Recovery Potential Metrics Summary Form

Indicator Name: CORRIDOR PERCENT AGRICULTURE

Type: Stressor Exposure

Rationale/Relevance to Recovery Potential: Croplands and pastures have been linked to a wide variety of water quality and biotic impacts on waters. Agriculture within stream corridors is sometimes more highly linked with several impairment types than agriculture generally distributed in the watershed, but often watershed percentage appears to be the stronger influence. Common effects seen at moderate to high agricultural proportions of land cover include less diverse and more intolerant macrobenthic communities, increased nutrient loading resulting in turbid water, overall homogenization of the fish fauna, accelerated erosion and bank destabilization, suspended sediment particles carrying pesticides, pathogens, and heavy metals, habitat degradation and reduced biodiversity, and increases in specific conductivity, DIN, DRP, and TP concentrations. See other highlights in literature excerpts, below. Although agriculture is commonly linked to degraded aquatic conditions that may be difficult to reverse and quite persistent over time, it is important to note that some degree of recovery is rarely considered impossible; for example, livestock access to channels may be more influential than corridor agricultural use and is commonly feasible to reduce. However, some studies claim that agriculture on floodplains can constrain the benefits of restoring natural hydrologic processes.

How Measured: Calculated as % by area within a set corridor width (e.g., 30 M or 90 M on each side) of the impaired water segment being assessed. Setting buffer = 0 enables calculation of agricultural lands adjacent to the water body, either as area % within a larger corridor, or as the linear % of stream miles in contact with agriculture on one or both banks. Simple GIS operation aggregating and measuring all agricultural classes from land cover data within each corridor.

Data Source: Land cover sources include the National Land Cover Data from 1992 (See: http://www.epa.gov/mrlc/nlcd.html), 2001 (See: http://www.epa.gov/mrlc/nlcd-2001.html) and 2006 (http://www.mrlc.gov/nlcd06_data.php) as well as various state sources. The USGS lists cropland by county since 1850 (See: http://landcover.usgs.gov/cropland/index.php). Corridors can be generated from hydrographic data (See: http://www.horizon-systems.com/nhdplus/) using a set buffer width for delineation. If the user chooses to use this indicator for a specific crop relevant to the study area, USDA has developed a national GIS crop dataset that can be downloaded from Geospatial Data Gateway (See: http://datagateway.nrcs.usda.gov/GDGHome.aspx). In addition, where applicable, BLM data set on range allotments and pastures can be used (See: http://www.geocommunicator.gov/GeoComm/).

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: Operational with widespread applicability across flowing waters in all regions.

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

- (Potter et al 2004) Two of the three watershed land cover variables — percent agricultural and percent forested — exhibited somewhat strong relationships. The percent of agriculture land cover at the watershed scale had a positive relationship with the indices, meaning that it was negatively correlated with aquatic ecological integrity. The percent of forest was correlated with better stream conditions. In our statewide analysis, the percent of forest cover at the watershed scale and in riparian zones were highly correlated enough (0.776) that the two have similar value as predictors of macroinvertebrate tolerance for water quality degradation. Forested land cover, at both the watershed and riparian scales, was a statistically significant predictor of benthic macroinvertebrate communities that are less tolerant of stream degradation, and that indicate a greater level of aquatic ecological integrity and better water quality. The opposite was the case for agricultural land cover at the watershed and riparian scales, and developed land cover in riparian zones.

- (Andersen et al., 2007) However, agriculture and other human developments on floodplains can constrain or eliminate the benefits of maintaining or restoring natural hydrologic processes (465).
- (Moore and Palmer 2005) Agricultural practices such as livestock grazing and tilling on land adjacent to streams can lead to soil erosion and subsequent runoff of fine sediments, nutrients, and pesticides (e.g., Schulz and Liess 1999, Cuffney et al. 2000, Kang et al. 2001). Urbanization leads to enhanced runoff, channel erosion, and reduced water quality due to inputs of metals, oils, and road salts (Hammer 1972, Booth and Jackson 1997, Paul and Meyer 2001) (1169).
- (Roy et al., 2007) Fish assemblages were correlated with urban, forest, and agriculture land cover variables, with the greatest number of strong relations with % forest and % urban in the catchment (eight strong models), and % forest and % agriculture in the 1-km riparian network (four strong models; Table 4). Cosmopolitan and lentic tolerant species were the only groups correlated with agriculture, with increased richness and abundance associated with agriculture at some spatial extents. For all except cosmopolitan species, the strongest relationships were with the largest spatial extents of land cover (catchment), followed by riparian land cover in the 1-km and 200-m reach, respectively. Endemic richness, endemic:cosmopolitan richness and abundance, insectivorous cyprinid richness and abundance, and fluvial specialist richness were all negatively correlated with % urban cover and positively correlated with % forest cover in the catchment (Table 4) (391-392).
- (Potter et al 2004)The resulting vulnerability models indicate that North Carolina watersheds with less forest cover are at most risk for degraded water quality and stream habitat conditions. Studies have found strong positive relationships between diverse assemblages of stream benthic macroinvertebrates that are intolerant of water quality degradation and watershed-wide forested land cover (Lenat and Crawford 1994, Stewart and others 2001, Weigel and others 2003) or forested land cover within riparian zones (Basnyat and others 1999, Sponseller and others 2001, Stewart and others 2001, Weigel and others 2003). Meanwhile, research has shown less diverse and more intolerant macrobenthic communities to be correlated with agricultural land cover (Lenat and Crawford 1994, Richards and others 1996, Weigel and others 2000, Genito and others 2002) and urban land use (Lenat and Crawford 1994, Morley and Karr 2002, Morse and others 2003, Roy and others 2003, Volstad and others 2003, Wang and Kanehl 2003).
- (Poole and Downing 2004) Stream sites often had riparian zones dominated by agricultural use and were generally characterized by poor water quality (Table 2). Multiple regression showed that the fraction of remaining woodland in the riparian zone, and the fractions of fine sediment, sand, gravel, and cobble substrate were significantly (*p* , 0.05) positively related to DR (Table 3). Positive variable loadings in this context indicated smaller declines or improvements in biodiversity, so areas with more riparian woodlands and more nearly equal fractions of fine sediment, sand, gravel, and cobble substrates had the least severe rates of decline in mussel richness. Riparian woodlands had the strongest positive partial effect on change in mussel species richness (Table 3) in multiple regressions. The effect is illustrated as a bivariate plot (Fig. 4A) showing that only sites with .50% woodlands in the riparian zone occasionally lost no species or increased in species richness. The median rate of species loss only approached 0 in

stream reaches with .80% wooded riparian zone. Riparian woodlands, previously the rule across this landscape (Andreas 1875), are of immense water-quality and biological benefit to stream animals (Karr and Schlosser 1978, Allan 1995), providing shading as well as water-quality protection (119-121).

- (Iwata et al., 2003) Moreover, recently expanded slash-and-burn (shifting) agriculture, a major cause of the forest destruction in Borneo, produces more excessive sediment than traditional swidden agriculture or logging operations (Douglas et al. 1993, MacKinnon et al. 1996). Therefore, riparian deforestation associated with slash-and-burn agriculture may impact on the stream biodiversity in Borneo more strongly than we expect on the basis of the empirical knowledge obtained in temperate streams (462).
- (Dodds and Oakes 2008) Riparian land use may be particularly influential and, in some cases, a better predictor of in-stream water quality than land cover in the entire catchment (Johnson and others 1997; Osborne and Wiley 1988). Intact riparian zones provide water quality benefits and help preserve the biological integrity of watersheds (Gregory and others 1991) (368).
- (Dodds and Oakes 2008) Across all studied watersheds, riparian land cover was a significant predictor of among-site variation in water chemistry concentrations at the watershed and first-order streams scales, particularly for nutrients (Table 1) (371).
- (Poole and Downing 2004) It seems reasonable, however, that the characteristics of whole watersheds should influence long-term resistance of mussel communities to perturbation when viewed at the small scale. Our analyses uphold this concept because watersheds with the most habitat converted to farmland had the greatest levels of decline in richness. This effect is echoed at the smallest scale by the association of deforested riparian zones in agricultural watersheds with declining richness. Also at the smallest scale, the lowest rates of declining biodiversity were associated with diversity of substrata (123).
- (Andersen et al., 2007) Agricultural and urban development typically results in habitat fragmentation and a reduction in mean patch size, which, in turn, can lead to a decline in the diversity of native species (465).
- (Ekness and Randhir 2007) Land use practices within a riparian zone are known to impact species richness and the diversity of amphibians, reptiles, birds and small mammals (Barclay, 1980; Mensing et al., 1998). Disturbance of the natural riparian riverine system may result in long-term modification to and reduction in natural biodiversity (Harding et al., 1998). Some of those impacts include changes in wildlife behavior, migration patterns, dispersal patterns, and distribution of species within a watershed (1470).
- (Ducros and Joyce 2003) The decision in this case to allocate at least 1 point to all criteria recognized the inherent environmental benefit of converting any intensively managed agricultural land into a buffer zone under the WFO scheme (255).
- (Ducros and Joyce 2003) The three criteria that varied from the usual scoring range were the WFO agreement adopted, stream lower-bank stability, and vegetation type within the buffer zone. In the first exception, the WFO agreement, scores ranged from 15 to 40 with greater value placed on 20-year withdrawal and arable conversion agreements (Table 2). This scoring range recognized that the type of WFO agreement was potentially a particularly important influence on riparian condition in this study. It also reflects the long-term nature of environmental enhancement and the potential habitat and water quality benefits of converting arable cropland to more natural vegetation (Dosskey 2001, Kemp and Dodds 2001). Furthermore, it was recognized that all WFO agreements potentially have considerable environmental benefit, so the minimum score possible was raised to 15. The second exception to the normal range of scores was for stability of the lower bank of the buffered stream. This criterion featured a depressed maximum score of 25 (Table 2) as lower-bank stability is not a substantial contributor to environmental enhancement in riparian zones compared, for example, to upper-bank character (Cooper and others 1987). The final exception related to the physical type or structure of vegetation in the buffer zone, which was assessed by recording the percentage of

different vegetation types in the field and allocating a score based on the proportion of each vegetation type present (Table 2). Thus, a buffer zone with 50% woodland cover and 50% open ground would score 50% of 30 points (15) for the woodland and 50% of 10 points (5) for the open ground, yielding a total of 20 points. The minimum score assigned to this criterion was 10, as even the lowest category of open vegetation, such as low grasses, represents valuable wildlife habitat and can contribute to effective buffer zone functioning (Lyons and others 2000) (255).

- (Ducros and Joyce 2003) Moreover, the presence of cattle watering points was identified on almost 50% of the Devon buffer zones, which could impair water quality through direct inputs of urine and feces, as well as causing bank collapse and erosion points (Jansen and Robertson 2001) (264).
- (Andersen et al., 2007) Our failure to detect a relationship between CF extent and either total annual discharge or peak discharge even when these differences in peak flow timing were taken into account (Fig. 4) suggests other factors, such as land use, are strongly influencing CF extent (464).
- (Norton and Fisher 2000) In addition to cropland 100–300 m from streams, forest far from local streams (\500 m) was important in reducing TN and NO3 concentrations (Table 5). A much larger portion of the Choptank watershed (50–85%) influenced local stream concentrations compared to that in the Chester (351).
- (Barker et al., 2006) In contrast, a set of studies by Goldstein *et al.* (1996) in Minnesota and North Dakota found fish to be more related to instream, riparian, and hydrologic conditions than to watershed agricultural land use. Lammert and Allan (1999) also found that land use immediate to the stream was more predictive of fish IBI than regional land use, but was less important than instream habitat variables.AWisconsin study by Fitzpatrick *et al.* (2000) found that several spatial scales influenced fish communities, but local riparian conditions appeared to be more important than watershed land cover (3).
- (Niyogi et al., 2007) Our estimates of riparian land cover did not account for greater variation in the abiotic characteristics of streams, including nutrient concentrations, than catchment land cover. It seems that catchment land use is a stronger determinant of certain abiotic characteristics, mainly nutrients, in medium-sized streams such as ours (Buck and others 2004; Strayer and others 2003). Although riparian land cover is closely related to physical habitat in many studies (e.g., see Allan and others 1997), a key feature of riparian status might be whether stock can access the stream, rather than riparian land cover itself (Quinn, 2000). However, riparian zones are certainly key sites of nutrient transformation (uptake, denitrification) in many other systems (e.g., Lowrance and others 1997; Osbourne and Kovacic, 1993) (221-222).
- (Niyogi et al., 2007) Riparian pastoral land cover did not account for more variation in biotic characteristics in our streams than catchment pastoral land cover. In part, this reflects the close relationship between catchment and riparian land cover in our dataset. (Niyogi et al., 2007) However, the role of riparian land use might be generally less significant in grassland catchments compared to forested situations, where stream biotic measures have been closely linked to characteristics of riparian vegetation (e.g., see Lammert and Allan, 1999; Sponseller and others 2001). As discussed earlier, stock access might be more important in determining the effects of pastoral land use on streams than riparian cover. Several of our sites with high pastoral cover in riparian zones (greater than 95%) had fencing or other barriers to limit stock access to the streams, and these sites had limited fine sediment (223).
- (Ekness and Randhir 2007) Spatial variations created by different riparian distance, stream order, and land use affect the type and quality of habitat potential at a particular position within a watershed. The buffer is often critical in the flow of mass and energy into and out of water bodies. The longitudinal dimension reflects upstream-downstream linkages, which is a key factor in watershed ecology. Various land uses contribute to the type and level of disturbances in a watershed. The intensity and the extent of land disturbance affect the habitat potential of a watershed (1471-1472).

- (Ekness and Randhir 2007) In general, habitat potential decreases with respect to land disturbance for most vertebrates. It is highest for birds, mammals, and amphibians in undisturbed forested, nonforested wetland, woody perennial, or open water areas. Reptiles are exposed to higher disturbance in cropland and pastures, possibly because of a higher availability of prey. There was an increase in habitat potential for birds, mammals, and amphibians between disturbance values of 1 and 2. The transition between the forested and urban areas could explain this increase. This is consistent with the intermediate disturbance hypothesis, which proposes that disturbance at intermediate levels can contribute to moderate increase in species diversity at particular levels (Dial and Roughgarden, 1998). Habitat potential for all four vertebrate species declines with increases in disturbance except for the transition between disturbance Levels 1 and 2 mentioned before (1475-1476).
- (Ekness and Randhir 2007) Maintaining land use in the riparian corridor within the lower disturbance categories along the whole longitudinal dimension of the watershed can benefit habitat potentials for multiple species. Policies can target lower order subwatersheds to achieve maximum benefits for habitat potential (1479).