Recovery Potential Metrics
Summary Form

Indicator Name: CONTIGUITY WITH GREEN INFRASTRUCTURE CORRIDOR

Type: Ecological Capacity

Rationale/Relevance to Recovery Potential: Based on extensive documentation of the importance of connectivity among suitable habitats and habitat size/extent supporting more diverse and resilient ecological communities. Corridors increase effective habitat size and access, afford migration and movement to avoid temporary stressors, and aid recruitment and recolonization of impaired areas. Basically, impaired water segments near, or hydrologically connected to, functionally intact waters identified as important corridors by a green infrastructure (GI) mapping effort have greater recovery potential than isolated impaired waters for the reasons above. Generally, GI corridors have relatively unimpaired aquatic systems and relatively uninterrupted, naturally vegetated riparian corridors.

How Measured: Relative differences in this metric can be summarized as follows. If a categorical scheme is developed, each impaired water segment could fall somewhere in the following classes (worst to best):

0. no hydrologic connection to green infrastructure corridor
1. no proximity to green infrastructure corridor (e.g., connected hydrologically but > 2 km from corridor terminus)
2. proximate to green infrastructure corridor (e.g., connected hydrologically and < 2 km from corridor terminus)
3. Connected to green infrastructure corridor
4. Connected to and bridging two or more green infrastructure corridors

Data Source: Green Infrastructure (McMahon and others) mapping at statewide and other large scales has established criteria by which the more intact and ecologically functional stream corridors and larger natural habitat 'hubs' are identified. Examples of available state data include Maryland (See: http://www.dnr.state.md.us/greenways/gi/gi.html) or California (See: http://imaps.dfg.ca.gov/viewers/biospublic/app.asp?zoomtoBookmark=2335).

Indicator Status (check one or more)

_______ Developmental concept.
___x__ Plausible relationship to recovery.
_______ Single documentation in literature or practice.
___x__ Multiple documentation in literature or practice.
_______ Quantification.

Comments: Widely applicable but somewhat limited to states that have mapped Green Infrastructure and have defined criteria for corridors. Potentially can be applied also where GI mapping has not occurred but criteria for GI corridors (e.g., mimimum % naturally vegetated corridor, minimum length, and absence of listed impairments) can be separately applied to available datasets.

Examples from Supporting Literature (abbrev. citations and points made):

- (Weber 2004) Although composed primarily of natural ecosystems, the RLA network contains a variety of environmental conditions, including some areas that are heavily degraded. Land-cover "gaps", which are agricultural, mined, cleared, or developed lands within hubs or corridors, could be targeted for restoration: converting to wetlands or forests with composition, functions and processes resembling native natural conditions. These human generated gaps are logical starting points when attempting to identify opportunities for landscape restoration actions; they offer a chance to improve the overall network while simultaneously addressing water quality or specific habitat concerns.

- (Weber 2003) describes how gaps in Maryland's green infrastructure network were prioritized for restoration efforts, according to their relative ecological benefits, reclamation ease, and programmatic considerations. Other types of targeting included wetland restoration, stream remediation, ditch filling, removal of stream blockages, constructing road or railroad underpasses, erosion control, removal of invasive species, and changing management practices incompatible with ecosystem functioning.
- (Weber 2004) The concept underlying the RLA was to link large, contiguous blocks of ecologically significant natural areas (hubs) with natural corridors that create an interconnecting network of natural lands across the landscape. Large areas of natural habitat are usually more effective than small areas for protecting water, sustaining viable populations of most interior obligates, providing core habitat for large ranging species, and permitting natural disturbance regimes (Bushman and Therres,1988; Brown et al., 1990; Dramstad et al., 1996; Hanski, 1997; Tilman and Lehman, 1997). When such areas are decreased in size or isolated, plant and animal populations, which fluctuate in size, are more likely to go locally extinct (MacArthur and Wilson, 1967; Harris, 1984; Harris, 1988; Dramstad et al., 1996; Hanski, 1997). Corridors allow wildlife to pass more easily between habitat blocks, thus increasing available habitat and animal populations (Forman and Godron, 1986; Harris, 1989). They also ease dispersal of native plant pollen and seeds (Tilman et al., 1997; van Dorp et al., 1997; Tewksbury et al., 2002). Corridors linking habitat patches in a landscape are essential for many organisms to recolonize unoccupied sites, and for the persistence of metapopulations in fragmented landscapes (Dunning et al, 1992; Anderson and Danielson,1997; Tilman et al., 1997; van Dorp et al., 1997; Beier and Noss, 1998; Bennett, 1999; With and King, 1999; Robichaud et al., 2002; Söndgerath and Schröder, 2002; Tewksbury et al., 2002). Corridors in the RLA are linear features, at least 1100 ft (335 m) wide, linking hubs together. least disturbed areas in the Chesapeake Bay watershed. "core areas" are thought to provide breeding habitat for native wildlife and suitable conditions for native plants. Terrestrial (upland or wetland) core areas were defined as blocks of forest, wetland, nearshore open water, beach, or bare rock at least 100 m from the nearest anthropogenic land cover, road or active railroad, or powerline corridor, and at least 100 acres in size. A terrestrial core area was defined as a wetland core area if it contained at least 50% wetland in its interior, or if it contained at least 100 acres of unmodified wetlands. All terrestrial core areas not designated as wetland core areas were defined as upland core areas. In addition, terrestrial core areas with at least 50% upland forest in their interior, or with at least 100 acres of upland interior forest, were designated as upland core areas. Hubs were defined as natural areas containing one or more core areas, bounded by major roads or anthropogenic land cover >100 m; thus, hubs were slightly fragmented aggregations of core areas, containing largely suitable matrix conditions.
- (Palik et al. 2000) The various cover maps of the study area (Figs. 1, 2, and 4) suggest two landscape considerations that may alter the prioritization. The first of these is the obvious *fragmentation* of the landscape. For instance, even among reference ecosystems, most large polygons contain many small disturbance patches. Most of these disturbance patches have low priority for restoration (Fig. 4). This is because they occur predominantly within ecosystems 11 and 12, relatively abundant ecosystems in the current landscape, and because the disturbance level of the small patches is high. A manager may choose to place high priority on restoring these small, highly disturbed patches because of the potential to reduce fragmentation within the least disturbed portion of the landscape. The effort needed to restore small embedded patches may be less than their level of disturbance suggests. This would be true if the patches receive substantial ecological inputs (e.g., diaspores, natural disturbances) from the surrounding matrix, as do small oceanic islands near the mainland (Simberloff 1990) (200-201).

- (Hylander et al. 2002) Riparian ecosystems are interspersed throughout the landscape (Forman 1995), and their connectivity enhances dispersal of organisms (e.g., Nilsson et al. 1993, Machtans et al. 1996). Therefore, when attempting to combine wood production and biodiversity conservation an initial priority would be to not fragment the watercourse network across landscapes (Tornquist 1996, Gustafsson and Hansson 1997, Fries et al. 1998) (797).
- (Sondergaard and Jepessen 2007) Human-induced fragmentation of the landscape and loss of rivers and lakes are among the factors reducing the number of natural corridors and the possibilities of (re)-colonization of plant and animal species with poor dispersal capacities (Hughes 2007). Therefore, establishing connectivity – both laterally and longitudinally– is an important element in freshwater management: it ensures migration and dispersal of organisms and, as a delay in recovery may be due to lack of colonization (Jansson, Nilsson & Malmqvist 2007), also reinforces the recovery process. A negative effect of establishing connectivity and improving the dispersal of organisms is the potential introduction of invasive species, which may have highly negative consequences for the natural flora and fauna (Sakai *et al*. 2001) (1090-1091).
- (Russell et al., 1997) The proximity criterion reflects the ecological importance of connectivity and patch size for species habitat requirements (Meffe & Carroll 1994). We believe that a maximum benefit from restoration efforts may be gained by restoring areas near existing sites. These benefits may be in the form of reduced habitat fragmentation, as well as enhanced species recruitment into the restored site. All eligible pixels within 90 m (3 pixels) of either water or an existing riparian area were given high-priority restoration status. The 90-m proximity boundary was largely arbitrary in nature, but it is consistent with the findings of Keller et al. (1993), who identified a 100-m corridor width as a minimum for many avian species dependent on riparian habitat in the eastern United States (64-65).
- (Poiani et al., 2000) Longitudinal connectivity between protected riparian areas within the watershed will also be important to maintain flows of energy, matter, and species. For example, propagules of riparian species commonly originate upstream or upwind of the open sand bars where they germinate. Lateral connectivity—particularly in the interface of the riparian mosaic with uplands—is also important, especially if the conservation focus expands to include coarse- or regional-scale biodiversity (144).
- (Puth and Wilson 2001) This viewpoint unites the often parallel treatment of boundaries and corridors and emphasizes the fact that a structure on the landscape may act as a boundary or a corridor or may play an intermediate role, depending on mover specificity and temporal and spatial dynamics (28).
- (Puth and Wilson 2001) The mover-specific qualities of the boundary-corridor continuum underscore the dangers of single species management in which a structure's influence on one mover is emphasized over all others (28).
- (Ekness and Randhir 2007) Focusing on the headwaters and limiting the number and types of land uses with high disturbance values could be beneficial to the whole drainage system. Some longitudinal policies could improve regional connectivity in open space and low disturbance areas. Longitudinal restoration can be increased by using greenways to establish regional connectivity in watersheds (Wenger and Fowler, 2000) (1480).
- (Ricketts 2001) Terrestrial habitat patches, however, are often surrounded by a complex mosaic of other land cover types, which may differ in their resistance to the movement of individuals among the patches. Therefore, patches may be more or less effectively isolated than simple distance would indicate, depending on the type of intervening matrix (87).
- (Ricketts 2001) Several authors have discussed the idea that the "connectivity" of a landscape depends not only on the distance between habitat patches but also on the presence of movement corridors or stepping stones of natural habitat between fragments and the resistance of the matrix to interpatch movement by individuals (e.g., Taylor et al. 1993; Fahrig and Merriam 1994; Rosenberg et al. 1997) (87).

- (Ricketts 2001) The results presented here indicate that the type of intervening matrix can significantly influence the effective isolation of habitat patches (95).
- (Ricketts 2001) For example, comparatively resistant matrix types should result in decreased species richness in isolated patches (Lomolino 1994; Aberg et al. 1995), lower patch occupancy within a metapopulation (Moilanen and Hanski 1998), and lower levels of gene flow among isolated populations (Westerbergh and Saura 1994) (96-97).
- (Ricketts 2001) One of the central concerns regarding fragmented landscapes is the genetic and demographic risk of isolation (Meffe and Carroll 1994; Sutcliffe and Thomas 1996; Rosenberg et al. 1997; but see Simberloff et al. 1992). In efforts to increase the connectivity of fragmented landscapes (Taylor et al. 1993), conservation biologists have focused on the distribution of remnant fragments and the presence of stepping stones and corridors of natural or seminatural habitat (Doak et al. 1992; Sutcliffe and Thomas 1996; Schultz 1998; Haddad 1999*a*). It often may be more feasible, however, to reduce the effective isolation of fragments by altering management practices in the surrounding matrix than to reconnect them with restored corridors (Simberloff et al. 1992; Mann and Plummer 1995; Bowne et al. 1999) (97).
- (Ricketts 2001) Nevertheless, in these systems, the patches and matrix also differ markedly in thermal characteristics, and these factors will likely be important to butterflies in human-fragmented landscapes as well (Daily and Ehrlich 1996). In general, the resistance of a given matrix type will depend on the interaction between autecological traits of species and characteristics of the matrix (Dennis and Shreeve 1997; Henein et al. 1998; Gascon et al. 1999). Matrix resistance therefore may be expected to vary among differing species (e.g., homothermic vs. poikilothermic animals) (97).