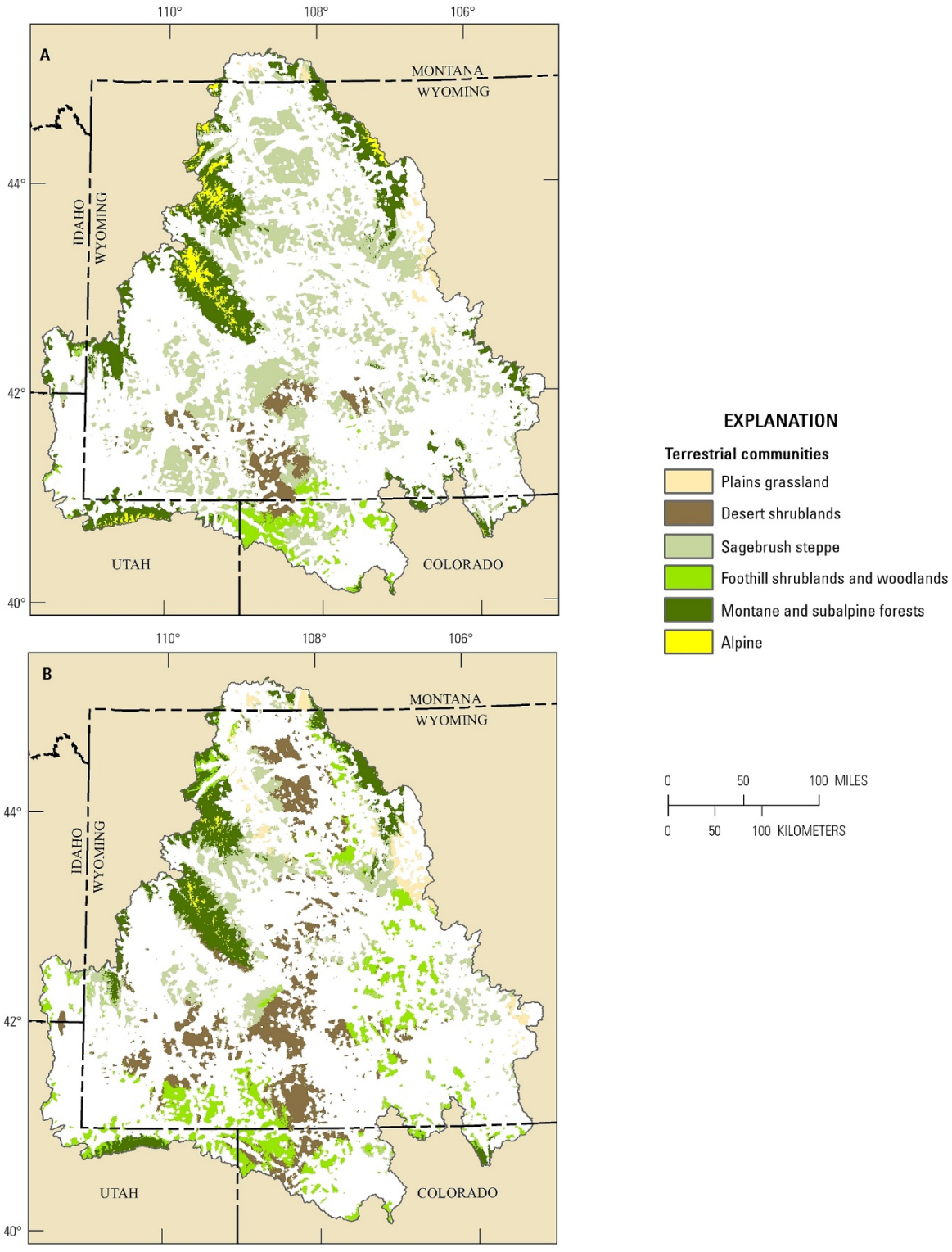

Figure 29–11. Potential changes in the proportional area of the projected bioclimatic envelopes for terrestrial communities in relatively undeveloped areas under (*A*) current conditions and (*B*) climate projections in the Wyoming Basin Rapid Ecoregional Assessment project area. Projected bioclimatic envelopes developed by Rehfeldt and others (2012) based on climate scenario I in 2030.

How well do relatively undeveloped areas represent terrestrial species evaluated as Conservation Elements (fig. 29–12)?

- There was relatively little overlap in the distribution of baseline habitats among species evaluated as Conservation Elements for the REA, as indicated by the low number of potential habitats present (fig. 29–12). For baseline habitats, 69 percent of the project area includes the habitats for three or fewer species evaluated as Conservation Elements, and only 8.3 percent of the project area contained habitat for five or more species.
- This pattern was similar for relatively undeveloped areas. Potential habitat for three or fewer species occurred in 76 percent of relatively undeveloped areas, and habitat for five or more species occurred in 5.4 percent of the relatively undeveloped areas.
- Collectively, all terrestrial conservation elements are represented by relatively undeveloped areas.

Where are the townships with the highest conservation potential for terrestrial species evaluated as Conservation Elements (fig. 29–13, table 29–4)?

- The map of townships with the highest conservation potential (fig. 29–13) includes the townships that were ranked with the highest conservation potential for at least one terrestrial species.
- The largest relatively undeveloped patches (>1,000 km^2) generally correspond to the townships that have the highest conservation potential for species (figs. 29–2 and 29–13).
- Numerous small relatively undeveloped patches (<100 km^2) were also ranked as having high conservation potential and may be important to particular species and may contribute to regional connectivity (fig. 29–13).
- As is the case for relatively undeveloped areas, the majority of townships with high conservation potential are predominantly on Federal lands but only the higher elevation sites have a U.S. Geological Survey National Gap Analysis Program (GAP) Protected Status of 1 or 2 (U.S. Geological Survey, 2012), and most of the townships on public lands are subject to extractive use (Fig. 29–13, table 29–4).

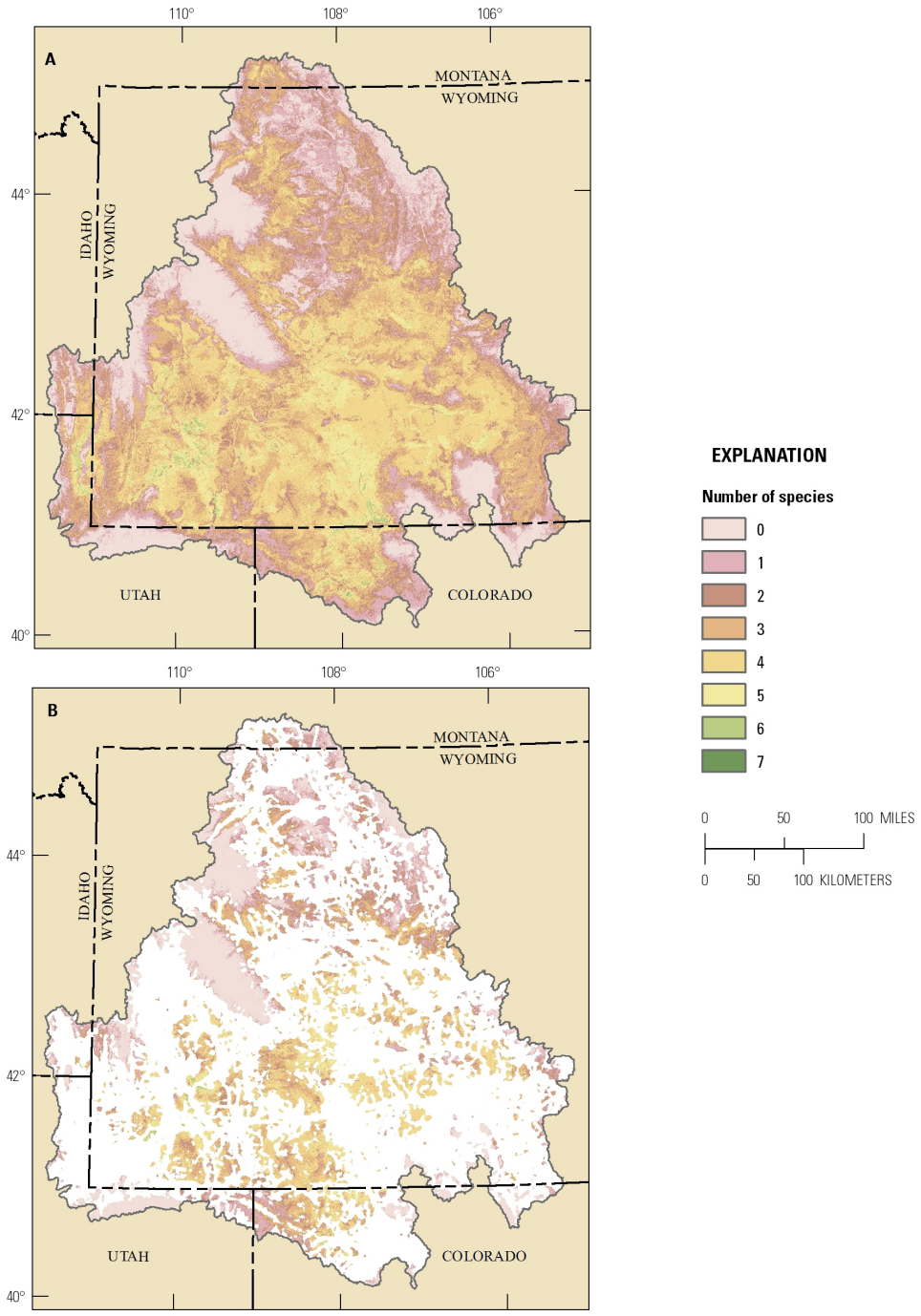

Figure 29–12. Number of habitat types present for terrestrial vertebrate species evaluated as Conservation Elements in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) baseline conditions and (*B*) relatively undeveloped areas. The number of species present in (*A*) is a reference for (*B*), to show the potential number of habitat types in relatively undeveloped areas. The comparison of baseline to relatively undeveloped areas also highlights where development affects a higher number of habitats for terrestrial species evaluated as Conservation Elements. The number of species present cannot be used as an index of integrity because that number was a function of the species selected for the Assessment (see fig. 1-6).

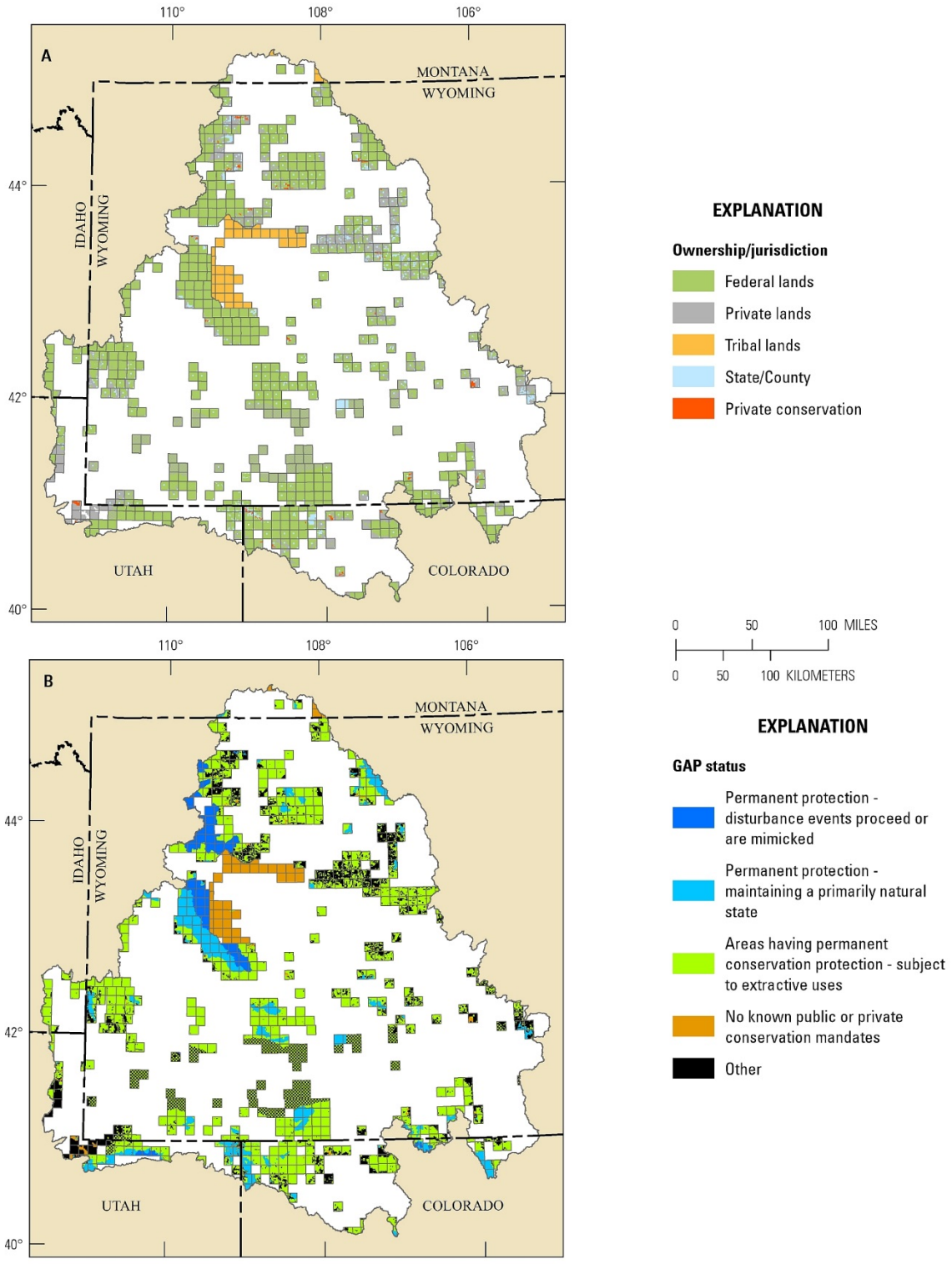

Figure 29–13. Townships with very high conservation potential for at least one terrestrial species evaluated as a Conservation Element: (*A*) by land ownership or jurisdiction and (*B*) by level of protection as defined by GAP status (U.S. Geological Survey, 2012) in the Wyoming Basin Rapid Ecoregional Assessment project area.

Table 29–4. Area of townships ranked as having very high terrestrial conservation potential by land ownership or jurisdiction in the Wyoming Basin Rapid Ecoregional Assessment project area.

[km^2, square kilometer]

Ownership or jurisdiction	Area (km^2)	Percent of area
Bureau of Land Management	19,570	38.2
Private	9,577	18.7
Forest Service[1]	15,414	30.1
State/County	2,576	5.0
Tribal	2,865	5.6
Other Federal[2]	625	1.2
Private conservation	277	0.5
National Park Service	162	0.3

[1] U.S. Department of Agriculture Forest Service.
[2] Bureau of Reclamation and U.S. Fish and Wildlife Service.

Where are the watersheds with the highest conservation potential for aquatic species evaluated as Conservation Elements (fig. 29–14, table 29–5)?

- The map of the watersheds with highest conservation potential (fig. 29–14) includes the watersheds that were ranked with the highest conservation potential for at least one aquatic species.
- The higher elevation watersheds ranked with the highest conservation potential for species generally correspond to the relatively undeveloped watersheds (figs. 29–7 and 29–14).
- In contrast, some watersheds ranked with high conservation potential do not correspond to relatively undeveloped watersheds, particularly in the southern and western portion of the project area. Likewise, some relatively undeveloped watersheds were not ranked as having high conservation potential, especially the Bighorn Basin, Wind River Basin, and northern portions of the Great Divide Basin (fig. 29–14).
- As is the case with terrestrial systems, the majority of watersheds ranked with high conservation potential are predominantly on Federal lands, but only the higher elevation sites have a GAP Protected Status of 1 or 2 (U.S. Geological Survey, 2012), and most of the townships on public lands are subject to extractive use (fig. 29–14, table 29–5).

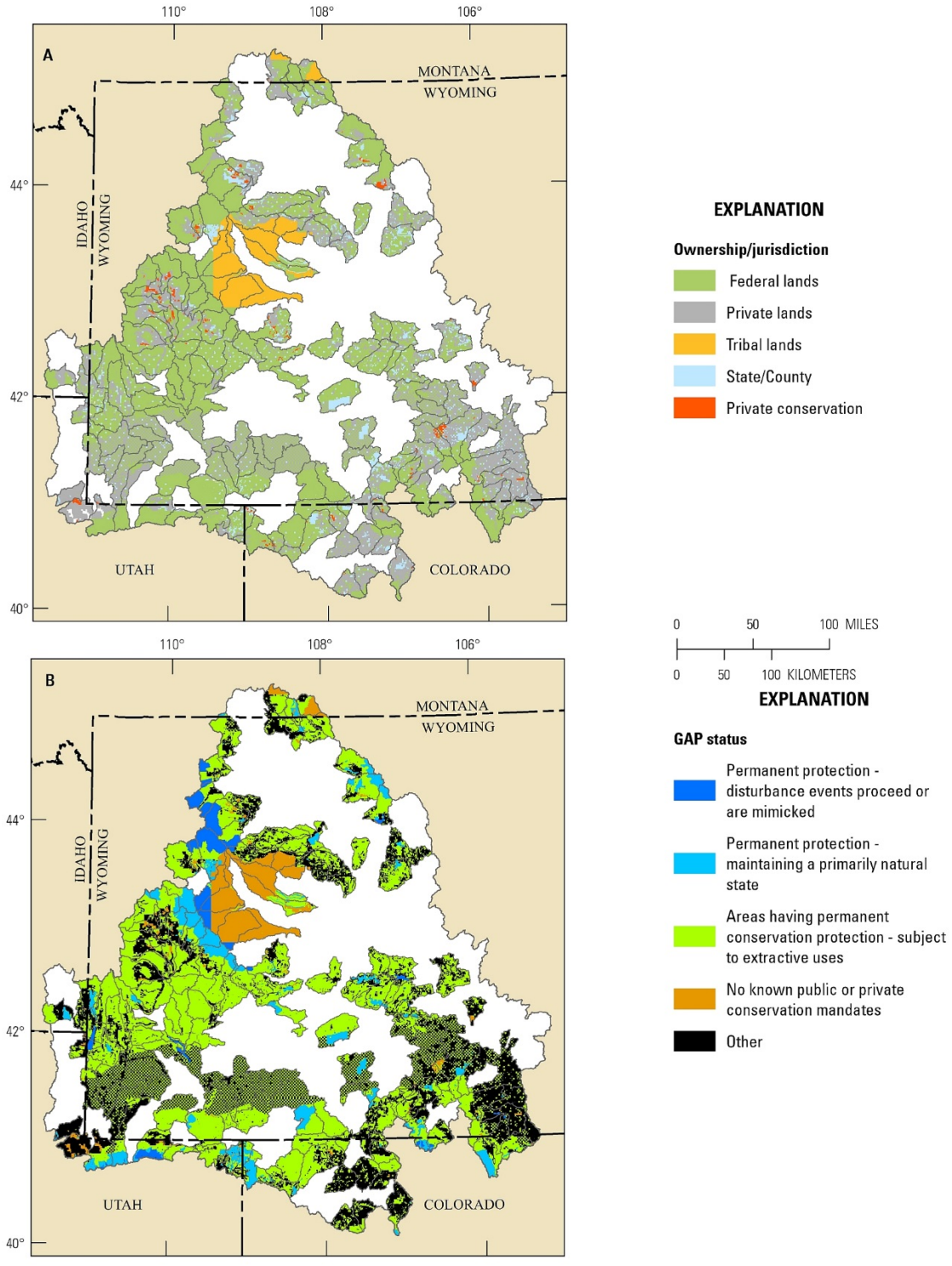

Figure 29–14. Fifth-level watersheds with high or very high conservation potential for at least one aquatic species evaluated as a Conservation Element: (*A*) by land ownership or jurisdiction and (*B*) by level of protection as defined by GAP Status (U.S. Geological Survey, 2012) in the Wyoming Basin Rapid Ecoregional Assessment project area.

Table 29–5. Area of fifth-level watersheds ranked as having high or very high aquatic conservation potential by land ownership or jurisdiction status in the Wyoming Basin Rapid Ecoregional Assessment project area.

[km^2, square kilometer]

Ownership or jurisdiction	Area (km^2)	Percent of area
Bureau of Land Management	36,355	35.5
Private	30,848	30.1
Forest Service[1]	19,493	19.0
State/County	6,181	6.0
Tribal	5,962	5.8
Other Federal	2,222	2.2
Private conservation	823	0.8
National Park Service	445	0.4

[1] U.S. Department of Agriculture Forest Service.
[2] Bureau of Reclamation, Department of Defense, Department of Energy, and U.S. Fish and Wildlife Service.

Summary

Large, relatively undeveloped areas represent lands that may have high landscape intactness. Local information on composition and other measures of condition will be necessary to fully evaluate the intactness of relatively undeveloped areas. Most of the relatively undeveloped areas occur on Federal lands, and most of these lands are under Bureau of Land Management jurisdiction and subject to extractive use. For terrestrial systems, relatively undeveloped areas cover 28.6 percent of the project area, most of which occur within the largest relatively undeveloped patches (<1,000 square kilometers [386 square miles]) covering 21 percent of the project area. Sagebrush steppe, which covers 55 percent of the ecoregion, is underrepresented in relatively undeveloped areas, as only 20 percent of sagebrush steppe falls within the relatively undeveloped areas.

For most terrestrial species, townships with the highest conservation potential correspond to relatively undeveloped areas for the entire ecoregion. For aquatic species, however, there were many watersheds with high conservation potential that were outside of the relatively undeveloped watersheds for the entire ecoregion. Because areas with high conservation potential for species and communities may occur outside of the largest relatively undeveloped areas for the ecoregion, landscape intactness at the ecoregion level is useful but not sufficient in evaluating conservation potential of public lands. Conservation potential for ecological communities and priority species may help to identify other areas of high ecological value and low risk.

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