Section IV. Assessments of Species and Species Assemblages

Chapter 21. Sauger

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Key Ecological Attributes

Distribution and Ecology

Sauger was once a widely distributed native fish species that historically occurred in the Missouri and Mississippi drainages (McMahon and Garder, 2001). The species occurred in the Mississippi River as far downstream as Arkansas and in the Missouri River upstream to Great Falls, Montana. Although species in the family Percidae generally do not disperse long distances, the sauger is considered the most migratory percid in North America, on the basis of documented movements of up to 600 kilometers (km) (372.8 miles [mi]) (Collette and others, 1977; Jaeger, 2004). Sauger typically inhabit large, turbid, cool-water (20–28 degrees Celsius °C [68–82 degrees Fahrenheit °F]) rivers and shallow turbid lakes, but they also occur in adjoining reservoirs (Wyoming Game and Fish Department, 2010).

Sauger have experienced substantial population declines and local extirpation across their range (McMahon, 1999). For example, in the Yellowstone River, it was estimated that sauger numbers declined 86–96 percent during the 1980s (McMahon, 1999). In the Wyoming Basin, sauger were historically found in the North Platte, Powder, Tongue, Bighorn, and Wind River drainages, but their distribution has been substantially reduced, and they have been extirpated from the North Platte River (Wyoming Game and Fish Department, 2010). Remaining populations in the Wyoming Basin are restricted to a small population in the Tongue River, a seasonal population in the Powder River, and one population each in the Bighorn drainage and the Wind River drainage. The populations in the Bighorn and Wind River drainages have been identified as conservation priorities because they are among the last genetically pure sauger populations in the Missouri River drainage (Wyoming Game and Fish Department, 2010). The Bighorn River population is considered to be stable or increasing, but the Wind River population has been experiencing declines and limited recruitment (Wyoming Game and Fish Department, 2010).

Sauger prefer turbid river segments with deep pools, cool temperatures, high alkalinity, and fine substrates (Amadio and others, 2006). They spend most of their time in large, deep pools (Kuhn and others, 2008) but may also use backwaters (Wilhite and Hubert, 2011). The upstream distribution of sauger appears to be limited by low summer temperatures, channel slope, and water diversions (Amadio and others, 2005). Sauger are primarily piscivorous, although juveniles will feed on aquatic invertebrates.

Landscape Structure and Dynamics

Sauger are highly migratory in the spring during the spawning season, but otherwise they are fairly sedentary (Bellgraph and others, 2008; Kuhn and others, 2008). Generally, sauger travel long distances to spawn, often aggregating in a few relatively discrete spawning areas (Jaeger, 2004). Spawning migrations of up to 600 km (372.8 mi) have been documented (Jaeger, 2004). In Wyoming, spawning migrations in both upstream and downstream directions have been observed (Kuhn and others, 2008).

For spawning, it has been thought that sauger seek out cooler tributaries (11–15 °C [52–59 °F]) with gravel and cobble substrates (Wyoming Game and Fish Department, 2010), but one telemetry study indicated that sauger spawned almost exclusively in river mainstems (Jaeger and others, 2005). Following emergence, larval sauger may drift considerable distances downstream (up to 300 km [186.4 mi]), and juveniles may seek off-channel sites during spring and summer before shifting to river mainstems in autumn (Jaeger, 2004). Therefore, structural connectivity between nonbreeding and spawning habitat is critical to maintaining self-sustaining sauger populations.

Flow-related variables, principally water velocity and depth, are important components of sauger habitat, but preferred conditions vary seasonally. During the nonbreeding season, sauger inhabit free-flowing, turbid river systems with deep, low-velocity pools and runs (Kuhn and others, 2008). In winter, low-velocity pools >1.83 meters (m) (6 feet [ft]) deep are preferred (Kuhn, 2005).

Change Agents

Declines in the abundance and distribution of sauger are largely attributed to habitat degradation. In the Wyoming Basin, primary concerns are loss of habitat and decreased structural connectivity due to dams and water diversions. Additional concerns include hybridization and competition with introduced populations of walleye. Angler exploitation also may affect populations adversely in some locations (Wyoming Game and Fish Department, 2010).

Development

Sauger are highly susceptible to habitat loss and alteration due to their migratory nature and the limited availability of suitable spawning areas (Jaeger, 2004). Dams can affect the availability of preferred habitat conditions by altering the flow regime, decreasing water temperatures, affecting turbidity, and disrupting pool formation, which can negatively affect sauger abundance, recruitment, growth, and survival (Wyoming Game and Fish Department, 2010). Dams and water diversions also can fragment or disconnect spawning runs, which may have important effects on sauger movements, and they can entrain drifting larvae. In the Bighorn and Wind River drainage systems, the Boysen and Yellowtail dams have divided a previously contiguous population into two isolated populations.

Energy and Infrastructure

There is little specific information about the potential effects of energy development on sauger, but energy development typically affects fish populations as a consequence of water withdrawal, surface disturbance and sedimentation of spawning habitats, and water contamination (Entrekin and others, 2011). Reduced streamflow resulting from water withdrawal can affect habitat availability and quality, thereby leading to decreased recruitment. Surface disturbance can increase sedimentation in streams, reducing the amount of suitable spawning substrate available, and water contamination can have toxic or chronic sublethal effects. A preliminary study, however, suggests that sauger may tolerate at least some water contamination associated with energy development because growth rates of sauger in the Tongue Reservoir on the Montana-Wyoming border did not appear to be negatively affected by effluents from the Decker surface coal mine (Riggs and Gregory, 1980).

Agricultural Activities

Compared to cold-water fishes, adult sauger may be relatively tolerant of livestock grazing because their preferred habitat (large, cool-water, turbid rivers) may be more buffered from the direct and indirect effects of grazing pressures than the small, cold-water streams preferred by cold-water fishes. Sauger, however, also will use tributaries, which could be degraded by livestock grazing through sedimentation, loss of riparian habitat, and increased water temperatures (Armour and others, 1991).

Water diversions pose significant management concerns, as they reduce population connectivity, thereby restricting movements and limiting access to spawning habitats. They also can entrain and kill sauger (Amadio and others, 2005; Jaeger and others, 2005), and extensive water use can result in the loss of backwater and side channel habitat (Wilhite and Hubert, 2011).

Invasive Species and Disease

Sauger can hybridize with walleye, which were introduced to some lakes and reservoirs of the Wyoming Basin. In some regions, fisheries managers have intentionally hybridized walleye and sauger to produce "saugeye," on the basis of the premise that the hybrid may be more tolerant of turbid reservoir conditions than walleye (Zweifel and others, 2010). Walleye have been stocked in Bighorn Lake and Ocean Lake, and historically they also were stocked in Boysen Reservoir (Bingham and others, 2012). Despite the co-occurrence of walleye and sauger populations, hybridization appears to be rare in wild populations. Bingham and others (2012) detected only 18 hybrids out of 925 individuals analyzed. Additionally, 50 percent of the hybrid individuals appeared to have a nonhybrid ancestor within the previous two generations, indicating that the hybridization event was recent. Walleye pose additional risks to sauger by functioning as potential predators, competitors, and disease vectors. There is considerable overlap in habitat use by sauger and walleye suggesting the potential for competition is high, although walleye are more common in lakes and reservoirs (Bellgraph and others, 2008).

Climate Change

Projected changes in drought frequency and severity and temperatures have the potential to affect sauger populations. An increase in the frequency or severity of droughts could decrease habitat availability and structural connectivity, strand eggs, limit downstream transport of larvae, and limit prey production and recruitment (Jaeger, 2004). Indeed, low streamflow is believed to be a contributing factor to sauger declines that occurred throughout Montana in the late 1980s (McMahon, 1999). Increased temperatures could decrease habitat availability by making downstream stream reaches too warm, or they could have positive effects by increasing availability of habitat where populations are currently limited by cold temperatures. Sauger tolerate water temperatures between 1–30 °C (34–86 °F) (Carlander, 1997) and have an upper temperature limit of about 31.2 °C (88.2 °F) (Fang and others, 2004). A national study modeling thermal and dissolved oxygen for coolwater fish (which included sauger) in lakes showed the potential for an increase in the number of days that would be conducive for growth on the basis of forecasted temperature and dissolved oxygen levels for the projected climate scenarios evaluated for the Wyoming Basin region (Fang and others, 2004).

Rapid Ecoregional Assessment Components Evaluated for Sauger

A generalized, conceptual model was used to highlight some of the key ecological attributes and change agents affecting sauger (fig. 21–1). Key ecological attributes addressed by the Rapid Ecoregional Assessment (REA) include (1) the distribution of sauger, (2) landscape structure (patch size and connectivity), and (3) landscape dynamics (fire occurrence and hydrologic regime) (table 21–1). Change Agents evaluated include development, nonnative fishes, and climate change (table 21–2). Ecological values and risks used to assess the conservation potential for sauger by fifth-level watershed are summarized in Table 21–3. Core and Integrated Management Questions and the number of the associated summary maps and graphs are provided in Table 21–4.

Methods Overview

The distribution of sauger in the Wyoming Basin REA project area was derived from mapped occurrences from state game and fish agencies (see table 21–1 for data sources) and was used to quantify baseline conditions. Sauger abundance was estimated by state game and fish biologists as rare, common, or abundant. The Aquatic Development Index (ADI) scores were derived from catchments coincident with sauger habitat. We used the length of occupied streams as an index of patch size. Stream segments were derived from natural and anthropogenic barriers (dams) that restrict bidirectional movements among sauger populations. To incorporate additional potential barriers, we summarized the number of points of diversion within 30 meters (m) (98.4 feet [ft]) and stream-road crossings within 10 m (32.8 ft) of occupied stream segments by sixth-level watershed. Competition, predation, and hybridization risk were derived from occurrence data for walleye compiled from Wyoming Game and Fish Department. Mean summer flow was derived from U.S. Department of Agriculture Forest Service data for sixth-level watersheds (table 21–1; see Methods section in the Streams and Rivers chapter for additional details). The summarized flow data for each watershed were assigned to stream segments coincident with the watershed. Stream segments predicted to have a mean summer flow near or at 0 cubic feet per second (ft^3/s) were considered at risk for drought due to low flow.

Landscape-level ecological values (amount of sauger habitat) and risks (ADI score, risk of low summer flow, hybridization risk) were compiled into an overall index of conservation potential for each fifth-level watershed (table 21–3). Conservation potential for sauger was summarized by fifth-level watershed based on overall landscape-level values and risks (table 21–3). Landscape-level values and risks, and conservation potential rankings are intended to provide a synthetic overview of the geospatial datasets developed to address Core Management Questions in the REA. 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 Chapter 2—Assessment Framework and the Appendix for additional details on the methods.

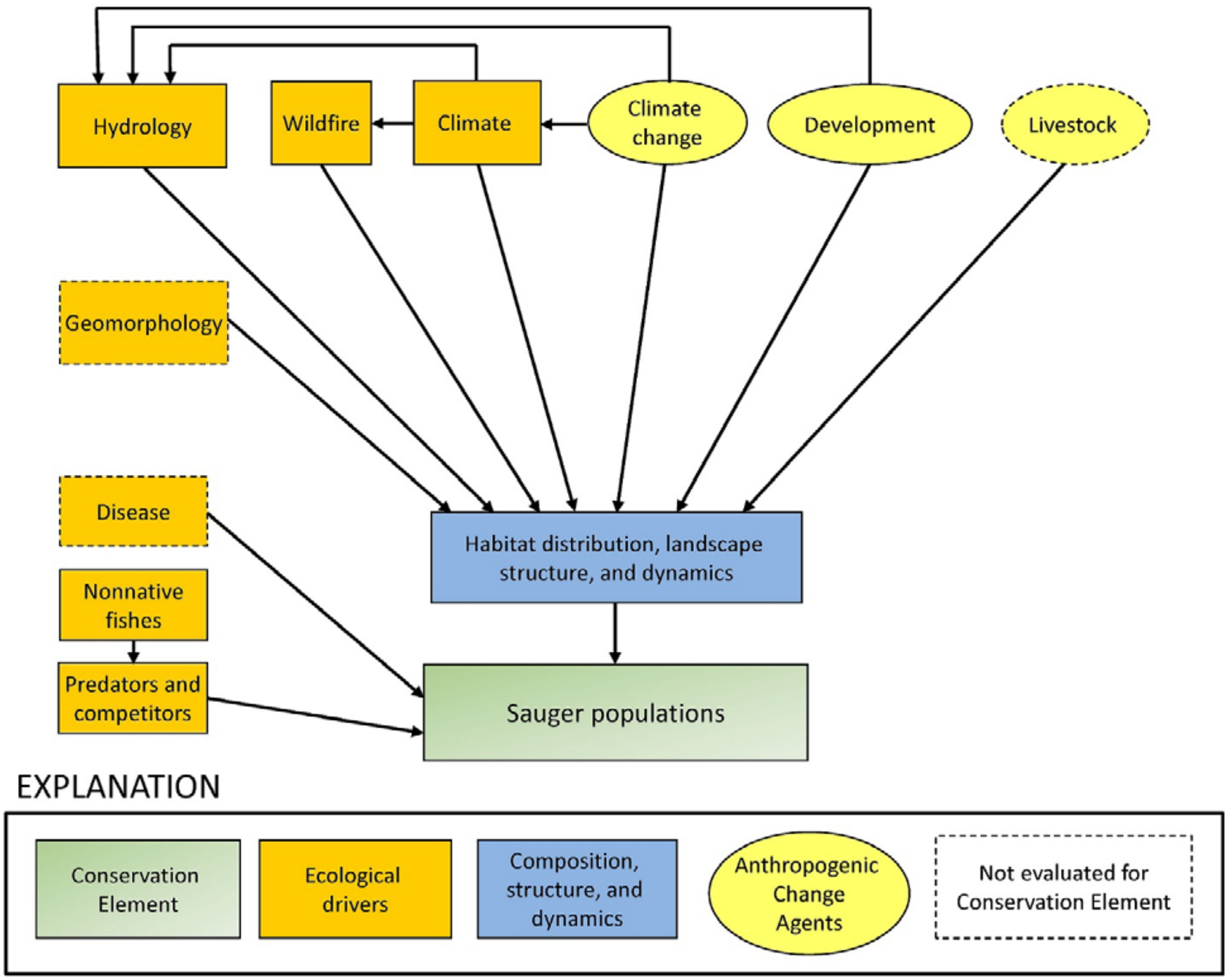

Figure 21–1. Generalized conceptual model of sauger habitat for the Wyoming Basin Rapid Ecoregional Assessment (REA). Biophysical attributes and ecological processes regulating the occurrence, structure, and dynamics of sauger populations and habitat are shown in orange rectangles; additional ecological attributes are shown in blue rectangles; and anthropogenic Change Agents that affect key ecological attributes are shown in yellow ovals. The dashed lines indicate components not addressed by the REA. Livestock is a Change Agent that was not evaluated due to lack of regionwide data.

Table 21–1. Key ecological attributes and associated indicators of baseline sauger habitat[1] for the Wyoming Basin Rapid Ecoregional Assessment.

Attributes	Variables	Indicators
Amount and distribution	Stream length and area of lakes/ reservoirs occupied	Habitat distribution derived from occurrence data[2]
Landscape structure	Patch size	Stream-segment length frequency distribution
Landscape dynamics	Fire occurrence	See Chapter 8—Streams and Rivers
	Hydrologic regime	Mean summer flow[3]

[1] Baseline conditions are used as a benchmark to evaluate changes in the amount and landscape structure of sauger habitat due to Change Agents. Baseline conditions are defined as the current distribution of sauger derived from occurrence surveys. However, dams have already altered conditions and increased isolation of populations. See Chapter 2—Assessment Framework.

[2] Data provided by the Wyoming Game and Fish Department.

[3] U.S. Department of Agriculture Forest Service; http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml (Wenger and others, 2010).

Table 21–2. Anthropogenic Change agents and associated indicators influencing sauger habitat for the Wyoming Basin Rapid Ecoregional Assessment.

[m, meter]

Change Agents	Variables	Indicators
Development	Aquatic Development Index (ADI)	Percent of sauger habitat in seven development classes[1]
		Frequency distribution of stream-segment lengths that are relatively undeveloped or have a low development score compared to baseline habitat[2]
	Barriers to movement	Number of potential barriers (dams and points of diversion within 30 m and stream-road crossings) [1]
Invasive species	Competition and predation with walleye	Co-occurrence of sauger with walleye[3]
Climate change	Hydrologic regime change	See Chapter 8—Streams and Rivers

[1] See Chapter 2—Assessment Framework and Appendix.

[2] Relatively undeveloped segments using ADI scores <20.

[3] Walleye occurrence data provided by the Wyoming Game and Fish Department.

Table 21–3. Landscape-level ecological values and risks for sauger distribution. Ranks were combined into an index of conservation potential for the Wyoming Basin Rapid Ecoregional Assessment.

[km, kilometer]

	Variables[1]	Relative rank Lowest	Medium	Highest	Description[2]
Values[3]	Amount of habitat	<22	22–40	>40	Mean length (km) of stream segments by watershed
	Number of populations	0	1	2–3	Number of stream segments by watershed
		0	1	2–5	Number of lakes/reservoirs by watershed
Risks	Aquatic Development Index (ADI)	<20	20–40	>40	Mean ADI score by watershed
	Stream segments at risk of very low summer flow	0	0–0.5	>0.5	Number of occupied stream segments with zero mean summer flow, standardized by total length of occupied stream segments, by watershed
	Competition/ hybridization risk	<37	37–78	>78	The percent of catchments per watershed with walleye present

[1] Fifth-level watershed was used as the analysis unit for conservation potential on the basis of input from Bureau of Land Management (see table A–19 in the Appendix).

[2] See tables 21–1 and 21–2 for description of variables.

[3] Amount of habitat was valued in three ways: (1) length of stream segment, (2) number of segments (populations), and (3) number of lakes/reservoirs. Watersheds with longer stream segments and (or) greater number of populations (occupied stream segments and lakes/reservoirs) receive the highest rank for ecological values.

Table 21–4. Management questions evaluated for sauger in Wyoming Basin Rapid Ecological Assessment.

Core Management Questions	Results
Where is baseline sauger habitat, and what is the total area occupied?	Figure 21–2
Where does development pose the greatest threat to baseline sauger habitat, and where are the large, relatively undeveloped habitats?	Figures 21–3 to 21–6
Where do dams, water diversions, and stream–road crossings pose potential barriers to sauger movements, and where are watersheds with high structural connectivity?	Figure 21–7
Where are sauger populations at risk from competition and hybridization with walleye?	Figure 21–8
Where are sauger populations at risk from low summer flows?	Figure 21–9
Integrated Management Questions	**Results**
How does risk from development vary by land ownership or jurisdiction for sauger habitat?	Table 21–5, Figure 21–10
Where are the watersheds with the greatest landscape-level ecological values?	Figure 21–11
Where are the watersheds with the greatest landscape-level risks?	Figure 21–12
Where are the watersheds with the greatest conservation potential?	Figure 21–13

Key Findings for Management Questions

Where is baseline sauger habitat, and what is the total area occupied (fig. 21–2)?

- Sauger currently have a very limited distribution in the Wyoming Basin, occupying only 656 km (407.62 mi) of streams and rivers and 113 km^2 (43.63 mi^2) of reservoirs (fig. 21–2).
- Sauger are abundant in the Boysen Reservoir and the Bighorn River, rare in the Greybull River, and their abundance is unknown in the remaining areas (fig. 21–2).

Where does development pose the greatest threat to baseline sauger habitat, and where are the large, relatively undeveloped habitats (figs. 21–3 to 21–6)?

- Almost all the habitat occupied by sauger has moderate or high levels of development as indicated by an ADI score >30 (fig. 21–3).
- Only 1.2 percent of river and stream habitat and 8.2 percent of reservoir habitat are relatively undeveloped (ADI score <20) (fig. 21–4).
- Nearly all baseline stream segments were between 100−500 km (62.12–310.67 mi). However, as a consequence of high disturbance levels, only one small segment (<50 km [31.07 mi]) occurs in relatively undeveloped habitat (fig. 21–5).
- The high development scores are primarily due to agriculture and, to a lesser extent, roads and water diversions. There is limited energy development in baseline sauger habitat.
- The only relatively undeveloped stream segment of habitat is located in the Popo Agie River (fig. 21–6).

Where do dams, water diversions, and stream-road crossings pose potential barriers to sauger movements, and where are watersheds with high structural connectivity (fig. 21–7)?

- The number of stream and road crossings per sixth-level watershed is relatively low, except for in the Nowood River (a tributary to the Bighorn), which ranged between 6 and 50 crossings.
- The number of water diversions was generally high, especially in the Bighorn, Nowood, and Popo Agie Rivers.
- Many sixth-level watersheds have between 6−50 potential barriers and four watersheds have >50 potential barriers (fig. 21–7).

Where are sauger populations at risk from competition and hybridization with walleye (fig. 21–8)?

- Walleye are present in 68 percent of riverine sauger habitat. The Wind, Little Wind, and Popo Agie Rivers are the only sauger habitat free of walleye.
- Walleye co-occur with sauger in all lakes and reservoirs.

Where are sauger populations currently at risk from low summer flows (fig. 21–9)?

- Sauger exist in streams with mean summer flow ranging from 0 to >10 cubic feet per second (fig. 21–9).

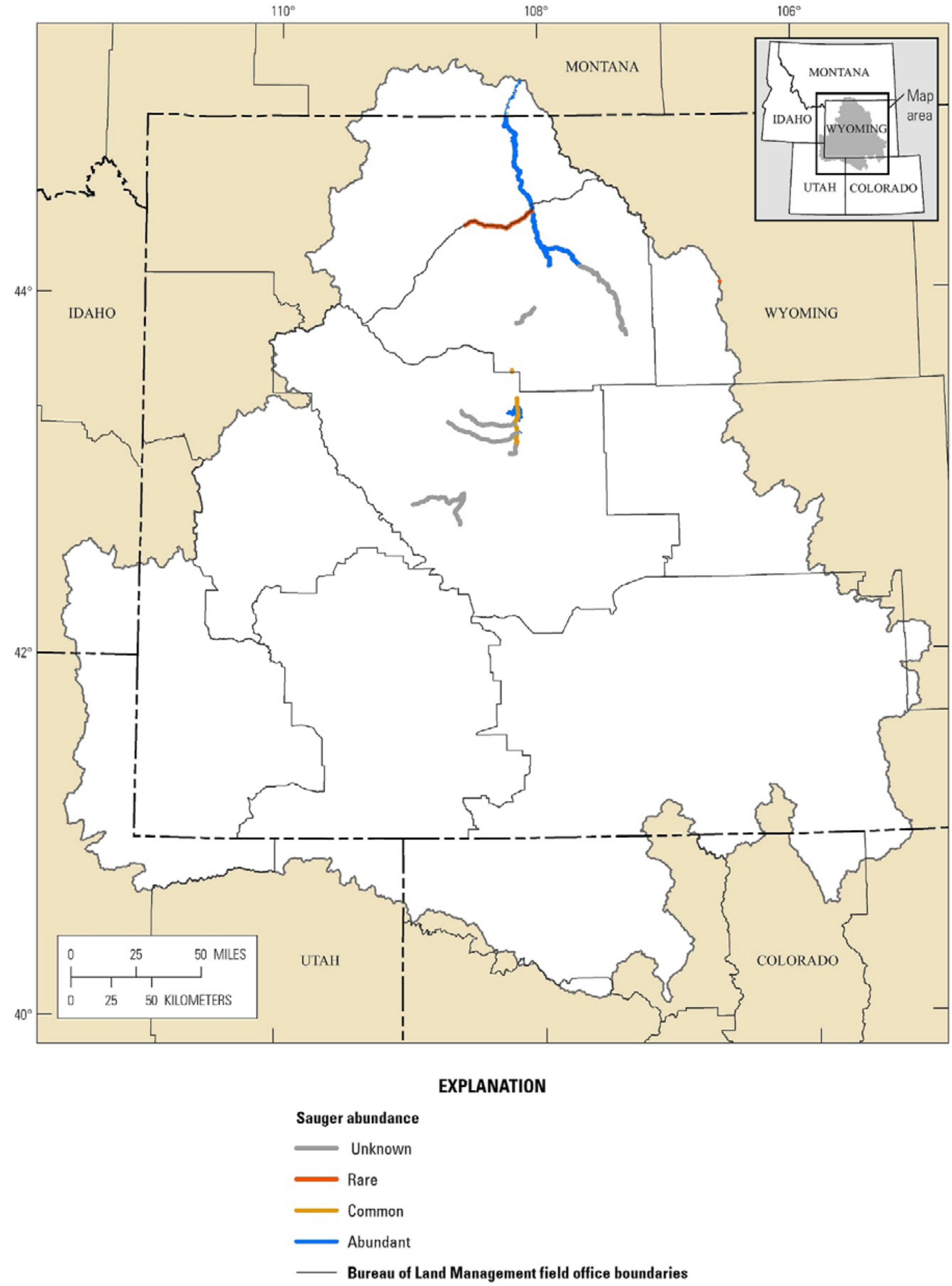

Figure 21–2. Distribution and abundance of sauger in the Wyoming Basin Rapid Ecoregional Assessment project area.

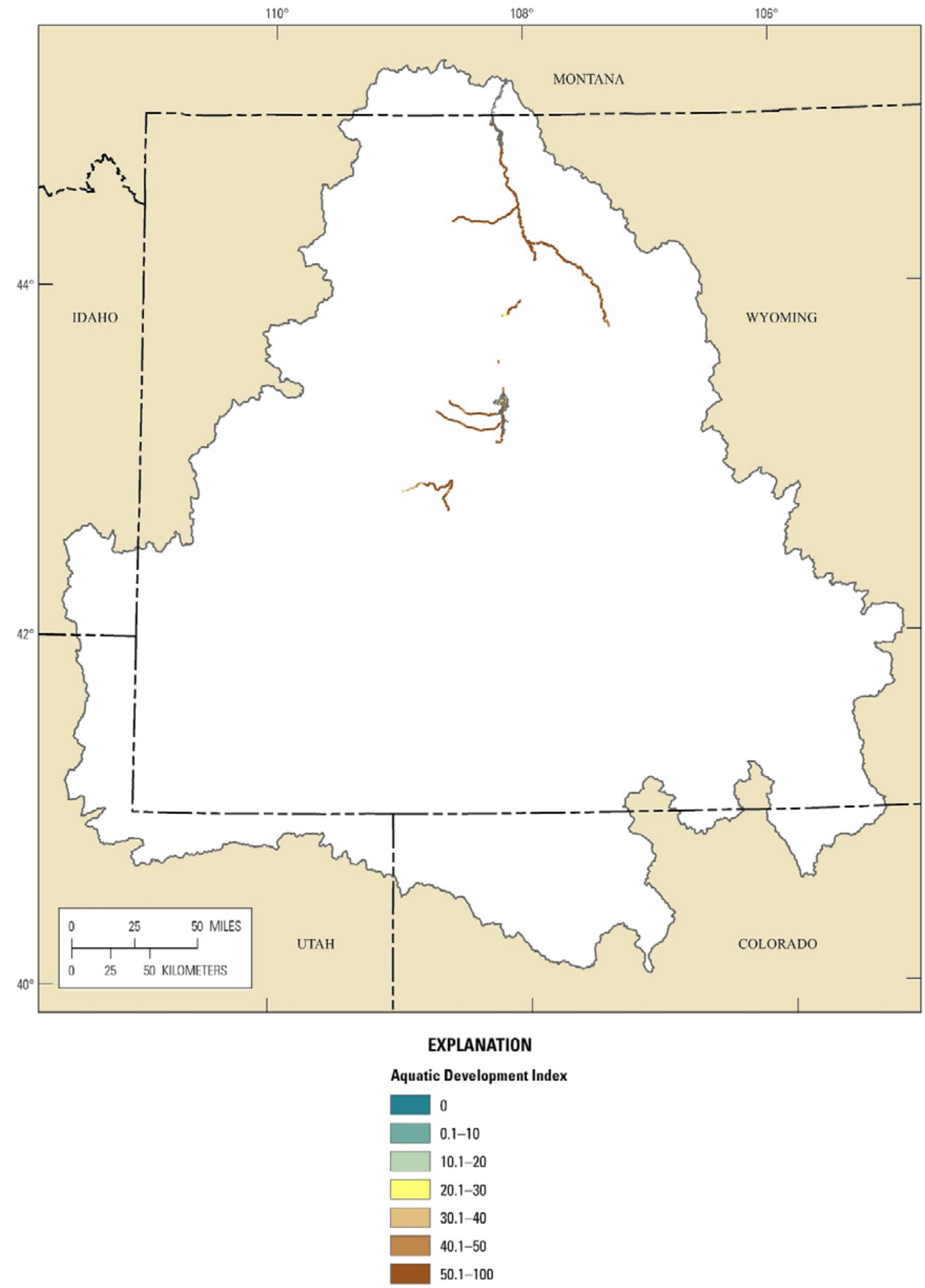

Figure 21–3. Aquatic Development Index scores for sauger habitat in the Wyoming Basin Rapid Ecoregional Assessment project area.

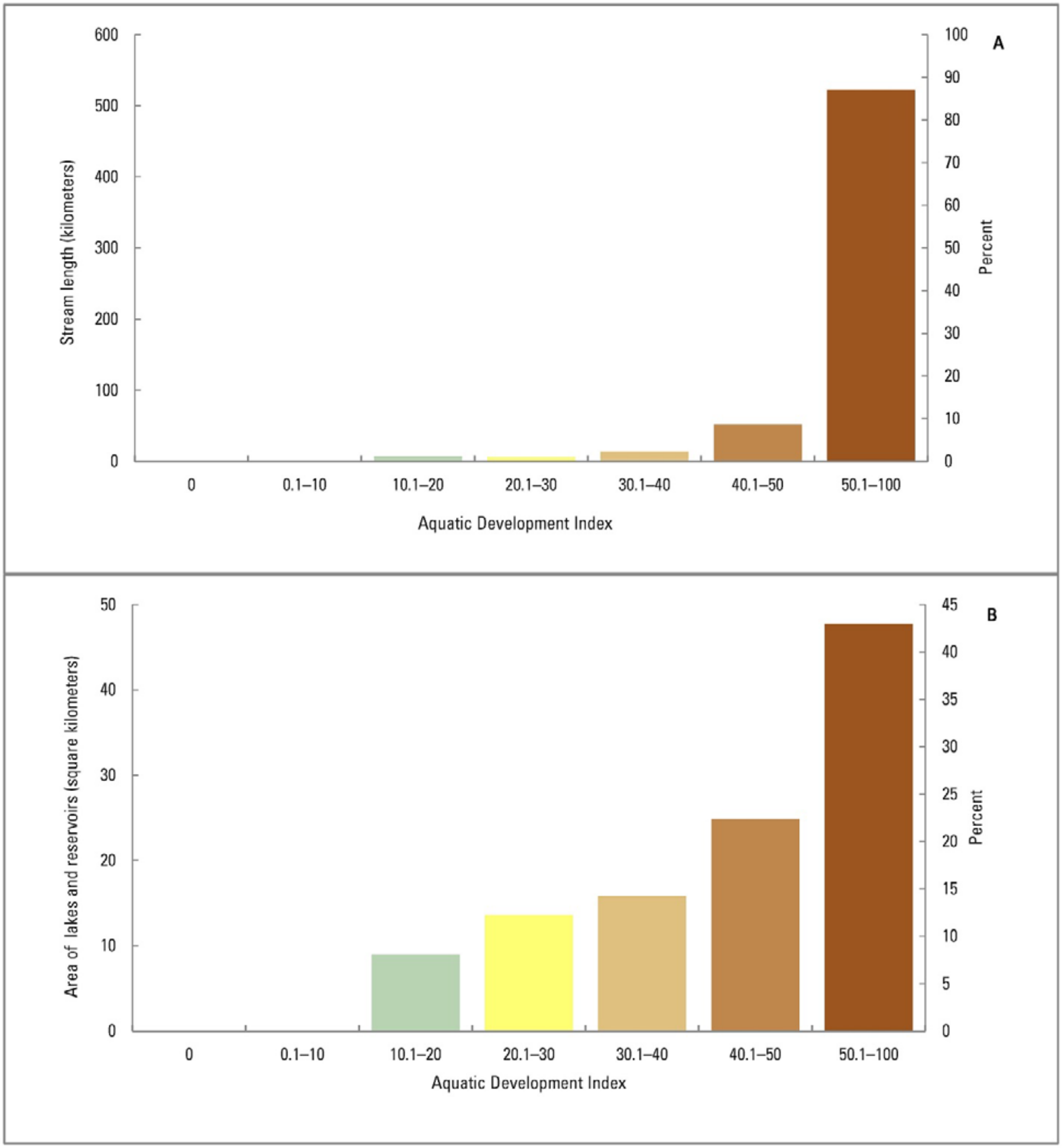

Figure 21–4. Sauger habitat as a function of the Aquatic Development Index in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) streams and rivers and (*B*) lakes and reservoirs.

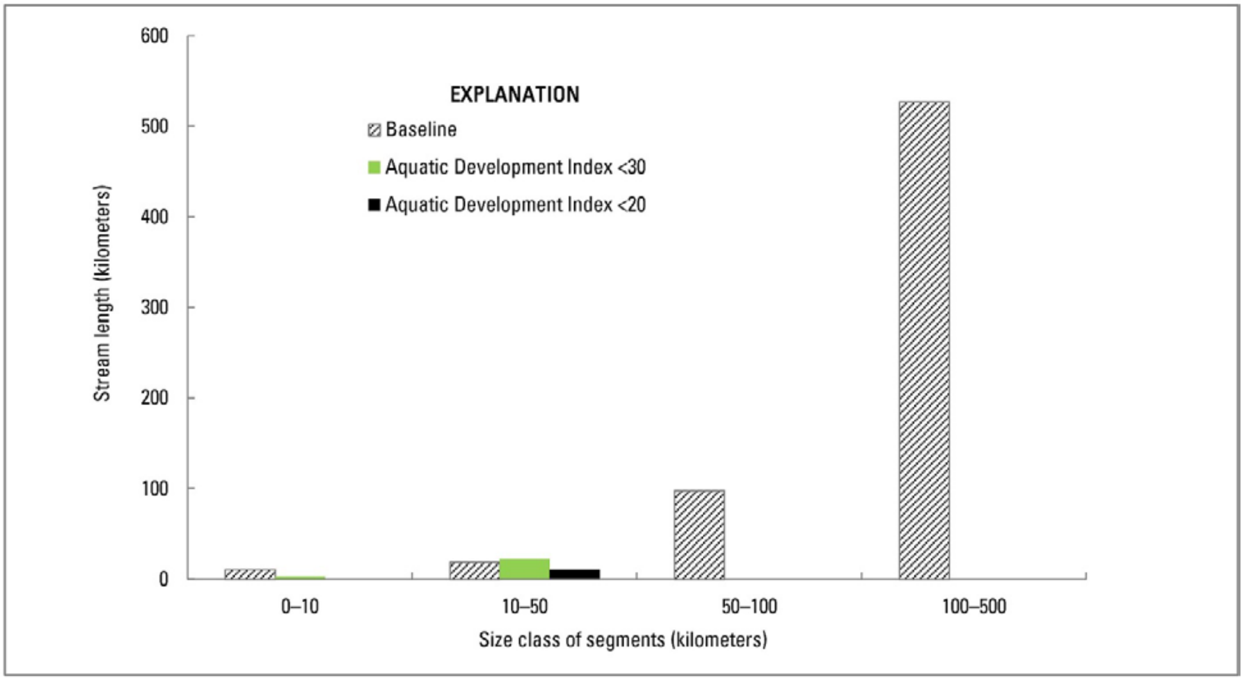

Figure 21–5. Amount of sauger habitat as a function of stream-segment size for baseline conditions and two development levels: (1) Aquatic Development Index (ADI) score <30, and (2) ADI score <20 (relatively undeveloped habitat) in the Wyoming Basin Rapid Ecoregional Assessment project area.

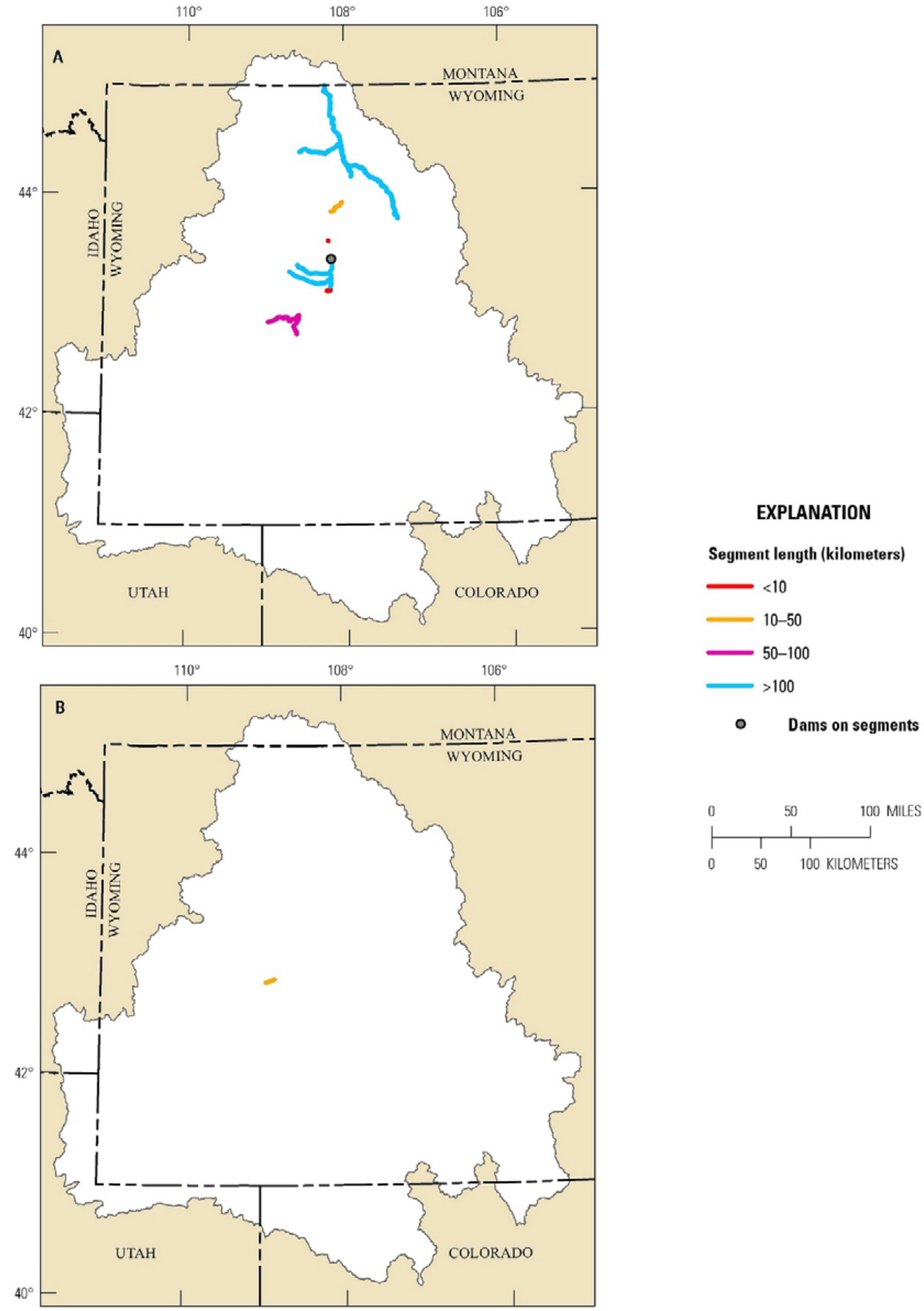

Figure 21–6. Stream-segment length of sauger habitat in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) baseline conditions and (*B*) relatively undeveloped areas (Aquatic Development Index <20).

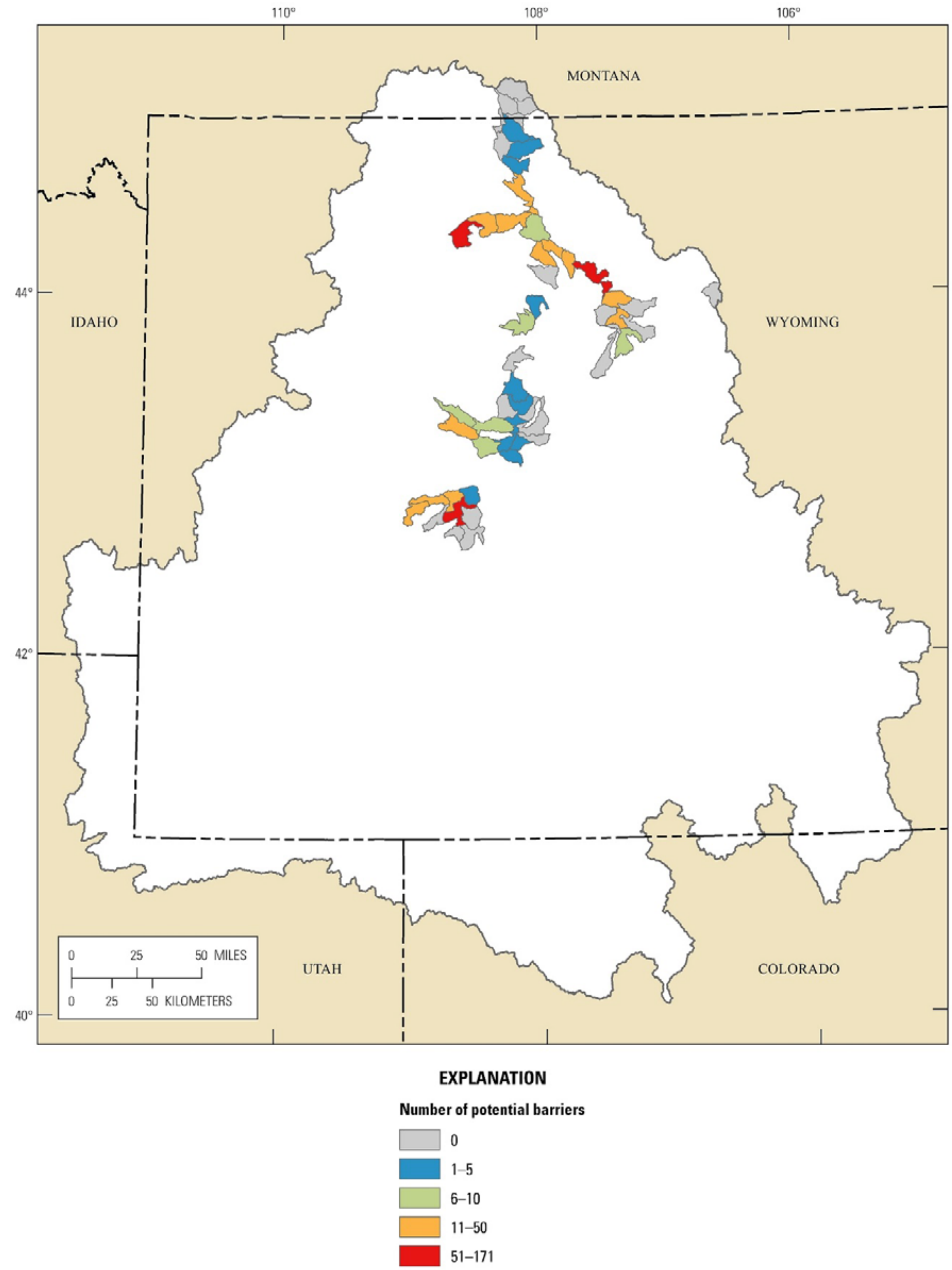

Figure 21–7. Potential barriers to sauger movement summarized by sixth-level watershed. Number of potential barriers includes dams, stream-road crossings, and water diversions in the Wyoming Basin Rapid Ecoregional Assessment project area.

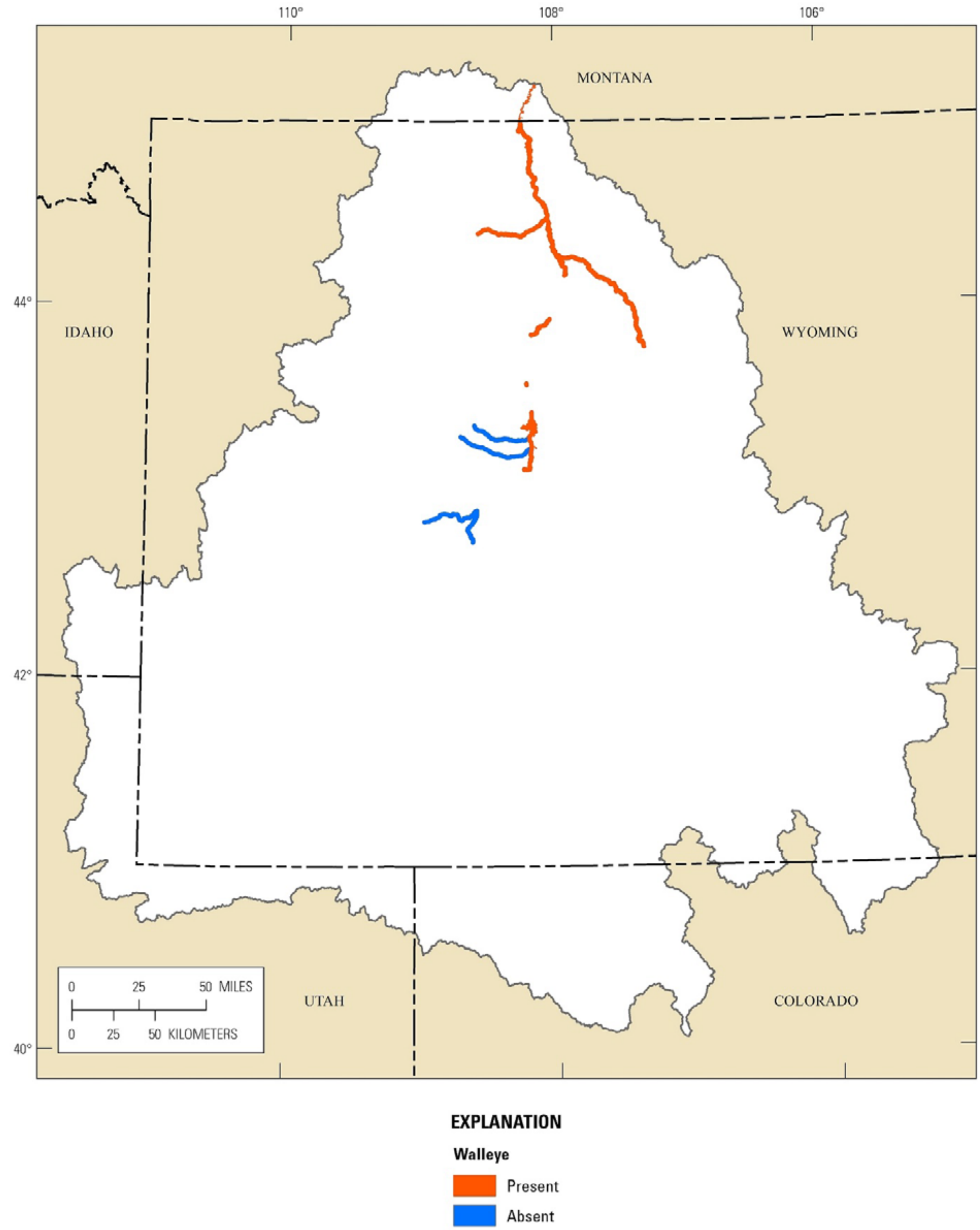

Figure 21–8. Competition and hybridization risk posed by walleye occurrence in sauger habitat within the Wyoming Basin Rapid Ecoregional Assessment project area.

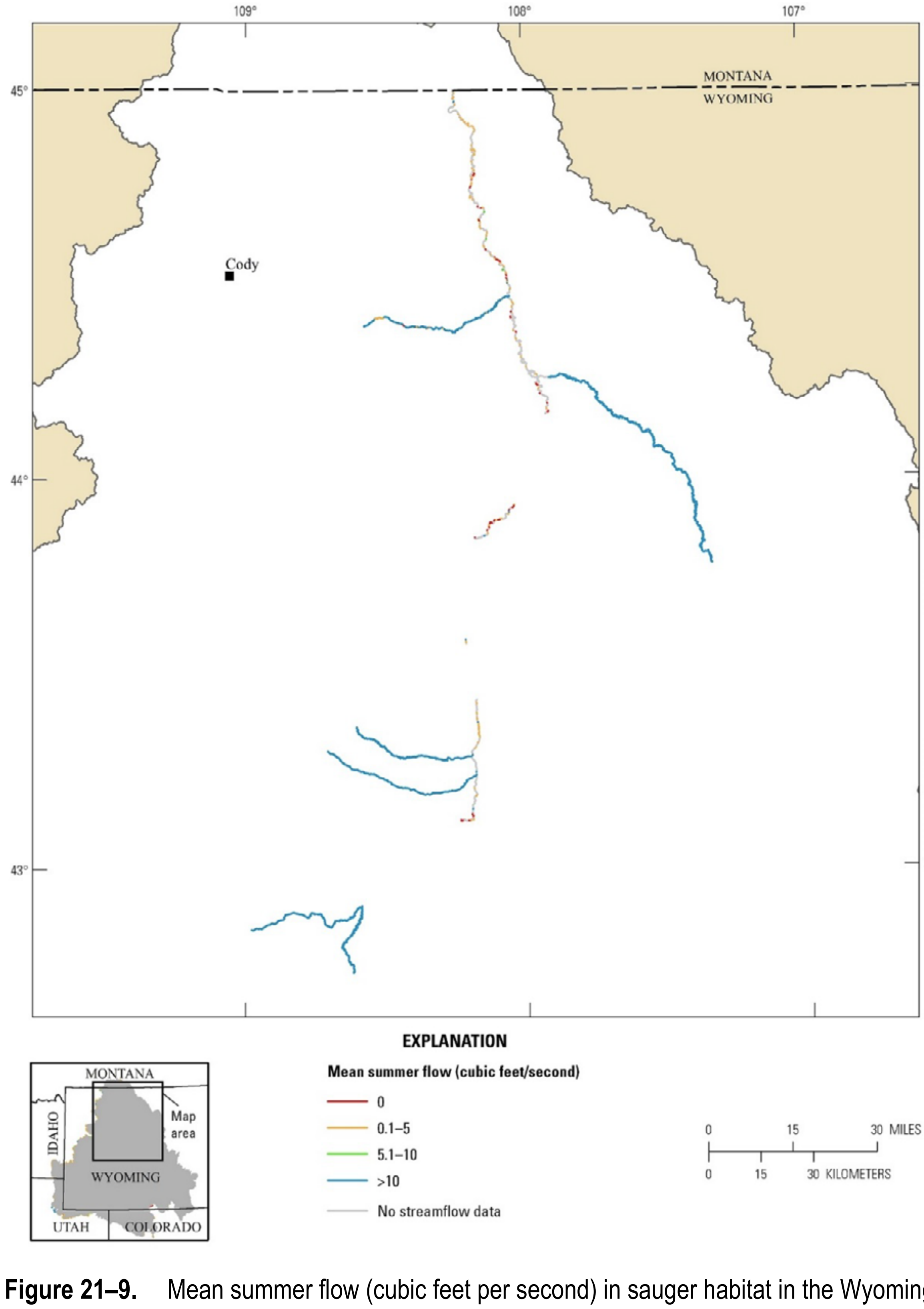

Figure 21–9. Mean summer flow (cubic feet per second) in sauger habitat in the Wyoming Basin Rapid Ecoregional Assessment project area. Mean summer flow near or at zero indicates potential for reaches to dry out during summer months.

How does risk from development vary by land ownership or jurisdiction for sauger habitat (table 21–5, fig. 21–10)?

- The two major types of land ownership or jurisdiction associated with sauger habitat are tribal land (48 percent) and National Park Service land (30 percent, table 21–5).
- Tribal land has moderate and high development levels, and National Park Service land has predominantly high development levels (fig. 21–10).
- There is no Bureau of Land Management land associated with current sauger habitat (fig. 21–10).

Table 21–5. Length and percent of sauger habitat by land ownership or jurisdiction in the Wyoming Basin Rapid Ecoregional Assessment project area.

[km, kilometer]

Ownership or jurisdiction	Stream length (km)	Percent of habitat
Tribal land	61	47.7
National Park Service	38	29.6
State/County	22	17.0
Other Federal[1]	4	3.0
Private	3	2.7

[1] Bureau of Reclamation.

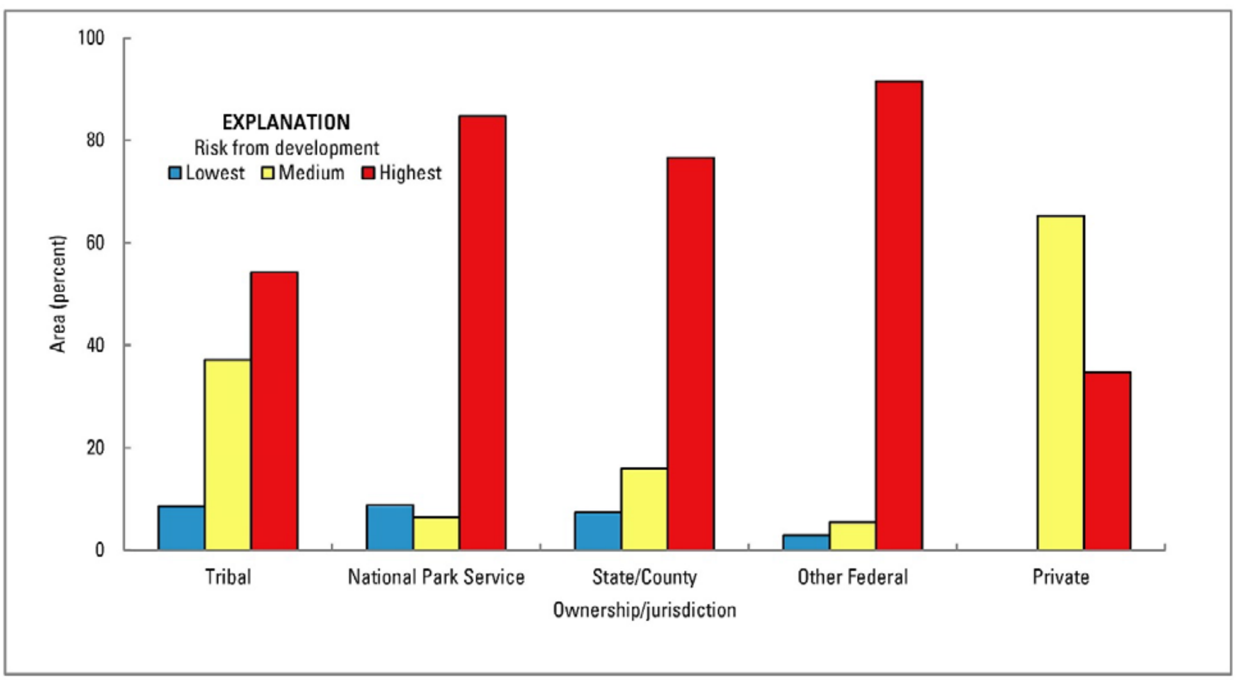

Figure 21–10. Relative ranks of risk from development, by land ownership or jurisdiction, for sauger distribution in the Wyoming Basin Rapid Ecoregional Assessment project area. Rankings are lowest (Aquatic Development Index [ADI] score <20), medium (ADI score 20−40), and highest (ADI score >40).

Where are the watersheds with the greatest landscape-level ecological values (fig. 21–11)?

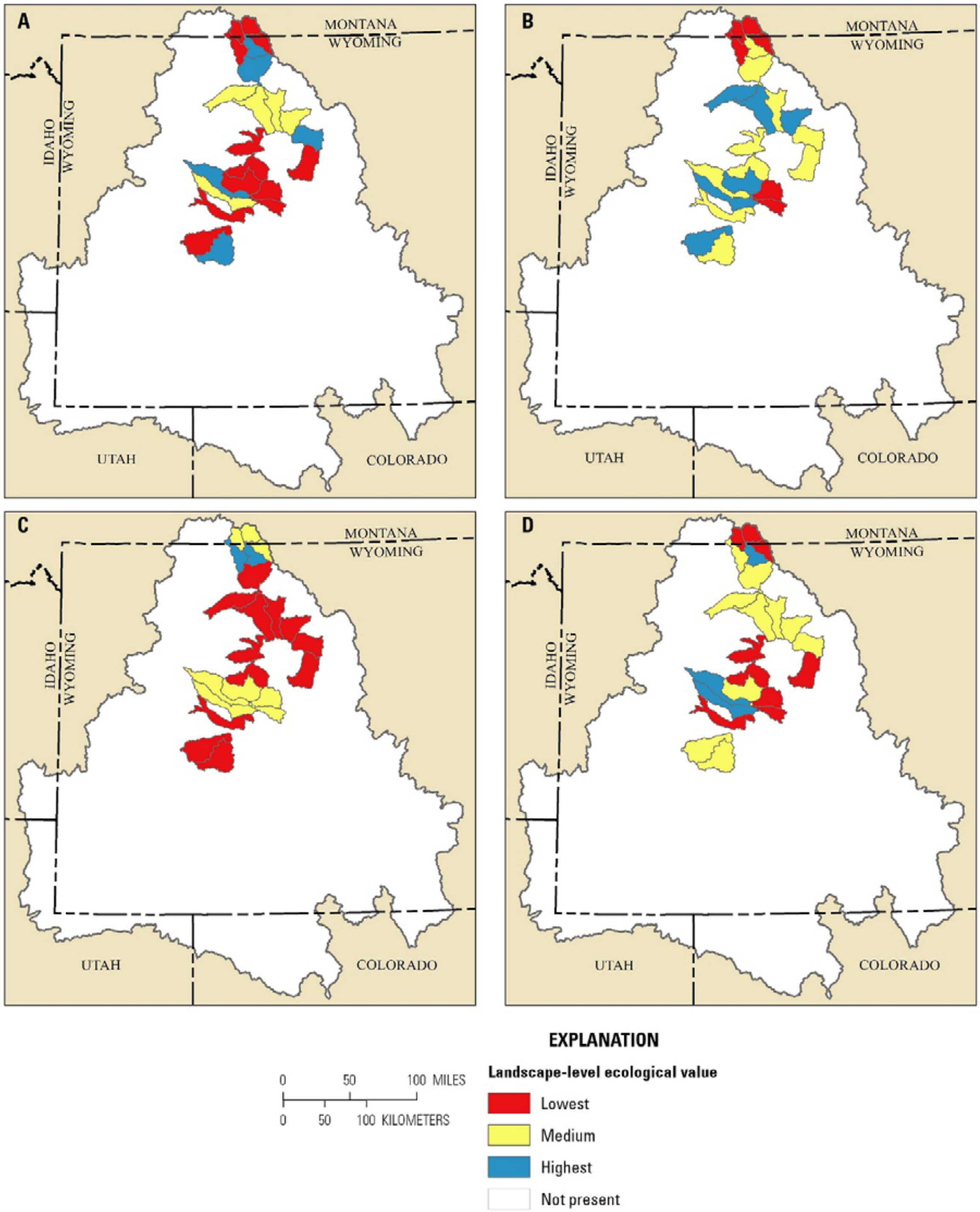

Figure 21–11. Ranks of landscape-level ecological values for sauger, summarized by fifth-level watershed, in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) stream/river segment length, (*B*) stream and river segment count, (*C*) lake and reservoir count, and (*D*) overall ecological values was based on the maximum of all three values (see table 21–3 for overview of methods).

Where are the watersheds with the greatest landscape-level risks (fig.12)?

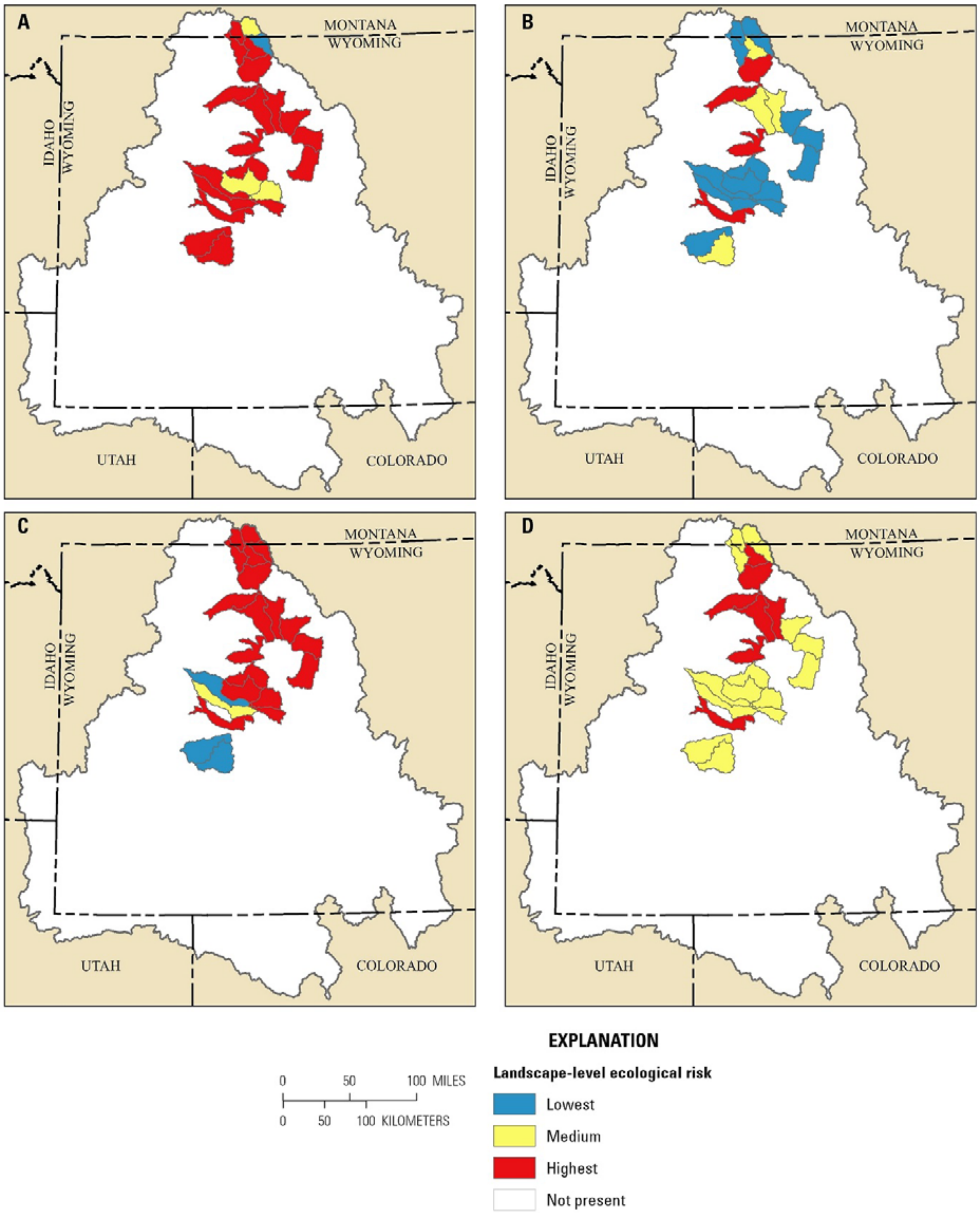

Figure 21–12. Ranks of landscape-level ecological risks for sauger, summarized by fifth-level watershed, in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) Aquatic Development Index, (*B*) zero mean flow, (*C*), walleye occurrence, and (*D*) overall ecological risk (see table 21–3 for overview of methods).

Where are the watersheds with the greatest conservation potential (fig. 21–13)?

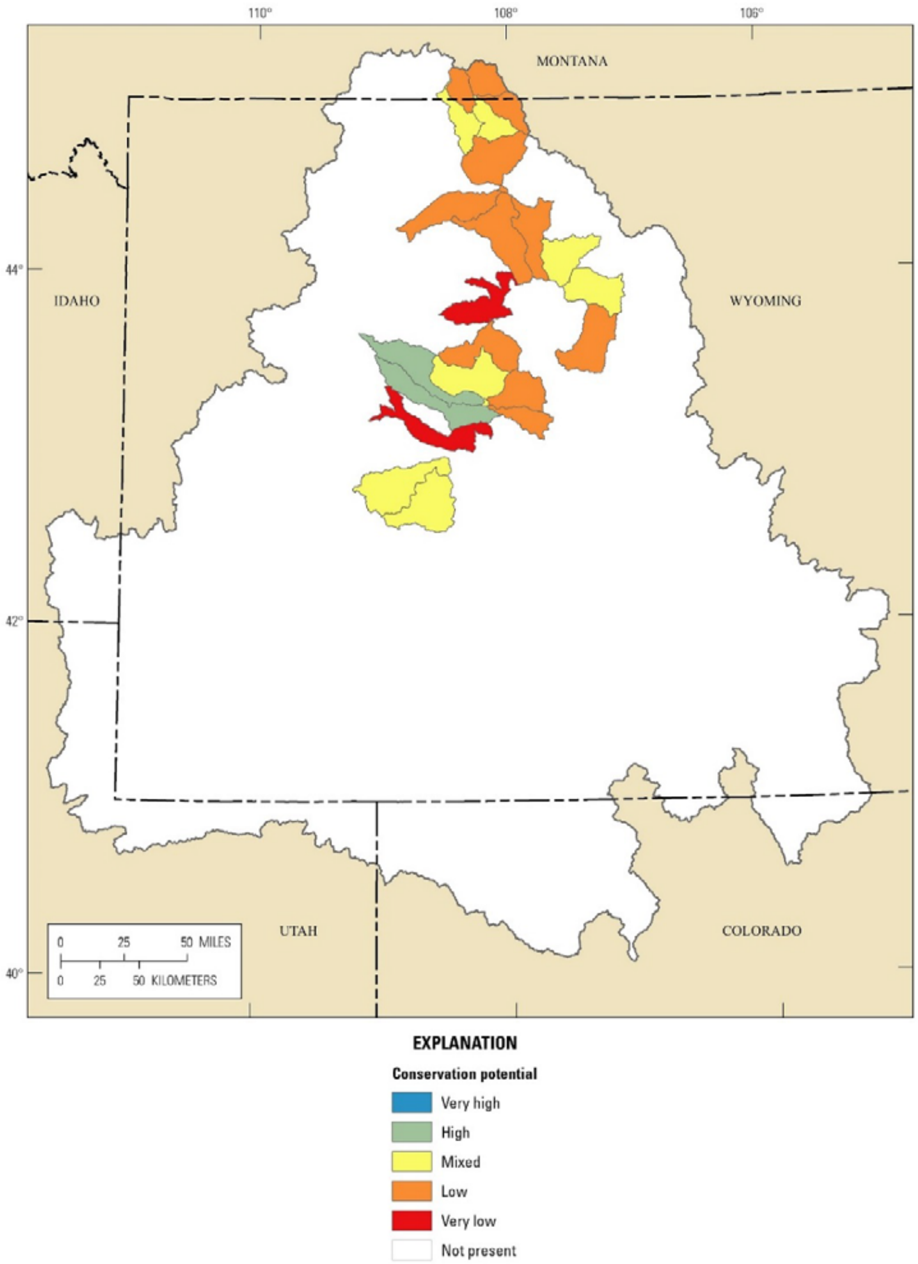

Figure 21–13. Conservation potential of sauger summarized by fifth-level watershed in the Wyoming Basin Rapid Ecoregional Assessment project area. Very high conservation potential identifies areas that have the highest landscape-level values and the lowest landscape-level risks. Very low conservation potential identifies areas with the lowest landscape-level values and the highest landscape-level risks. No watersheds ranked very high for sauger because there were no watersheds ranked with the highest values that also were ranked with the lowest risks. Ranks of conservation potential are not intended as stand-alone summaries and are best interpreted in conjunction with the geospatial datasets used to address Core Management Questions.

Summary

The current range of sauger in the Wyoming Basin is restricted to the Bighorn and Wind River drainages. These populations in the Wyoming Basin are among the last genetically pure sauger populations in the Missouri River Basin and consequently are a conservation priority (Bingham and others, 2012). Most sauger populations, however, are at risk for hybridization with walleye due to extensive overlap of the two species distributions within the Wyoming Basin. In addition, walleye pose risks as potential predators, competitors, and disease carriers. Walleye and sauger do not co-occur in the Wind, Little Wind, and the Popo Agie Rivers; consequently, these populations are important for maintaining genetically pure sauger populations, although the isolation from larger populations is a concern.

Development poses significant threats to sauger habitat. Almost all habitat occupied by sauger has moderate to high levels of development, with the exception of a small segment of the Popo Agie River. The Bighorn and Wind River drainages have a high level of agricultural development, extensive road networks, and numerous water diversions. The Boysen and Yellowtail dams have fragmented a population that likely was previously connected to the Yellowstone River. The long-term viability of these isolated headwater fragments is unclear, especially given concerns about very limited recruitment in the Wind River population (Wyoming Game and Fish Department, 2010). The amount of habitat needed to protect a highly migratory species such as the sauger is not known. In addition, the limited remaining sauger populations are affected by local potential barriers, such as water diversions that further restrict fish movements. For example, water diversions have been found to limit access to upstream habitats in the Wind River drainage (Amadio and others, 2005). The barriers to movements consequently limit access to spawning habitat, which further compounds the problems posed by the highly restricted distribution of this species.

Watersheds with relatively high landscape-level ecological values occur in both the Bighorn and Wind River drainages. Because of the high development pressures and occurrence of walleye, all watersheds have medium or high landscape-level ecological risks; consequently, none of the watersheds where sauger occur are ranked as having very high conservation potential due to the management challenges for this species in the Wyoming Basin. Indeed, it remains unclear whether the few watersheds ranked as having high conservation potential compared to other watersheds can maintain viable sauger populations given the reduction of population connectivity as a result of the Boysen and Yellowtail dams.

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