A summary of selected research on Lahontan cutthroat trout

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Introduction

We are working on several projects that may be related to viability analysis of cutthroat trout. Our approaches can be crudely divided into "coarse" and "fine" filter analyses (Hansen et al. 1999; Table 1). Coarse filter approaches are generally thought of as approaches that involve multiple species, but within a species, there is a continuum of scale as well. A large part of our current research focuses on a single species, Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*). Lahontan cutthroat trout are one of three interior subspecies currently listed under the Endangered Species Act. The other two listed subspecies include a very close relative of the Lahontan cutthroat trout, Paiute cutthroat trout (*O. c. seleniris*) and greenback cutthroat trout (*O. c. stomias*).

Table 1. Definition of coarse and fine filter studies/management approaches with examples from ongoing or potential future research on Lahontan cutthroat trout.

Coarse Filter	**Fine Filter**
Large area Many habitats Many populations Many species	Small area Few habitats Single or few populations Few or single species
Examples for Lahontan cutthroat trout	
Patch-based models of occurrence Geographic distribution models Biogeographic studies of genetic variation	Fish distributions within streams Demographic models Microgeographic patterns of genetic variation

Our focus is on stream-living populations in the eastern Lahontan basin (Figure 1), where local populations persist in about 10% of their original historically occupied habitat (Coffin and Cowan 1995). Primary threats to persistence of local population include declines in the total amount and quality of habitat and nonnative trout invasions.

Important controlling influences on habitat quantity and quality include water temperature and stream discharge. Both are very sensitive to land management, and may influence nonnative fish invasions. Nonnative fish invasions include hybridizing (especially rainbow trout, *Oncorhynchus mykiss*) and nonhybridizing (especially brook trout, *Salvelinus fontinalis*) species. Major issues with nonnatives include factors affecting invasions (e.g., Adams 1999), impacts (Fausch 1988; 1998; Schroeter 1998),

and control (Rinne and Turner 1991). These two major issues (habitat and nonnatives) and reintroductions (Harig 2000) are the major management actions associated with recovery of Lahontan cutthroat trout (Coffin and Cowan 1995).

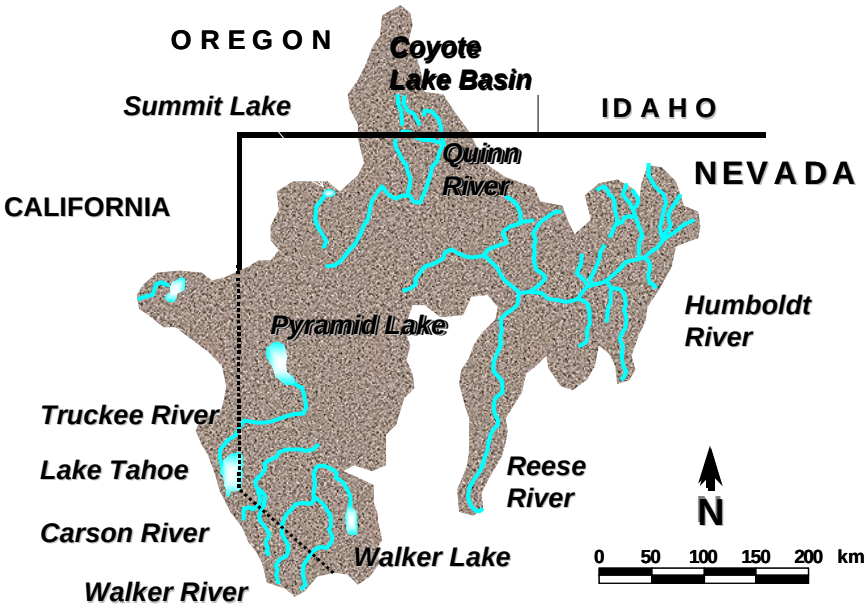


Figure 1. Map of the Lahontan basin. The eastern Lahontan basin, as defined here, consists of the Coyote Lake, Quinn, Reese, and Humboldt basins.

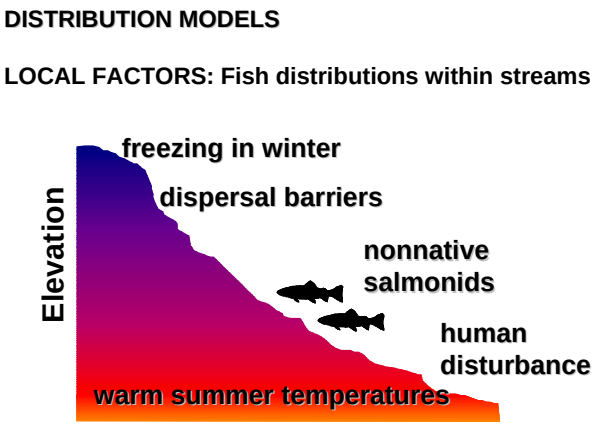
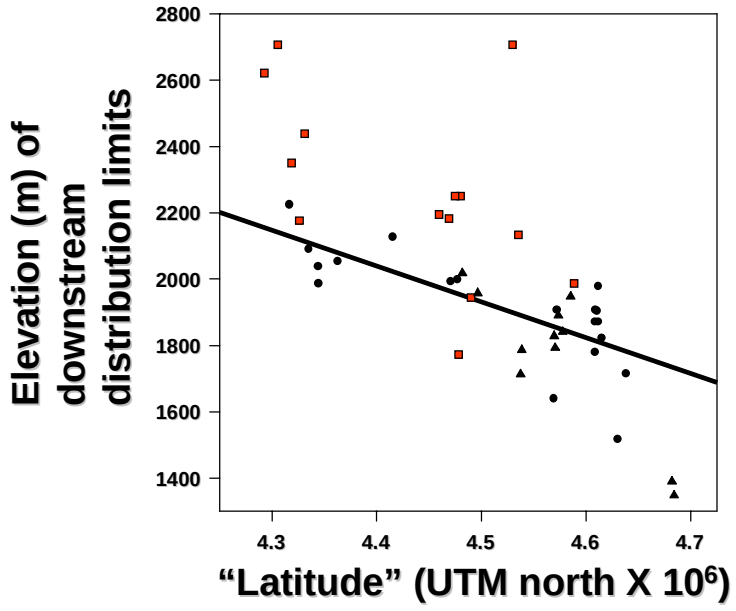


Figure 2. Illustration of local factors that may influence fish distributions within streams.

Studies to support fine-filter approaches

Fish distributions within streams. Fish distributions can be considered in relation to a number of local factors (Figure 2), including gradients in stream size, temperature, occurrence of native and nonnative fish, and human disturbance (e.g., changes in land use impacts). Natural (geomorphic barriers such as steep cascades and waterfalls, or natural stream desiccation) and human-caused barriers (e.g., culverts, dams, and water diversions) may also be important. Our research on fish distributions within streams has identified important influences of nonnative species (Figure 3) and temperature (Figure 4), but only the effects of temperature are predictable (Dunham et al. 1999; Dunham 1999). Stream desiccation is also an important local factor. Many streams lose surface flow as they flow off mountain slopes onto alluvial valleys (Dunham, personal observations).

Figure 3. Plot of elevation of downstream distribution limits of stream-living Lahontan cutthroat trout populations in relation to latitude. About 70% of the variation in the elevation of downstream distribution limits for streams without nonnative trout (Lahontan cutthroat trout only, circles and triangles) was explained by geographic (latitude and longitude). Distribution was generally reduced when nonnative trout were present (squares), but the effect was highly variable and less predictable (see Dunham et al. 1999). Additional detail on the influence of nonnative salmonids can be found in Schroeter (1998) and Dunham et al. (2000).



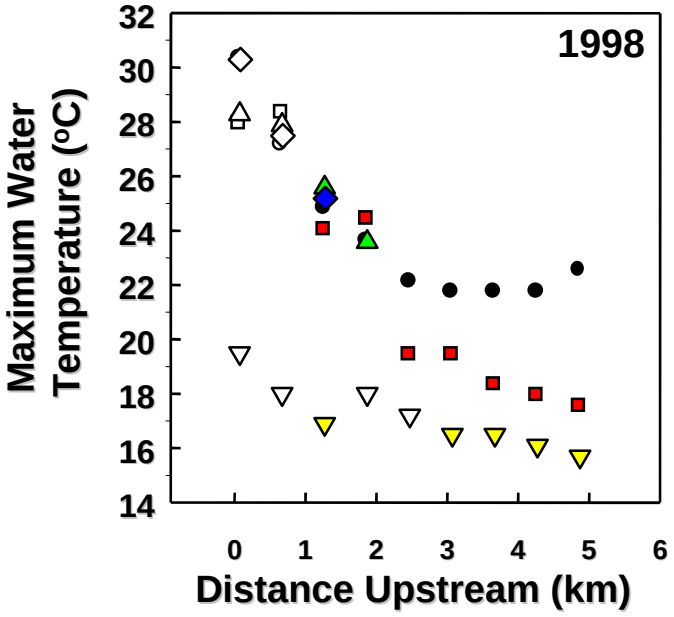
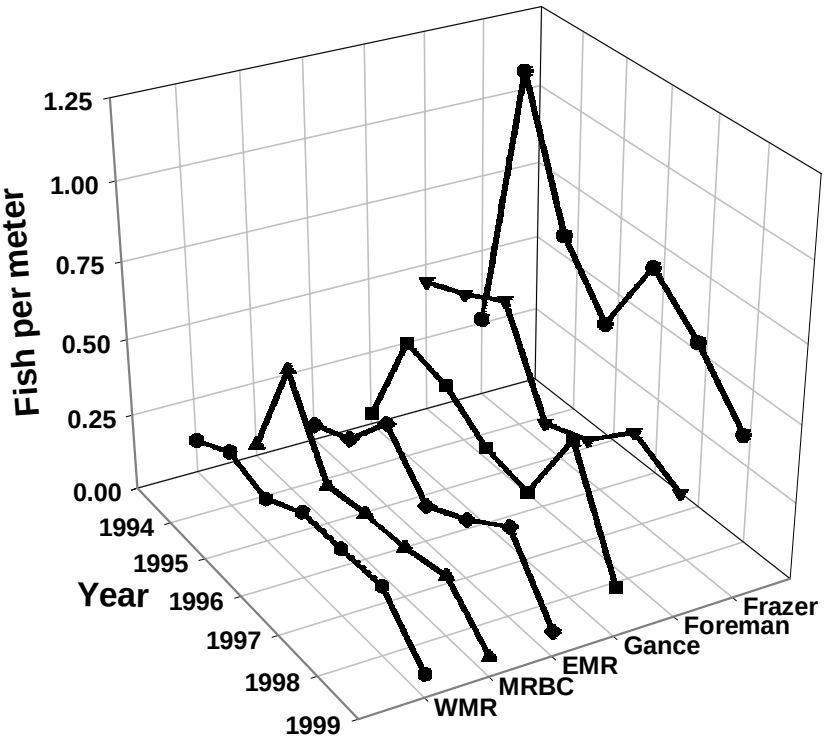


Figure 4. Distribution of Lahontan cutthroat trout in several streams of the eastern Lahontan basin in relation to maximum daily water temperatures. Filled symbols represents sites with Lahontan cutthroat trout present. Different symbol shapes and colors represent different streams. Generally, Lahontan cutthroat trout are not found in waters exceeding daily maximum temperatures of 26 C. Long-term chronic exposure to temperatures of this magnitude are lethal (Dickerson and Vinyard 1999) and short-term acute exposure to temperatures exceeding 22 C can inhibit feeding and growth (Meeuwig 2000).

Demographic and genetic modeling. Time series of population data from several streams in the eastern Lahontan basin (Figure 5) are being used to develop demographic models of population persistence in isolated and interconnected populations of Lahontan cutthroat trout (Peacock et al. 2000; Ray et al. 2000). Data analyses are preliminary, but results indicate recruitment of age 1 fish can be predicted well by variability in spring stream discharge in the first (age 0) and second (age 1) years of life. Dynamics of older (2+) age classes is a function of density dependence within age classes. Persistence of populations over various timeframes can be simulated in response to existing conditions or hypothetical changes in discharge regimes and amount of suitable habitat (e.g., as controlled by temperature or stream desiccation). Building these models requires long time series of abundance and stream discharge data. Logistical and funding constraints limit application of this approach to only a few populations, but the dynamics of these populations have revealed key insights into the demographic response of LCT to environmental variation.

Most streams in the eastern Lahontan basin support isolated populations of Lahontan cutthroat trout (Dunham et al. 1997). Historically, stream networks were functionally interconnected, and there was greater opportunity for migration among habitats, which may have supported more widespread migratory life histories and linked demographic processes (Rieman and Dunham 2000). Demographic models are being developed to simulate linked demographic processes in stream networks for Lahontan cutthroat trout (Ray et al. 2000). Patterns of genetic of variation within interconnected stream basins are also being investigated to better understand spatial population structure (H. Neville, University of Nevada, Reno, unpublished data).

Figure 5. Time series of population density for six populations of Lahontan cutthroat trout. Frazer, Foreman, and Gance Creeks are isolated stream habitats. West Marys River (WMR), East Marys River (EMR), and Marys River Basin Creek (MRBC) are part of a network of interconnected stream habitats.



Studies to support coarse-filter approaches

Patch-based models of species occurrence. Distribution models (Figure 3) indicated elevations of downstream distribution limits of Lahontan cutthroat trout could be predicted by a simple linear function of latitude and longitude. This geographic model was integrated with a geographic information system to predict the size, isolation, and location of suitable habitats for Lahontan cutthroat trout in the eastern Lahontan basin (Dunham et al., in press). Predicted elevation distribution limits were used to delineate watersheds or "patches" with potentially suitable habitat (Figure 6).

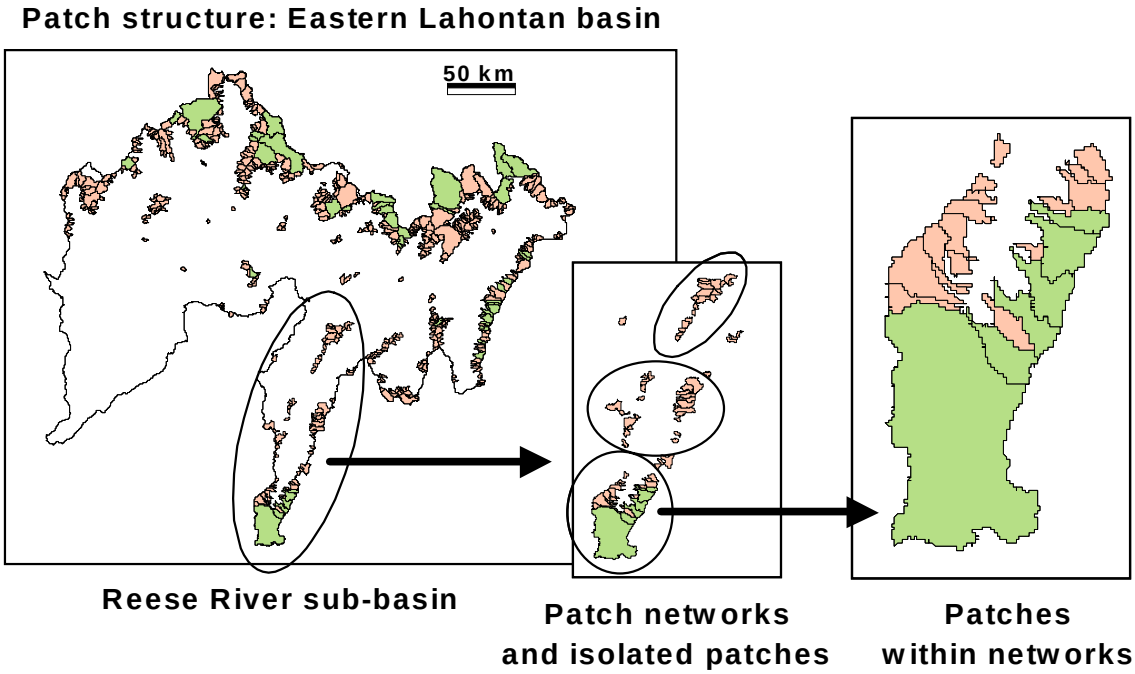


Figure 6. Patch structure for suitable habitat for Lahontan cutthroat trout in the eastern Lahontan basin. Patches highlighted in green are occupied by cutthroat trout, while patches highlighted in tan are unoccupied. Patch structure can be considered across the entire basin, within individual subbasins (e.g., Reese River subbasin), among patch networks within subbasins, or within patch networks themselves.

Geographic data are still being developed and refined, but a preliminary analysis indicated occurrence of Lahontan cutthroat trout was strongly related to patch area (Figure 7). The model correctly classified over 90% of cutthroat trout occurrences using a leave-one-out cross validation. Other data to be considered in future analysis include patch isolation (see Dunham and Rieman 1999), occurrence of nonnative trout, maximum basin elevation, and other physical landscape descriptors. The influence of nonnative species was addressed in a related analysis (Dunham et al. 1997). In that work, occurrence of Lahontan cutthroat trout was not related to occurrence of nonnative species. Distribution models (Figure 3) and other studies at finer scales (Schroeter 1998; Dunham et al. 2000) do indicate nonnatives may have important influences, however.

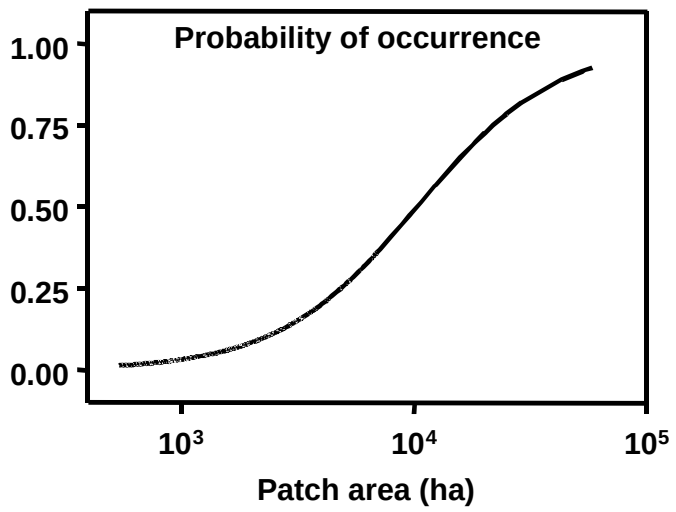


Figure 7. Occurrence of Lahontan cutthroat trout in relation to patch area (see Figure 5 for illustration of patch structuring).

Landscape-scale conservation assessment. Conservation assessments for species consist of four elementary components: 1) identification of conservation units, 2) assessment of status or risk of those units, 3) identification of threats, and 4) evaluating the biological consequences of local extinctions.

Conservation units (see Nielsen 1995) can be delineated at several scales. In the case of Lahontan cutthroat trout, conservation units may be delineated regionally (e.g., western versus eastern Lahontan basin), by subbasin (e.g., Coyote Lake basin, Quinn River/Black rock basin, Humboldt and Reese River subbasin within the eastern Lahontan region), individual subbasin, network, or patch (e.g., Figure 6). Conservation units can be defined in terms of genetic, demographic, or ecological data. In the case of Lahontan cutthroat trout, patch structure can be used as a guide to delineating conservation units in the absence of detailed genetic or demographic information.

Risks to populations occupying individual units can be assessed through use of models of species occurrence (e.g., Figure 7). Predicted probabilities of occurrence do not necessarily translate directly into population persistence (Araújo and Williams 2000), but such models can provide a coarse filter for risk assessment (e.g., Hansen et al. 1999). For example, extant populations in habitats with lower predicted probabilities of occurrence (e.g., smaller habitats) can be considered to be at greater risk than populations in larger habitats.

Identification of threats can be conducted at a variety of scales commensurate with how conservation units are delineated. Units (e.g., patches) can be attributed with various characteristics (Table 2; Figure 8). For inland cutthroat trout, habitat loss and nonnative species are perceived to be major management challenges (Young 1995). Reintroductions are also an important management opportunity (Harig 2000).

Table 2. Example of an approach to ranking vulnerability to threats in individual patches. Three general categories of patches are recognized: occupied without nonnative species, occupied with nonnatives present, and unoccupied habitat. The latter habitats are opportunities for reintroductions, while occupied habitats represent management opportunities for habitat restoration and/or control of nonnative species. Major factors assumed to contribute to success of reintroductions include presence of nonnative species and habitat size (Harig 2000), and habitat isolation. Habitat fragmentation (e.g., patch size and isolation), and restricted distributions (e.g., compared to baseline in Figure 3) are assumed to be the major threats to occupied habitats without nonnative species. Both habitat loss and effects of nonnative species are important when the latter are present.

Habitats Occupied by Cutthroat Trout		Unoccupied Habitat
Habitat Loss	Nonnative species	Reintroductions
Is the habitat large? (e.g., >10,000 ha)[1] Yes; Score = 0 No; Score = 1 Is the habitat isolated? (e.g., > 30% of inter-patch distance?)[2] Yes; Score = 1 No; Score = 0 Is the distribution limited (e.g., >30%) by habitat?[3] Yes; Score = 1 No; Score = 0	Are nonnatives hybridizing?[4] Yes; Score = 1 No; Score = 0 Is the distribution limited (e.g., > 30%) by nonnatives?[5] Yes; Score = 1 No; Score = 0 Are nonnatives sympatric? (e.g., >30%)[6] Yes; Score = 1 No; Score = 0	Are nonnatives present? Yes; Score = 1 No; Score = 0 Is the habitat large? (e.g., >10,000 ha) Yes; Score = 0 No; Score = 1 Is the habitat isolated? (e.g., > 30% of inter-patch distance?) Yes; Score=1 No; Score=0

[1]Habitat size refers to catchment or watershed area (see Dunham et al., in press)
[2]The "30%" value for "isolation" is arbitrary
[3]This value is arbitrary, and based on currently suitable habitat, as defined by distribution models reported in Dunham et al. (1999). Potential habitat (that attainable through basin restoration) is probably much larger.
[4]Hybridizing nonnatives include rainbow (*O. mykiss*) trout, and other subspecies of cutthroat trout.
[5]This value is arbitrary, and based on distributions limited only by nonnatives (e.g., limited distributions not due to temperature, stream desiccation, dams, diversions, or other barriers).
[6]"Sympatric" can refer co-occurrence of any life stage of the species within a particular habitat. The 30% value is arbitrary.

Biological consequences of local extinctions can be addressed by considering evolutionary or ecological uniqueness (Allendorf et al. 1997). For example, the Coyote Lake subbasin may be considered to be a unique part of the ecological and evolutionary legacy at the scale of the entire eastern Lahontan basin. Lahontan cutthroat trout have persisted in this isolated satellite basin for thousands of years, and represent unique ecological conditions and evolutionary diversity (Williams et al. 1992). Extinction of

Lahontan cutthroat trout in this subbasin would be a significant loss to the species as a whole. Within the Coyote Lake basin, there are only two major drainages supporting indigenous populations of cutthroat trout. Loss of either one of these populations would be significant at the scale of the subbasin. Loss of a 100 meter segment of the population within one of those streams due to a localized disturbance may have few consequences because recolonization of habitat is often very rapid in such instances (Dunham et al. 1997).

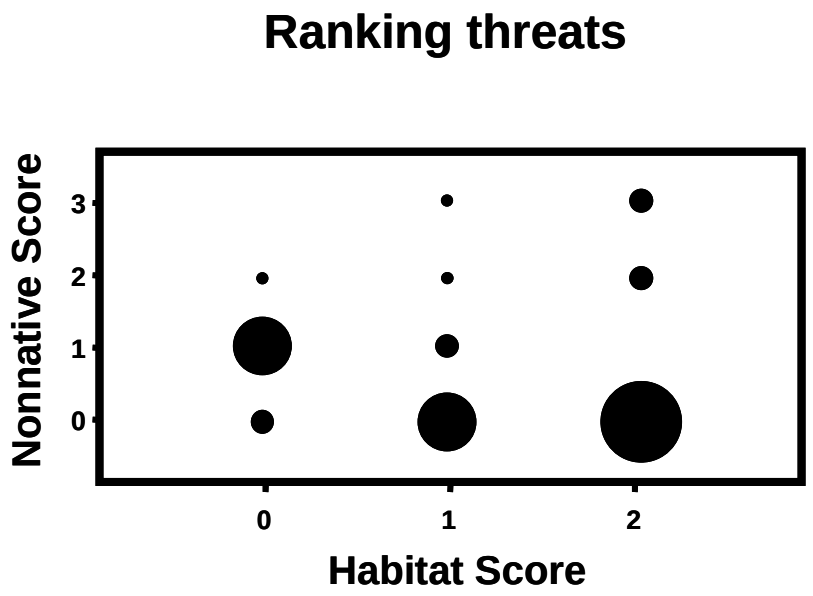


Figure 7. Application of ranking scheme in Table 2. Ranks were applied to a sample of 23 occupied patches within the eastern Lahontan basin to contrast threats posed by habitat loss and nonnatives. The size of each circle is proportional to the number of patches in each category. No patches received a habitat score of three because distributions were not limited by current habitat conditions. However, there were many small and isolated patches (total habitat scores of 1 or 2). Overall in this sample of streams, it appears that habitat loss is the primary threat, which is consistent with previous analyses (Dunham et al. 1997, 1999; Dunham et al., in press). The reader is advised this is only a very simplified example of a ranking scheme, and different threats or methods of quantification may be warranted for specific applications.

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Lahontan cutthroat trout from "T" Creek, Nevada (Marys River basin)