Evidence Dossier: *Stygobromus spp.* SSA

1. Context

The US Fish and Wildlife Service is undertaking a Species Status Assessment (SSA) for *Stygobromus cooperi*, *S. morrisoni*, and *S. parvus* in order to support Endangered Species Act decision making. This SSA is meant to characterize the species' current conditions and forecast future conditions by explicitly considering species' responses to potential stressors. Available data include point localities of amphipod occurrence and cannot be reliably used to infer population condition or temporal trends. Due to this uncertainty, we have organized an elicitation workshop to obtain a balanced scientific assessment of how populations of these three *Stygobromus spp.* may respond to current and projected levels of major stressors.

2. Quantities of Interest (QoI)

We are concerned with estimating species viability, or probability of persistence. Data are available to estimate levels of several major threats using proxy variables (*e.g.*, land use patterns; see section 4). The missing quantities of interest are species' responses to various stressor levels. This workshop seeks to elicit the probability of persistence for known populations (localities) of each *Stygobromus sp*. based on the empirical habitat conditions for that locality. Known populations will be grouped based on observed threat combinations when practical, leading to a probability of persistence based on the identified stressor magnitudes and their potential interactions (Fig. 1).

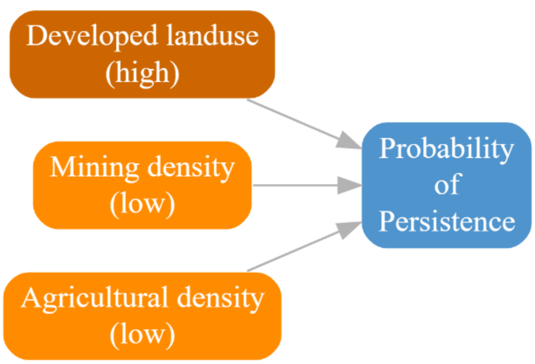

Figure 1. Simplified conceptual model for linking empirical landscape data to expert judgments on probability of persistence, with a hypothetical combination of threat levels.

3. Available Data

3.1 Life History

Table 1. Known life history and habitat characteristics of three *Stygobromus* species.

Life History Element	*S. parvus*	*S. cooperi*	*S. morrisoni*	Reference
Max lifespan (years)	4–6	4–6	4–6	Assumed; Dickson and Holsinger (1981), Voshell (2002)
Age at maturity (years)	1	1	1	Assumed; Fasulo (2005)
Max length (mm)	3.0 (male) 4.2 (female)	6.0	8.0	Holsinger (1978), (Lewis 2001)
Size at maturity (mm)		2.3	2.3	Holsinger (1978)
Gestation (weeks)	1–3	1–3	1–3	Assumed
Sex ratio (f/m)	> 1	> 1	> 1	Culver and Holsinger (1969)
Habitat	epikarst; mud-bottom, drip, and seep pools	epikarst; drip pools	small gravel-bottom stream, mud-bottom lake	Holsinger (1978), Pipan et al. (2010)

3.2 Distribution

Sampling of stygobionts is generally limited, with less than 10% of the known caves in the Appalachian region sampled to date (Culver et al. 2016); however, Christman et al. (2016) compiled over 11,000 records of cave-limited species spanning the Appalachian region and available data suggest that the three species of *Stygobromus* being considered are restricted to portions of Virginia and West Virginia (Fig. 2 and Table 2). Data from European stygobionts suggest that species ranges > 200 km are extremely rare (Trontelj et al. 2009) and nearly half (44%) of US species are known from a single county (Culver et al. 2000). This suggests that *S. parvus* and *S. morrisoni* may occupy a large range relative to other stygobionts (although still highly restricted).

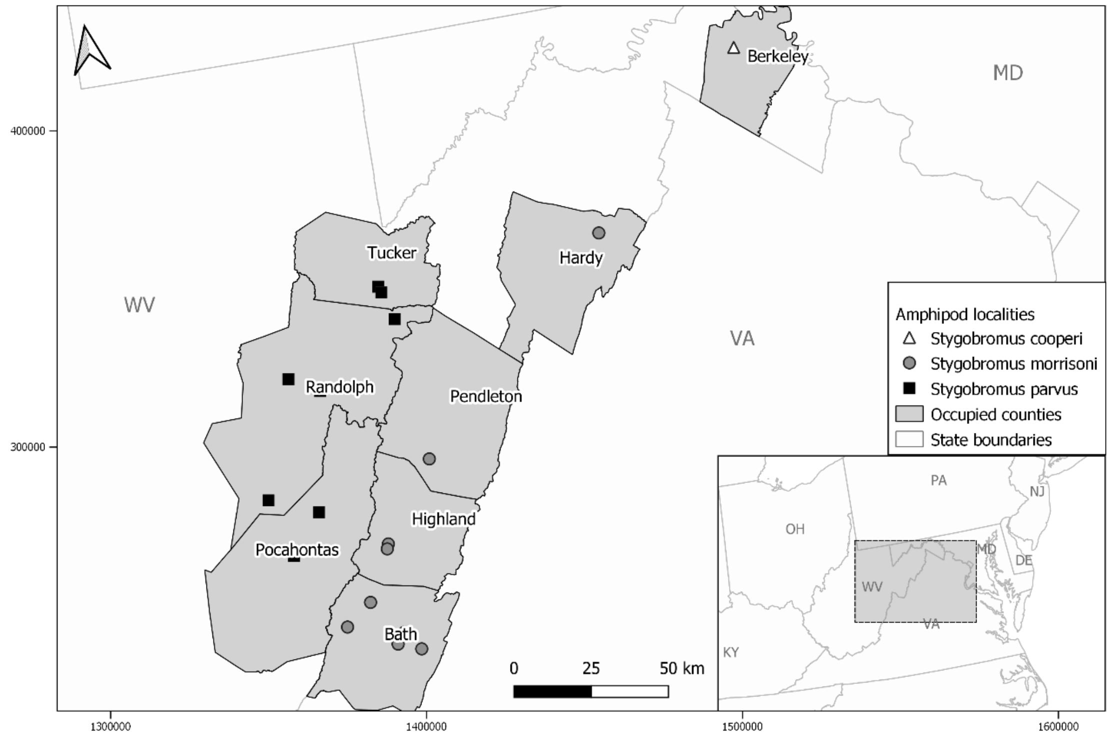

Figure 2. Known localities with counties occupied

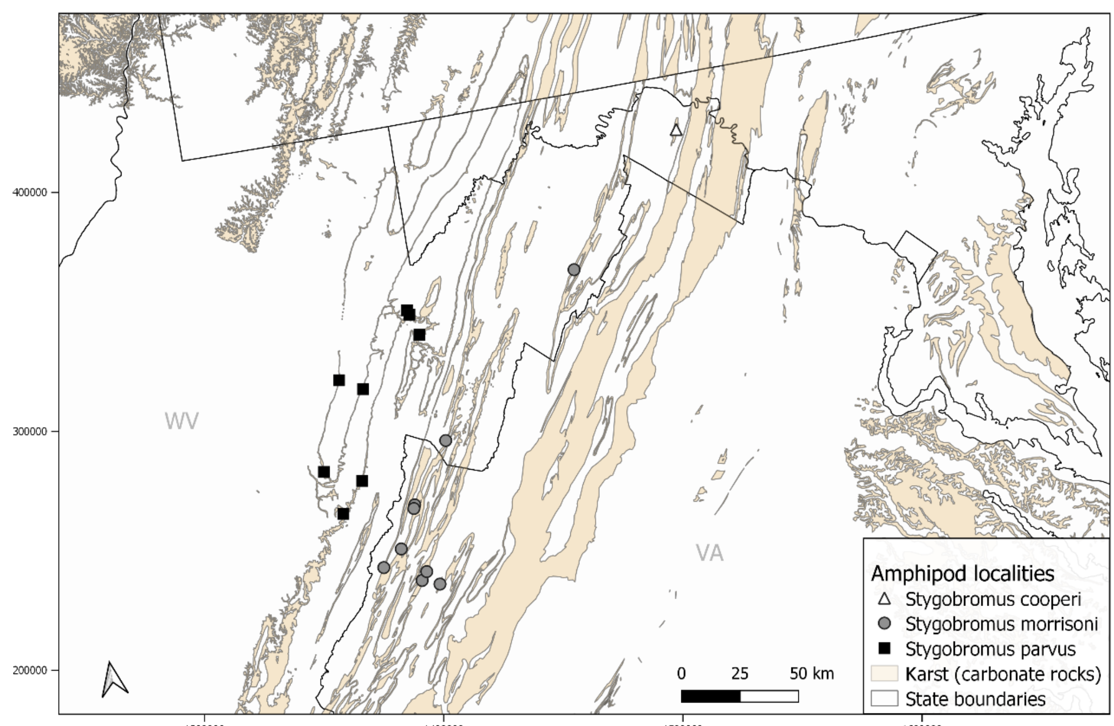

Figure 3. Known localities and karst regions

Table 2. Known localities of *Stygobromus spp*. with available collection information

Species	Locality	Number	Year	Ownership	Reference
S. morrisoni	Crossroads Cave	2	2014		(Holsinger et al. 2013); T. Malabad (2020) *pers. com.*
	Clarks Cave				Holsinger et al. (2013)
	Witheros Cave	14	1967 2014		Holsinger et al. (2013) T. Malabad (2020) *pers. com.*
	Starr Chapel Saltpetre Cave			Federal	Holsinger et al. (2013)
	Mountain Grove Saltpetre Cave	1	2000	Federal	Holsinger et al. (2013); T. Malabad (2020) *pers. com.*
	Corbett Cave				Holsinger et al. (2013)
	Secret Anthodite Cave				Holsinger et al. (2013)
	Dyers Cave	 6	1966 2006		(Fong et al. 2007); WVDNR
	Kenny Simmons Cave		1966		Fong et al. (2007)
S. cooperi	Silers Cave	2	1967		Fong et al. (2007); Pipan et al. (2010)
S. parvus	Bonner Cave	12	1992		Fong et al. (2007); WVDNR
	Bonner Mountain Cave				Fong et al. (2007)
	Bonner Pit Cave	12	1992		Feller (1992) unpublished; Lewis (2001)
	Izaak Walton Cave	2	2005		Fong et al. (2007); WVDNR
	Crawford Cave No. 2		1969		Fong et al. (2007); Lewis (2001)
	Cassell-Windy Cave	1	1969		Fong et al. (2007); Lewis (2001)
	Piddling Pit	4 4	1972 1990 2005		Fong et al. (2007); WVNDR
	Shreve-Howell Pit	2	2001		Fong et al. (2007); WVDNR

3.3 Population structure

No direct data is available to estimate population size or structure of the three focal species. Holsinger (1978) stated that additional populations of *S. parvus* likely remain to be discovered between presently known localities. *Stygobromus cooperi* is known from only two specimens in a single location of isolated karst (Table 2; Fig. 3). Mark-recapture studies of *S. emarginatus* (a non-focal species) in a 350 m stream section in Organ Cave, WV revealed densities around 10/m and a population estimate around 3,500, suggesting that not all range-restricted stygobionts are numerically rare (Knapp and Fong 1999). Data from epikarst copepods suggest that populations generally extend less than 1km along a cave passage (Pipan and Culver 2007) and genetic differentiation or meta-population structure can be detectable at scales as small as tens of meters (Sbordoni et al. 2000).

3.4 Groundwater and karst influence zone

We are not aware of direct dye-tracing studies from the identified caves that could aid delineation of groundwater basins. While we cannot assume that groundwater basins follow surface basins, impacts to surface waters in karst areas also impact groundwater quality. For example, cave streams in WV show elevated nitrate and pesticide levels in agricultural areas (Boyer and Pasquarell 1995, Pasquarell and Boyer 1996). Protection of surface areas is critical for the conservation of subterranean fauna, particularly epikarst specialists (Culver et al. 2000, Pipan et al. 2010). The appropriate spatial extent to consider for surface impacts represents a secondary QoI in the elicitation process (see section 4.1), but Pipan et al. (2010) have suggested 1 km as a starting point based on data from epikarst copepods.

4. Major threats to persistence

The broad categories of threats to cave and karst biota are well known (e.g., Culver et al. 2000, Pipan et al. 2010; Fig. 4). For example, *Stygobromus mackini* (a non-focal species) have shown occurrence patterns consistent with negative impacts of groundwater pollution by septic systems in Banner Cave, VA (Simon and Buikema 1997) and toxic/pollutant spills represent a broad threat to many karst species (Loop and White 2001, Pipan et al. 2010). The magnitude of various stressors that *Stygobromus* populations can withstand represents a QoI in the elicitation process. Data from the Edwards Aquifer region of TX suggest that the 10–15% impervious cover threshold often referenced for surface waters (Paul and Meyer 2001, Walsh et al. 2005, Schueler et al. 2009) represents a reasonable starting point in the absence of site- or karst-specific information (Veni 1999).

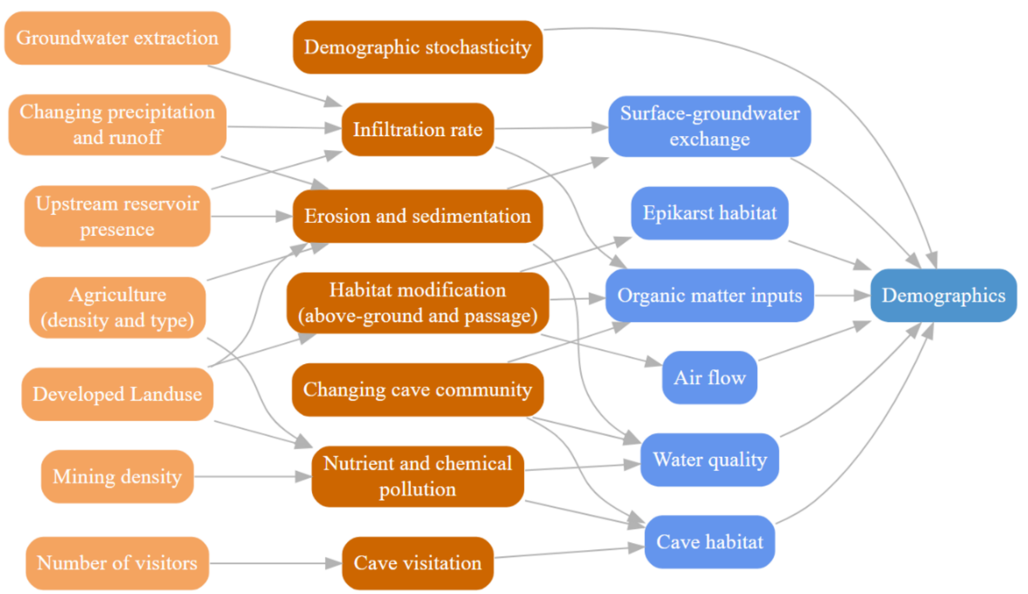

Figure 4. Conceptual model of major threats to amphipod persistence, showing ecological needs in light blue and stressors and stressor proxies in dark orange and light orange, respectively.

4.1 Quantification of threats and spatial scale of analysis

During the elicitation, a site narrative will display information on threat proxies at several spatial scales due to experts' beliefs that the appropriate scale depends on the specific threat. Based on data from epikarst copepods (Pipan et al. 2010), we will assume a 1km buffer around sampling localities represents the potential area occupied by the population. Local catchments and the upstream watersheds represent a relevant area of influence due to the potential for surface water to act as a vector for contaminants moving both downstream and laterally through karst environments. Hydrology will be based on the US National Hydrography Plus Version 2 data. While certain land use statistics will be quantified at the upstream watershed scale (Table 3), visual assessment will be possible at other scales not captured numerically. The largest extent provided will reveal landuse patterns at least 10 km away from the known locality due to high uncertainty in below-ground movement of water through karst environments, and the metapopulation dynamics likely operating for these species.

Table 3. Quantification of stressor proxies for elicitation

Stressor Proxy	Measure	Stressors	Data source
Developed land use	% in upstream watershed	Habitat modification Erosion and sedimentation Nutrient and chemical pollution	USGS; EPA
Agricultural land use (crop or pasture)	% in upstream watershed	Nutrient and chemical pollution Erosion and sedimentation	USGS; EPA
Animal agriculture	# of animal feeding operations (per county)	Nutrient and chemical pollution Erosion and sedimentation	EPA
Dams/reservoirs	# dams in upstream watershed	Groundwater infiltration rate Erosion and sedimentation	USGS
Changing precipitation	Change in annual average for region	Groundwater infiltration rate Erosion and sedimentation	MACA downscaled climate data
Mining density	# mines in upstream watershed	Nutrient and chemical pollution	US EIA
Oil and gas proximity	Within/outside of shale play	Nutrient and chemical pollution	US EIA
TMDL or 303(d) status	Impaired streams in watershed	Nutrient and chemical pollution	EPA; VA; WV
	Qualitative, as available	Cave visitation	Expert discussion
	Qualitative, as available	Changing cave community	Expert discussion

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