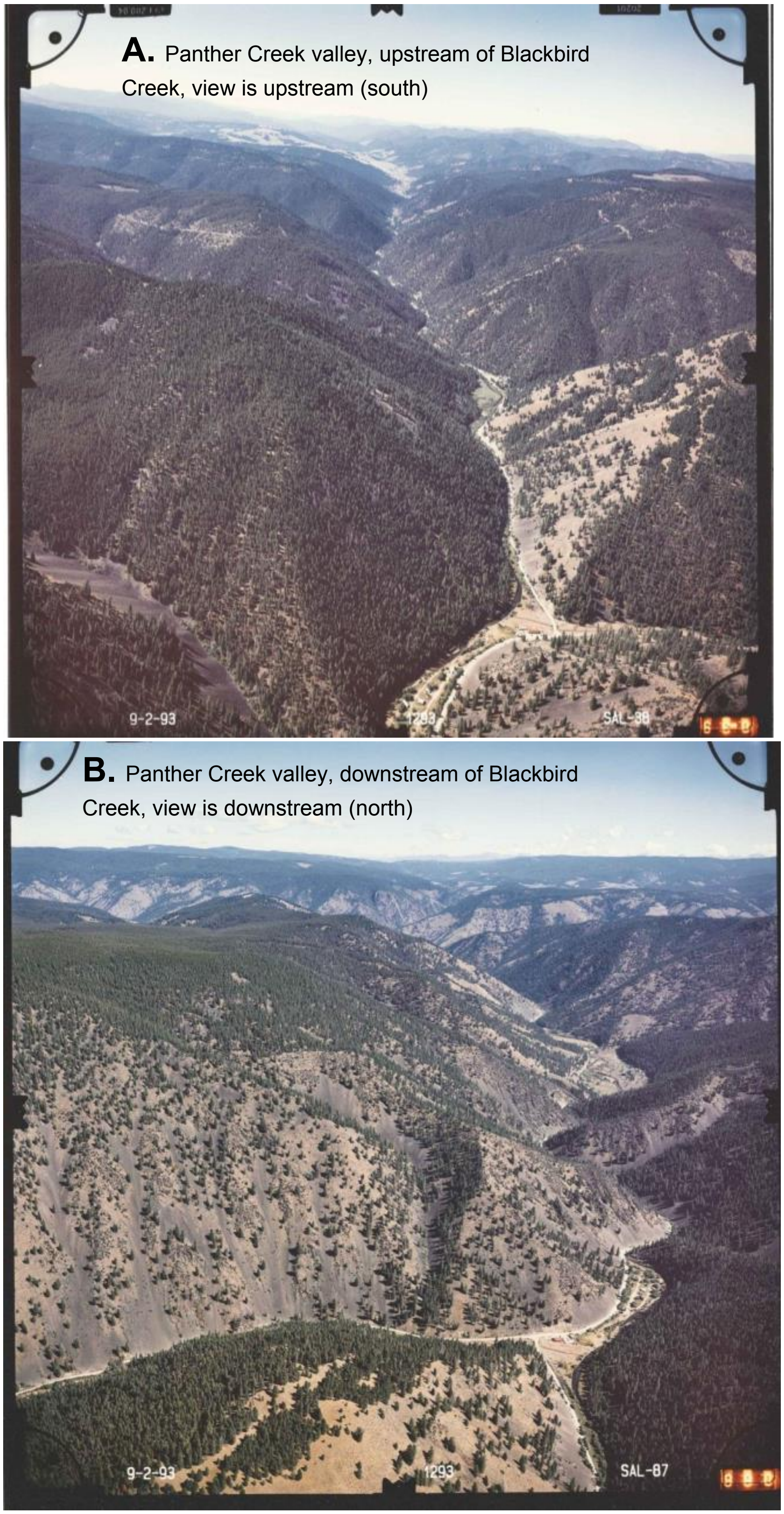
Elementa: Science of the Anthropocene http://dx.doi.org/10.12952/journal.elementa.000042.s003

Figure S3. Supporting information for the article "*Recovery of a mining-damaged stream ecosystem*" by Mebane, C.A., R. J. Eakins, B.G. Fraser, and W.J. Adams. doi:10.12952/journal.elementa.000042.s003



This file includes photographs of habitat features at selected study sites, including substrates and organisms.

Figure S3-1. Aerial views of the Panther Creek , Idaho, valley upstream **(A)** and downstream **(B)** from the Blackbird Creek confluence.

The Panther Creek valley upstream of mining-influenced areas is free from profound human-caused alterations. Human influences are limited and include forest roads, limited timber harvest and livestock grazing, and localized water withdrawals to irrigate pastures. Stream gradients are shallower in the upper valley, upstream of Blackbird Creek than in lower Panther Creek, and most anadromous Chinook Salmon and Steelhead spawning occurs in the upper watershed. Blackbird Creek joins Panther Creek from the lower right of the top photo, and from the lower left in the bottom photo. Photos courtesy of the Salmon National Forest.

Figure S3-2. Long-term monitoring reference sites on Panther Creek upstream of Blackbird Creek. **(A).** Site PA-km47 is located about 7.5 km upstream of the Blackbird Creek confluence.

(**B).** PA-km39 is located about 0.3 km upstream of the Blackbird Creek confluence. At these two sites, Panther Creek is a 4th order stream, with mean wetted widths of about 12 and 14m respectively.

(C). View of substrates at Panther Creek site PA-km39. Substrates in Panther Creek upstream of Blackbird Creek are typically covered with light periphyton (biofilm) growth and little accumulation of fine particles.

Figure S3-3. Long-term monitoring mining-influenced site on Panther Creek downstream of Blackbird Creek PA-km37.

(A). At this site, Panther Creek is a 4th order stream, with a mean width of about 15 m. Substrates, biofilms, and aquatic plants at this site have a rustier appearance than in Panther Creek upstream of Blackbird Creek (B and C). Patchy, thin reddish veneers of what appears to be iron hydroxide floc are characteristic on substrates at this site.

(B). Chinook Salmon (*Oncorhynchus tshawytscha*), and

(C). Shorthead Sculpin (*Cottus confusus*) against substrates in Panther Creek downstream of Blackbird Creek, PA-km37.

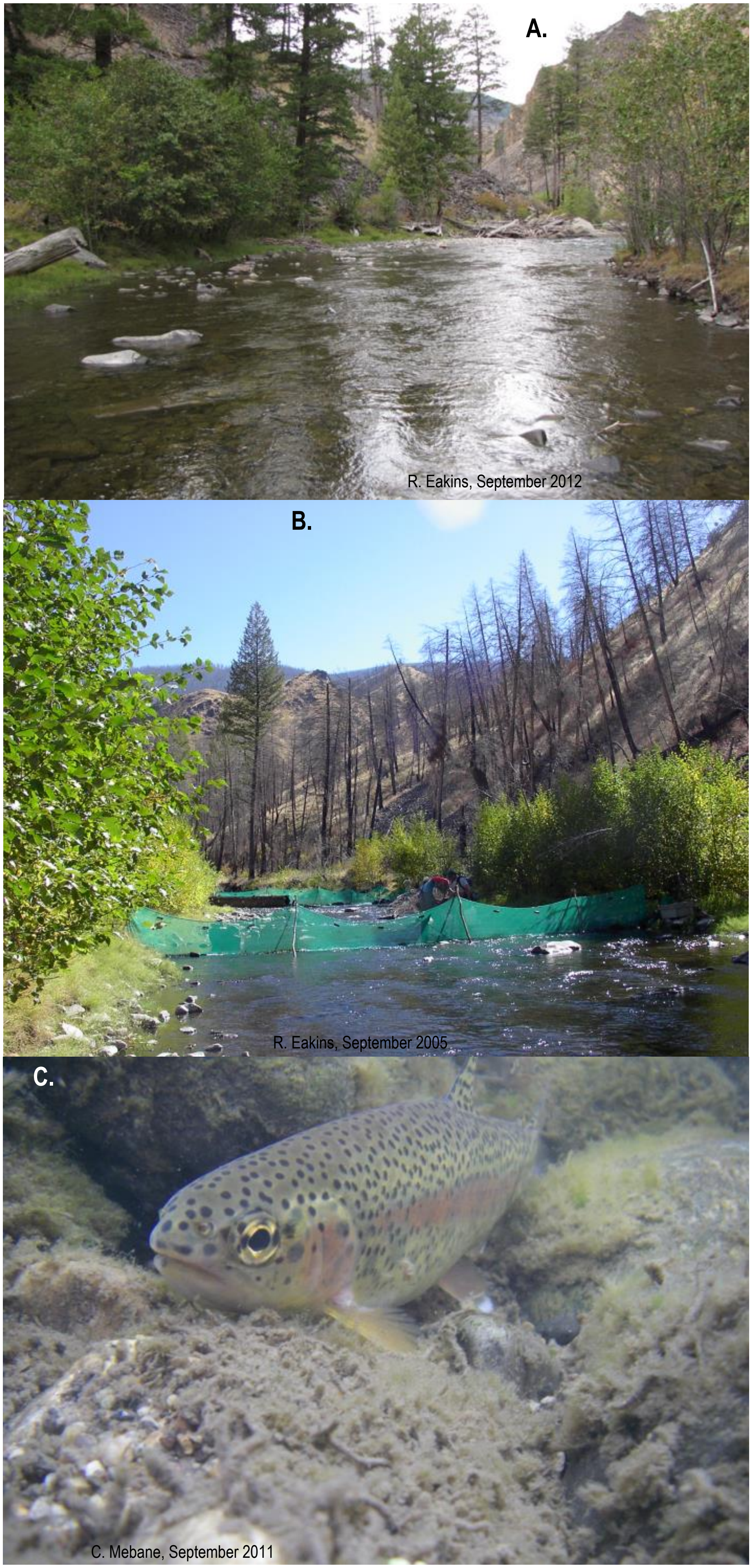


Figure S3-4. Panther Creek upstream of Big Deer Creek, mining-influenced (PA-km22).

(A). At this site, Panther Creek is a 5th order stream, with mean wetted channel width of about 22 m.

(B). Fish sampling at this location is undertaking within a split channel in order to get adequate blocknet closure.

(C). Rainbow Trout *(O. mykiss)* against substrates at PA-km22. Substrates here are visually indistinguishable from those at reference sites, with no iron hydroxide floc visible by eye.

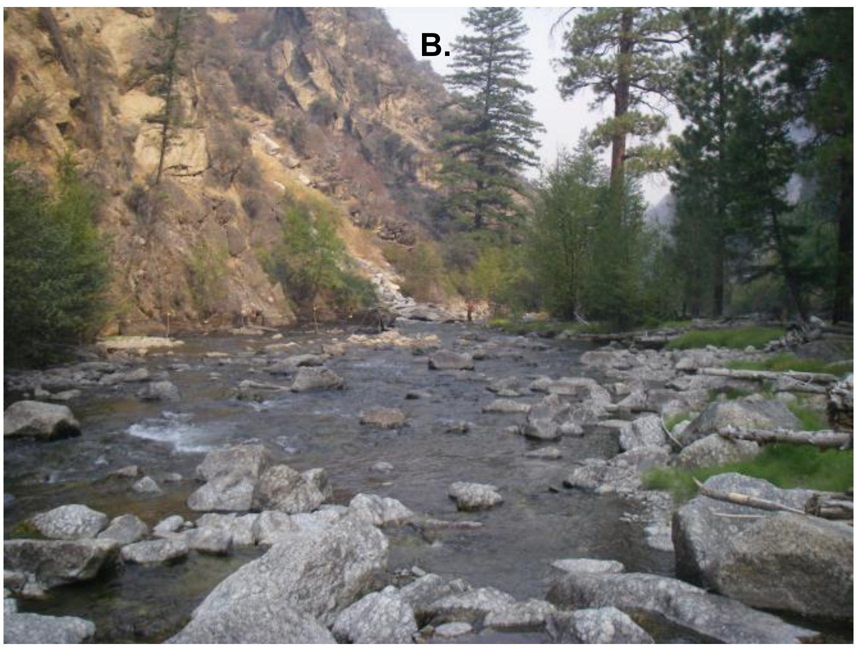


Figure S3-5. Panther Creek downstream of Big Deer Creek, mining-influenced (PA-km17).

(A). At this site, Panther Creek is a 5th order stream, with mean wetted channel widths of about 34 m. **(B).** Fish sampling at this location was also undertaken in a side channel in order to get adequate blocknet closure

(C). Fine-grained substrates in quiescent pocket water with a Mountain Whitefish, (*Prosopium williamsoni)*, and

(D). cobble substrates in faster water with a Rainbow Trout. Substrates are visually indistinguishable from those at reference sites.

Photos: C. Mebane, September 2011

A. Big Deer Creek, BD-km5.6 (reference)

B. Big Deer Creek, BD-km5.3 (mining-influenced)

C. Big Deer Creek, BD-km2.4 (mining-influenced)

Figure S3-6.

(A) Big Deer Creek upstream of South Fork Big Deer Creek (BD-km5.6). This reference site, located about 0.2 km upstream of the confluence with South Fork Big Deer Creek, generally serves as a reference site for mine-influenced sites Big Deer Creek.

(B) Big Deer Creek downstream of South Fork Big Deer Creek (BD-km5.3). This mining-influenced site is located about 0.1 km downstream of the confluence with South Fork Big Deer Creek.

(C) Big Deer Creek downstream of South Fork Big Deer Creek (BD-km2.4.) This mining-influenced site is located about 3 km downstream of the confluence with South Fork Big Deer Creek. As water quality improved, Rainbow Trout recolonized this site about 3 years later than at site BD-km5.3.

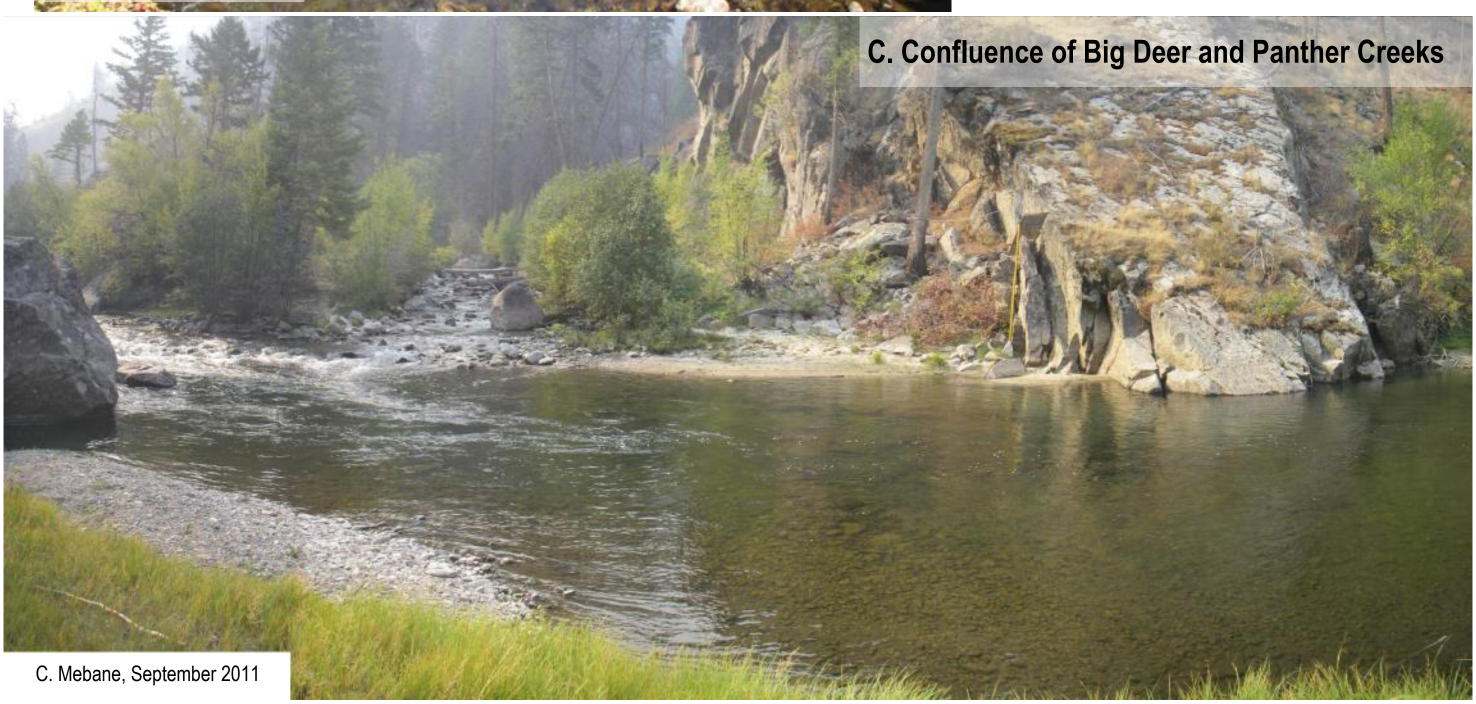
A. Big Deer Creek near mouth (BD-km0.1)

B. Napias Creek, reference for fish in lower Big Deer Creek

Figure S3-7. Big Deer Creek near the mouth, mining influenced (BD-km0.1). This site is located immediately upstream of the confluence with Panther Creek.

(A). View downstream (BD-km0.1), with Panther Creek visible in the background. **(B).** Napias Creek near the mouth, NA-km0.1, which we considered the best available reference site for the fish community at BD-km0.1; **(C).** The confluence of Big Deer and Panther Creeks.

Because fish at BD-km0.1 can move freely between Panther Creek and Big Deer Creek, but upstream movements are blocked by waterfalls within 1 km, the fish community at site BD-km5.6 (solely Rainbow Trout) is an unsuitable reference site for the more diverse, Panther Creek influenced fish community for Big Deer Creek near its mouth. Napias Creek is well matched with Big Deer Creek in terms of watershed location, connectivity, size, gradient, and thermal profile. However, Napias Creek might be influenced by an inactive mine situated in its headwaters. Benthic macroinvertebrate richness at NA-km0.1 has consistently been lower than that at other reference sites including nearby Deep Creek and upper Big Deer Creek, at BD-km5.6 (Text S2). Hence, reference comparisons for site BD-km0.1, used site BD-km5.6 for benthic macroinvertebrates and site NA-km0.1 for fish.



C. Confluence of Big Deer and Panther Creeks

Figure S3-8 Changes in substrate appearance in Bucktail Creek, tributary to South Fork Big Deer Creek.

(A). Prior to water quality restoration efforts, metals concentrations draining from the Blackbird Mine to Bucktail Creek were extreme. Lower Bucktail Creek was covered in a dense, blue copper and cobalt rich precipitate.

(B) Lower Bucktail Creek, September 1992. Dissolved Co and Cu at this location were measured at 3495 and 4630 µg/L respectively.

(C) Lower Bucktail Creek, September 2012. Dissolved Co and Cu were measured at 146 and 56 µg/L respectively.

(Data sources: Sep. 1992- unpublished data from RCG/Hagler Bailley, Inc. Boulder, CO; Sep. 2012-unpublished data from Golder Associates, Redmond, WA.)

1974 photo courtesy of Joe Baldwin, Idaho Department of Environmental Quality (retired). 1992 and 2012 photos by Chris Mebane.

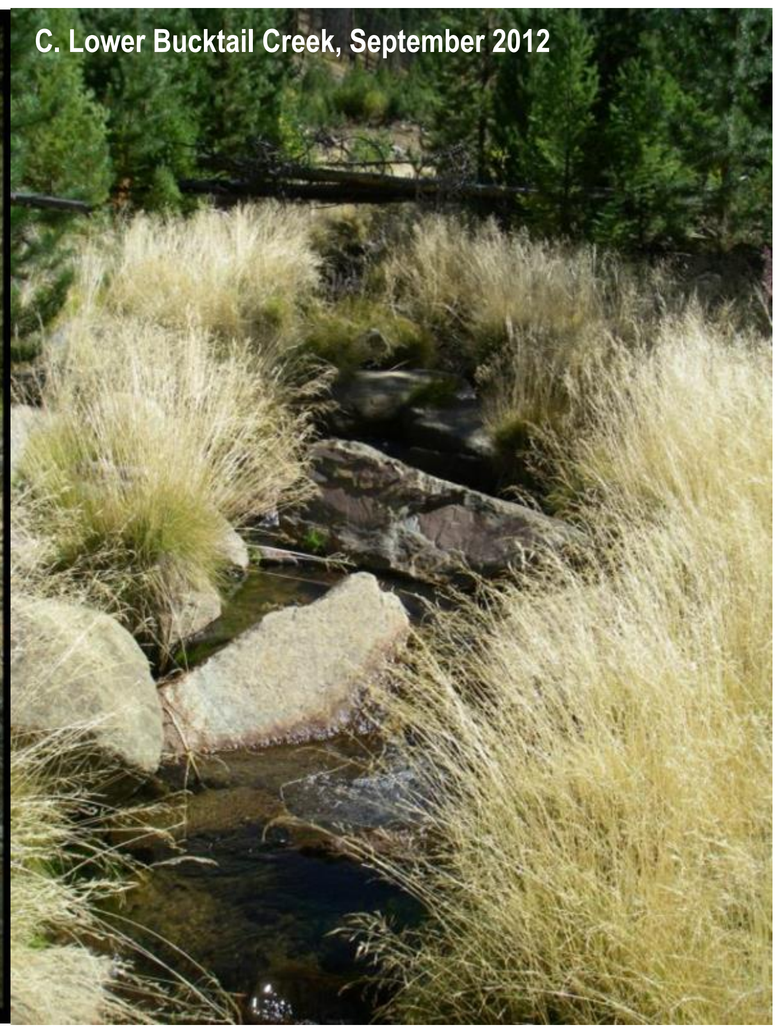


Figure S3-9. Substrates in Big Deer Creek characteristically have very low periphyton growth, and very clear water with very little suspended material.

(A). Even the most severely contaminated site, South Fork Big Deer Creek downstream of Bucktail Creek (SFBD-km0.1) has bare substrates without visual evidence of precipitates

Other examples are from mining-influenced **(B)** sites BD-km2.4, with a Rocky Mountain Tailed Frog tadpole (*Ascaphus montanus*), and **(C)** from site BD-km1.4, with a Cutthroat Trout (*O. clarki lewisi*)

Substrates at all mining-influenced sites on Big Deer Creek are visually indistinguishable from those at reference sites, with no precipitates visible by eye.

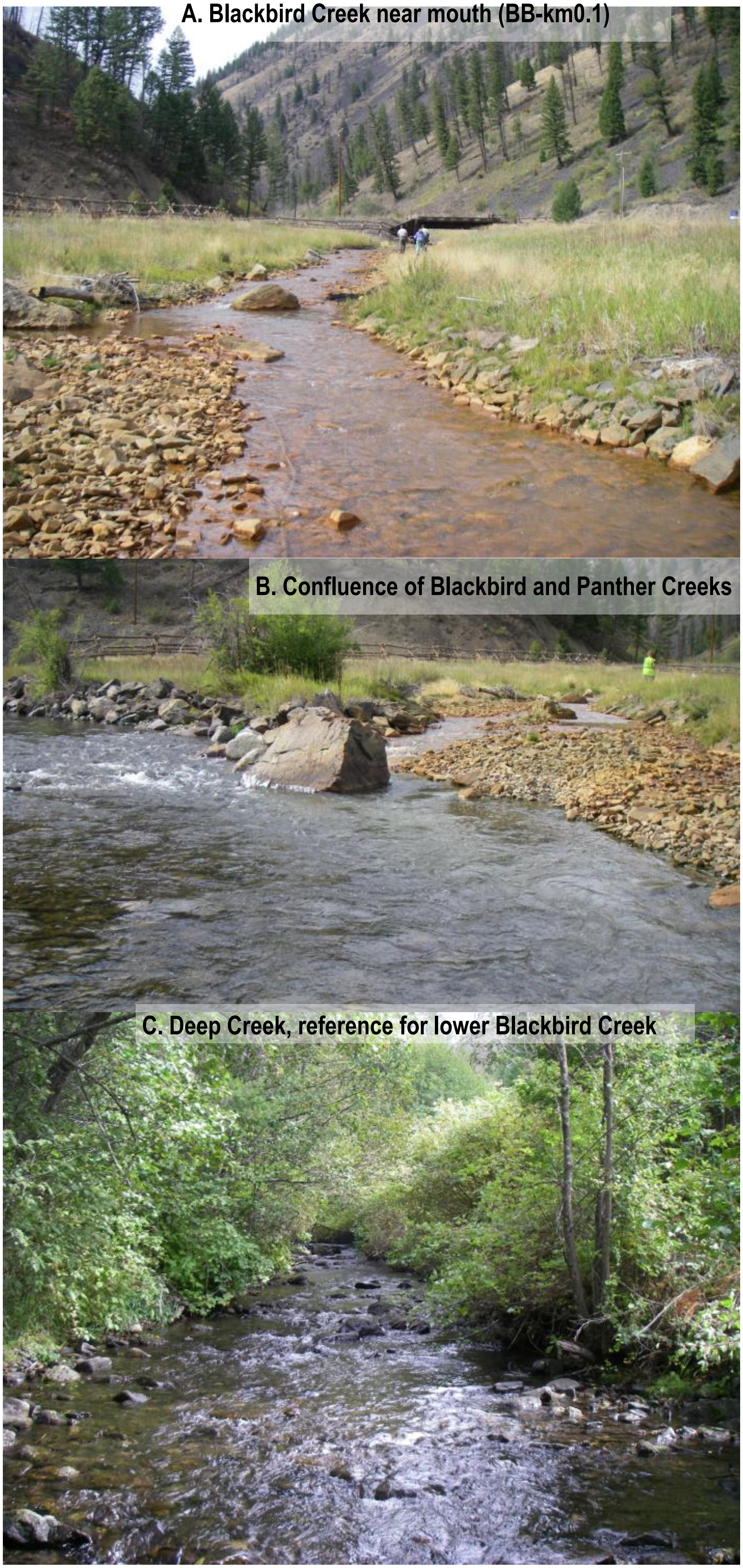


Figure S3-10.

(A) Blackbird Creek near the mouth (BB-km0.1),

(**B**) confluence of Blackbird and Panther Creek, and ,

(C) Deep Creek near the mouth (reference for lower Blackbird Creek). Substrates and rocks along the waterline in lower Blackbird Creek have an obvious reddish hue, which extends to Panther Creek. Fish are reasonably abundant at this site, despite the substrate conditions and lack of riparian vegetation.

Photos: C. Mebane, September 2013

A. Substrate coatings in Blackbird Creek where fish were present

C. Substrate coatings in Blackbird Creek where fish were not present

Figure S3-11. Close-ups of substrates in Blackbird Creek at locations with and without fish.

(A) At Blackbird Creek near the mouth (BB-km0.1), although superficially the substrate appears completely covered by iron rich precipitates, the precipitates form a low density floc that readily sloughs off with current. Fish have been consistently present at this location from 2002-2013, ranging from 3 to 46% of reference for total fish density. We speculate that the patchy flocs at this location still allow invertebrate grazing and fish access to interstitial spaces.

In 2013, fish persisted up to 1.1 km upstream of Panther Creek, but by 1.9 km **(B),** no fish were found, despite otherwise suitable physical habitats and similar Cu concentrations (7 to 9 µg/L in May 2013). The iron-rich flocs at fishless sites were thicker, denser, and appeared to fill or block access to the interstitial spaces between rocks **(C)**. No chironomids or any macroinvertebrates were obvious on the flocs, although

B.

Figure S3-12. In upper Blackbird Creek, upstream of the tailings impoundment inputs, substrates are free from iron precipitates.

(**A**) Clean substrates and Bull Trout (*Salvelinus confluentus*) in the West Fork Blackbird Creek, upstream of the tailings impoundment.

(**B**). In Blackbird Creek upstream of the West Fork Blackbird Creek confluence, substrates are free from iron flocs, but no fish have been found. The location shown (BB-km9.2) is only 0.5 km below a source population of Cutthroat Trout occupying undisturbed, upper Blackbird Creek. Dissolved Cu concentrations ranged from at least 24-40 µg/L in this fishless reach, compared to 5-14 µg/L in lower, fish bearing reaches.

(**C**). Mixing zone of iron and cobalt rich drainage from the toe of the West Fork tailings impoundment with Blackbird Creek, coming in from the left.

Figure S3-13. Similar views of the South Fork Big Deer Creek just above the confluence with Big Deer Creek (SFBD-km0.1) in June 2001 **(A)** and September 2010 (**B**). The site had burned during August-October 2000. In 2001, a blue-green tint on the substrates from copper precipitates was still discernable. Dissolved Cu concentrations in June 2001were measured at 92-104 µg/L. In 2010, dissolved Cu concentrations were about 15 µg/L and no apparent precipitates or substrate discoloration were visible (see also underwater view in [Fig S3-9A](#).

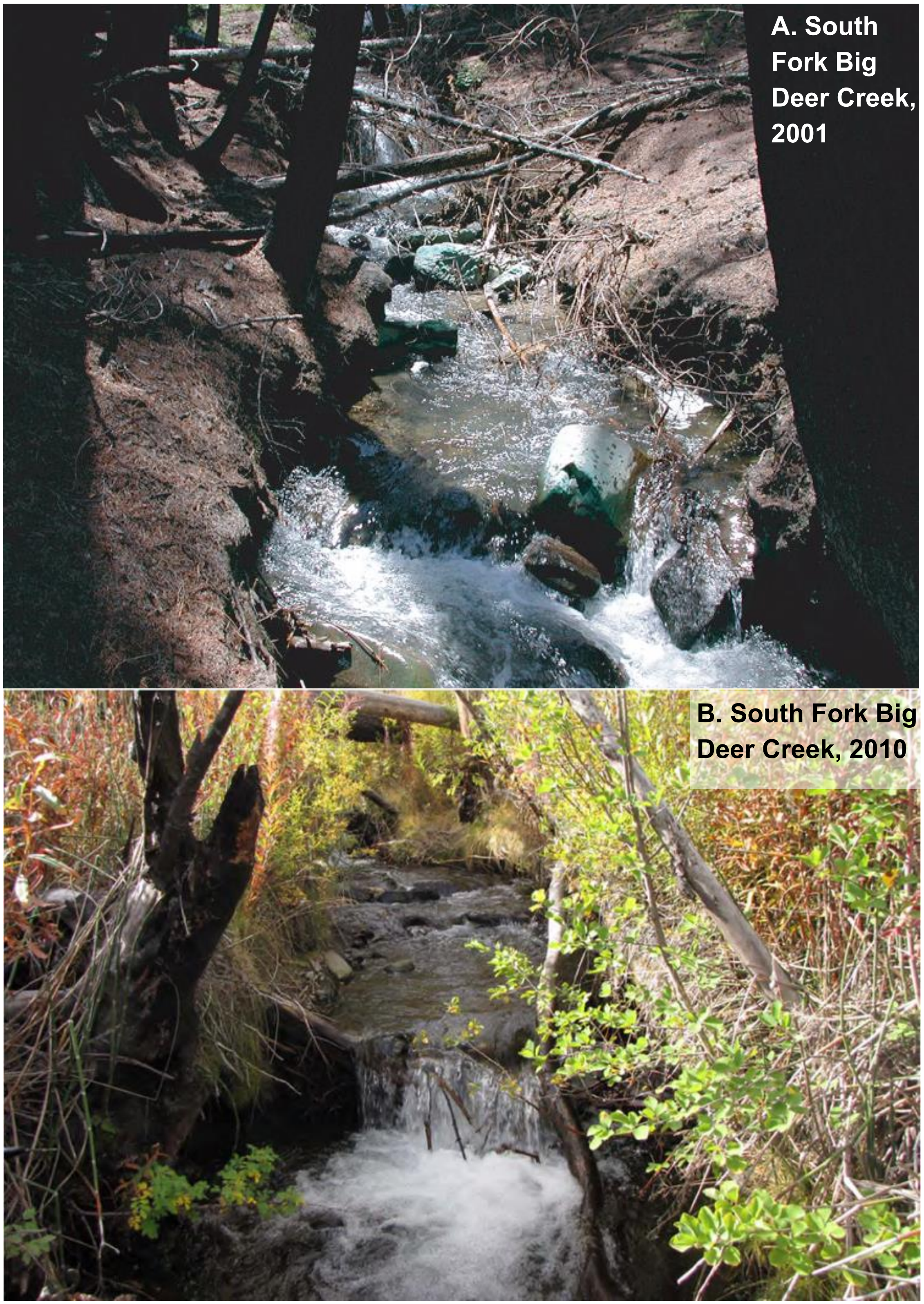


Photo credits: 2001 (A) Eppinger et al. 2003; 2010 (B), R. Eakins.

Reference:

Eppinger, R.G., et al. 2003. Geochemical data for stream sediment and surface water samples from Panther Creek, the Middle Fork of the Salmon River, and the Main Salmon River, collected before and after the Clear Creek, Little Pistol, and Shellrock wildfires of 2000 in central Idaho. U.S. Geological Survey Open-File Report 2003-152. Accessed from http://pubs.usgs.gov/of/2003/152/ [Accessed July 2014].

A. 1992

C. 2011

B. 2001

Figure S3-14. Views of Big Deer Creek near the confluence of South Fork Big Deer Creek, (**A**) prior to, (**B**) shortly after, and (**C**) 11 years after the Clear Creek forest fire of August-October 2000. Prior to burning, Big Deer Creek riparian zone had canopy of conifers up to about 40m in height (A), which were mostly killed by the fire (B). Subsequently, the riparian zone has regrown with alders of <10m in height (C) . The expected influences of the fire include increased sedimentation from loss of vegetation and increased solar insolation, increased productivity, and increased summer stream temperatures.

Photo credits: 1992 and 2011, C. Mebane; 2001 from Eppinger et al. 2003;