DEVELOPMENT OF A COMMUNITY-BASED, LANDSCAPE-LEVEL TERRESTRIAL MITIGATION DECISION SUPPORT SYSTEM FOR TRANSPORTATION PLANNERS

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Introduction

The Pennsylvania Department of Transportation (PennDOT) has committed itself to a policy to provide compensatory mitigation for impacts to terrestrial habitat when such mitigation represents a reasonable expenditure of public funds. A historical perspective of the impact assessment and compensatory mitigation approaches is adequately presented by Dodds and Maurer, 1996. Recent evaluation of the appropriateness of these approaches has revealed opportunities for improvement.

Regulatory Context

Neither federal nor Pennsylvania regulations require mitigation for terrestrial habitat impacts. However such efforts are not completely free from regulatory issues. Prior to the passage of the Transportation Equity Act for the 21^{st} Century (TEA-21), the ability of the Federal Highway Administration to provide federal matching funds for these activities was not expressly stated, however, neither was it prohibited. TEA-21 represented a significant change in that it expressly allowed federal matching of such efforts. Guidance for such provisions have been recently promulgated in a supplementary notice of proposed rulemaking. This guidance mirrors PennDOT policy that such efforts must represent a reasonable expenditure of public funds.

The National Environmental Policy Act requires full and consistent consideration of federally funded project impacts on the environment. In Pennsylvania, Act 120, which established PennDOT, requires essentially the same efforts for environmental documentation. Additionally, all state agencies in Pennsylvania have a constitutional mandate to preserve the natural values of the environment for the benefit of all current and future citizens.

Background

PennDOT has traditionally used a species/habitat structure approach to assessing the impacts of its project on terrestrial habitats. This approach has its roots in early environmental studies conducted in the 1970s. At that time, typical projects approach impact assessment qualitatively. Studies typically involved a review of applicable secondary information supplemented by field observations. PennDOT then used best professional judgement to assess the impacts of projects. This methodology was often valid, but highly subjective. And, as with all methods based upon best professional judgement, quality evaluations were totally dependent on the availability of highly qualified individuals.

In the 1980s Pennsylvania experimented with the United States Fish and Wildlife Service Ecological Service=s Habitat Evaluation Procedures of 1980 (HEP). This represented a significant advancement over previous efforts in that it was replicable, semi-quantitative and had considerably less reliant on the availability of highly qualified personnel. This method proved problematic in terms of the level of effort and manpower required to complete such an evaluation. In response to this problem, PennDOT, the Pennsylvania Game Commission and the U.S. Fish and Wildlife Service cooperated to develop the Pennsylvania Modified Habitat Evaluation Procedures or, PAM HEP. PAM HEP has been in continuous use in the development of Department projects since that time.

The primary difference between HEP and PAM HEP is in the lessened quantitative rigor and increased agency coordination components of PAM HEP. PAM HEP uses the same approach to modeling as is found in HEP. In fact, often the same models are used. But, instead of physical measurements of the life requisite variables, ecologists from different agencies independently estimate the criterion. If all the estimates are close (within 0.3) the estimates are averaged and the Habitat Suitability Index (HSI) is determined. If this is not the case, additional data is collected and exchanged until a consensus (within 0.3) is reached. Experience with PAM HEP indicates that results closely approximate the results of HEP with a significantly lessened level of effort.

Some recent criticism of PAM HEP from the U.S. Fish and Wildlife Service has made project manager=s more reluctant to use it. On the U.S. 220/Interstate 99 project in Centre County Pennsylvania, habitat fragmentation and its effects on biodiversity, especially to amphibians and neotropical migrant birds, became a controversial concern. PAM HEP species based models focus on structural habitat components to establish habitat suitability. Then study sample compartment HSIs are aggregated to establish a cover based HSI for the project area. Criticisms of PAM HEP centered on five issues, biodiversity impact, road effect zone impacts, averaging, scale, and decision-making.

PAM HEP has been criticized for inadequately addressing biodiversity. PAM HEP currently relies specifically on species based models. Most of these models have been regionally developed for species foci of wildlife management emphasis (e.g. White-tailed Deer, Eastern Wild Turkey, Gray Fox) or common foundation species (e.g. White-footed Mouse, American Toad, Black-capped Chickadee). Conversely, species of conservation importance have lagged far behind in model development. On key project in Pennsylvania was particularly controversial because of the lack of a model for Yellow-crowned Night Heron. A model for Bobcat habitat has been identified as a need for more than a decade but is still under development. Similarly, little effort has been given to developing models for other species of conservation concern such as neotropical migrants, salamanders and bats. As a result PAM HEP data synthesis process, highly mosaic landscapes often tend to achieve artificially high (from a biodiversity standpoint) HSIs in comparison to large intact expanses which may support a reduced species richness but within which endemic species of higher conservation priorities exist. For example, a typical result of a PAM HEP study might indicate higher values for habitat supporting Raccoon with connectivity with diverse habitat types over habitat which could support Eastern Woodrat because specifically because such habitat is insulated.

Highway projects don=t subtly alter exiting habitat structure; they replace it with pavement. Consequently, PAM HEP has been criticized for focusing too much on the direct impacts of the road when the direct impacts are relatively straightforward. Instead what often is of greater importance is the road zone effect of highway construction with fragmentation receiving the most attention. Although HEP allows for the development of community based models rather than species based models, only one such model is available (Midwestern Shelter Belts). Community-specific development of sufficient models for transportation evaluation in the short term is not practicable. Similarly, some species specific models may have potential to provide for the evaluation of indirect transportation impacts to the road effect zone (Blue-gray gnatcatcher, Goshawk). However the use of the species for this type of evaluation is controversial because such species do not currently inhabit the project study area, or because some experts remain unconvinced that the life requisite parameters provide adequate sensitivity or specificity of such indirect impacts such as fragmentation or noise impacts.

Since averaging is an important component of the data synthesis process in PAM HEP one criticism has been that evaluations using the methodology lose the quality of specificity. That is, initial estimates of life requisite variables are averaged. Then, the HSIs of all compartments of the same cover type are combined using weighted averages and uniformly applied over the project study area. Thus, specific observations of very high or very low habitat quality are lost in the averaging process.

Another criticism of PAM HEP is the scale of the evaluation. With wetlands, science and policy are urging a watershed-based approach to evaluating wetland functions. The argument that an evaluation of the functionality of terrestrial habitat makes sense only in a landscape context makes equal sense. This is especially true with highway projects that are a landscape level endeavor with landscape level impacts. PAM HEP is an excellent tool to evaluate impacts on the ? diversity level. Highway projects seldom have significant effects on this level, but can have substantial impacts on ? and ? diversities. The main impact of highways is on the potential of the landscape to sustain its level of ecosystem integrity. PAM HEP lacks an effective means of dealing with this issue.

The final criticism of PAM HEP revolves around its insufficient support to the decision making process. PAM HEP allows comparison between existing conditions and potential future conditions. Therefore, it can be use to support decision-making as it relates to avoidance and minimization. It does not support compensatory mitigation decision-making. It is not atypical for a PAM HEP analysis to reveal that a project will result in an impact of six hundred habitat units (HUs). No methodology is available to translate that information into a decision regarding how much compensatory mitigation should be provided or what the objectives of such an effort should be.

Setting Objectives

When not subject to legislation or regulation that specifically requires or prohibits such activities, the Pennsylvania Department of Transportation is developing a policy to mitigate terrestrial impacts resulting from transportation project development when such mitigation represents a reasonable expenditure of public funds. The focus of compensatory efforts will be based on an analysis of project specific impacts in terms of the statewide conservation performance measures established by PennDOT in the policy. The overarching goal of this policy is to ensure that the Department=s projects do not permanently impair the integrity of the ecosystems of Pennsylvania.

Ecosystem integrity is the ability of a community of organisms in an abiotic matrix to maintain a dynamic balance of species composition, diversity and functional organization. This balance ensures the sustainability of the key ecosystem processes of:

? hydrologic cycling and storage;
? energy cycling and storage;
? biogeochemical cycling and storage;
? gross biological productivity; and,
? the capacity for system self repair.

This proposed policy does not propose a Ano net loss@ of ecosystems. Transportation projects will permanently impact ecosystems. Often this will occur without compensatory mitigation. Protecting the <u>integrity</u> of ecosystems means that no natural communities will be extirpated and that remaining ecosystems will be continually self-supporting and an evaluation of the effort necessary to maintain such integrity forms the basis of reasonability. (Leslie, et.al. 1996) Because current science does not allow an accurate and sensitive measurement of the level of ecosystem process functionality, measurable performance objectives for PennDOT=s conservation effort must be established. The following are proposed:

<u>Ecosystem integrity is the basis for the Department=s evaluation of terrestrial impacts.</u> For two reasons the Department will focus on landscape level ecosystem integrity in terms of naturally occurring communities, not individual species or areal impacts. First, transportation project development occurs at the landscape scale. Second, it is impossible to assess ecosystem integrity while focusing on individual species. While the gross size of available habitat is one factor in evaluating ecosystem integrity, using it as the sole measure of a project=s impacts ignores potentially more important aspects of ecosystem integrity (e.g. core habitat area).

<u>Transportation activities do not contribute to species extinctions or statewide extirpations.</u> PennDOT will comply will all laws and regulations intended to prevent extinctions and extirpations. When development of a specific project provides appropriate opportunities to go beyond regulatory requirements in the conservation of these species, the Department will focus its terrestrial mitigation efforts towards the recovery of the species. When species populations or communities of conservation concern are present in the project area but are not self-supporting, efforts to restore the integrity of such populations or communities will be prioritized.

<u>Ecosystems supporting sensitive communities and/or species before a project will continue to do so after the project is realized.</u> Except where prohibited by statute or regulation, individuals of sensitive species or portions of communities of conservation concern may be permanently lost as a result of transportation project development. The Department will take such actions as are reasonable to ensure that such priority populations or communities remain present in the project study area and that such remnants continue the ability to be self-sustaining. Sensitive communities or populations will have Nature Conservancy status rankings of Globally Vulnerable (G3), Globally Imperiled (G2), or Globally Critically Imperiled (G1) as well as those highly vulnerable in the state (S2/3), State Imperiled (S2), and State Critically Imperiled (S1). When these species are protected by statute or regulation the Department will fully comply with such laws.

<u>Local loss of individuals of a species will be balanced by recolonization from nearby populations.</u> Transportation Project Development may result in the temporary extirpation of local populations of species that are ecologically secure. Natural communities that are ecologically secure may be permanently lost in the project area. The Department will take such actions as are reasonable to enhance the opportunity for project study area recolonization. The Department will make a reasonable effort to replace examples of extirpated communities.

<u>Landscape level patch dynamics will remain relatively constant with respect to changes resulting from transportation project development.</u> The Department believes landscape level patch dynamics, the presence of sensitive species or communities, and evidence of ecological conservation efforts to be the most quantifiable and holistic indicators of ecosystem integrity. The Department will use VARMINT to quantify changes to the landscape as a result of a project and base the scope of reasonable compensation efforts upon this analysis. The Department will focus its compensatory efforts on maintaining or restoring patch dynamics. When species or community conservation priorities are identified, maintenance or restoration of patch dynamics will complement compensatory efforts on their behalf.

<u>The Department uses adaptive management techniques in achieving its conservation performance measures.</u> The Department=s terrestrial mitigation efforts are made with the intent of achieving established conservation performance measures and are based on the best available science. The Department will evaluate its terrestrial mitigation program regularly to determine its effectiveness in achieving established performance measures. As shortfalls between goals and accomplishments are identified the Department will modify its management techniques in an attempt to improve its program.

Requirements of a Decision Support System

Over ten years of project development and agency coordination experience have yielded a basic set of requirements for data collection, analysis, and synthesis that allows for informed and reasoned decision-making. While PennDOT=s experience with HEP and PAM HEP allowed early support of many of these requirements. The need for more sophisticated tools tailored to compensatory decision-making is now needed. This must be an integral system that considers the quality of existing habitats, the impacts to them, and the economics of compensatory efforts.

? <u>Comparison</u> B A decision support system for terrestrial mitigation decision-making must be able to compare existing and multiple potential future conditions.

- ? Reasonableness B Since the basis for decision-making is a reasonability test the system must be able to comparatively balance the need for mitigation with the ability to provide mitigation.
- ? Practicality B The decision support system should be practical to implement in terms of time, money, and manpower.
- ? Sensitivity B The system should be sensitive enough both to identify the scale of the impact and to characterize what factors of impact are most meaningful.
- ? Data B The data used by a decision support system should be scientifically accurate but allow the general public to understand its role in supporting the decision support system.
- ? Process B The process that a decision support system follows should be open and understandable. This allows modification and amendments as requirements or objectives change and as scientific advancement occurs. (USFWS, 1980)
- ? Decision-making B The system should lead the users towards a meaningful decision. Facts, analysis and synthesis within the may meet all the other requirements but not lead to a meaningful decision.

Variables for Assessing Reasonable Mitigation IN New Transportation (VARMINT)

Habitat Importance B This metric scores the relative importance of the terrestrial habitat based on the presence or probable presence of special concern species such as state threatened and/or endangered species, state or federal candidate species, and whether the species assemblage is sensitive or tolerant to human disturbance. AWatch-list@ species are also included and are those species, which are declining but not to the point where they are listed as candidate, threatened or endangered. Federally listed species are not included because they require separate coordination and investigation under Section 7 of the Endangered Species Act. The metric has been structured to first evaluate species of special concern, then species intolerant to disturbance. These may include forest interior species, landscape dependent species, etc.

The term Ahabitat@ as used in this metric is scale dependent. The habitat evaluation is conducted at a landscape scale and utilizes the Anderson land use and cover types (i.e. deciduous forest, herbaceous rangeland). It allows the use of Geographic Information Systems (GIS), aerial photography, satellite imagery, and color-infrared photography. If possible, the terrestrial land cover types should be classified to Anderson Level III.

To determine whether a habitat supports the type of species composition identified in the metric, coordination with the U.S. Fish and Wildlife Service (USFWS), the Pennsylvania Game Commission (PGC), the Pennsylvania Fish and Boat Commission (PFBC), the Pennsylvania Natural Diversity Inventory (PNDI), and other local conservation groups will be required. Support is defined as currently supporting, potentially supporting, and/or historically supporting species based on agency coordination, literature, searches and field investigations. Detailed field studies (i.e. population and habitat measurements) are not required unless requested. If historical occurrences of state threatened or endangered species are reported, then a field search must be conducted to determine whether the species is still utilizing the habitat. Support also refers to the habitat supporting species that are either year-round residents and/or migrant species that utilize the habitat for breeding purposes.

The species array of each habitat and their tolerance to human disturbance will be based on the information collected and the list of species prepared by the Pennsylvania Department of Transportation in consultation with the U.S. Fish and Wildlife Service, the Pennsylvania Game Commission, and the Pennsylvania Fish and Boat Commission for amphibians and reptiles. This list includes game and non-game species. Species that are less tolerant to human interaction include forest interior dwelling species, landscape dependent species, and species with stenotypic habitat requirements.

Scoring is based on the information collected and the best professional judgement of the evaluator. If more than one statement in the metric is applicable, the highest appropriate score is assigned. The scoring process is conducted for baseline and post project conditions. Scoring for baseline conditions is as follows:

Importance	**Points**
Habitat supports multiple species of special concern	20
Habitat supports State endangered species	18
Habitat supports State threatened species	16
Habitat supports State or Federal candidate species	14
Habitat supports Awatch-list@ species	12
Habitat supports a species array that is less tolerant of human interaction than average	10
Habitat supports a species array with average tolerance of human interaction	6
Habitat supports a species array with greater than average tolerance of human interaction	4

The evaluator will need to determine, based on the type and location of the proposed project, the magnitude of the impact. In other words, does the project impact 0%, 10%, 25%, etc., of the habitat and if so, will the remaining habitat still support the species composition that have been identified as occurring and/or potentially occurring within it. This will require an understanding of how fragmented the habitat becomes, the degree of isolation from similar habitat, and whether it is connected to like habitats by a corridor that is similar in vegetation composition and structure.

For species of special concern, the evaluator should be familiar or consult with a specialist that is familiar with the species and their habitat requirements to determine whether they will remain in that habitat after disturbance. If this location is one of the few occurrences in the state, then the evaluator must consider that as critical in determining the impact score.

It should also be noted whether species, special concern or otherwise, are sedentary or mobile. If mobile there may be an opportunity to move to another location within that habitat or to adjacent similar habitats. If sedentary, the evaluator must determine whether key life history requisites supported by that habitat will be disturbed thus affecting the survival of that species within the habitat.

To score the impacts of the proposed project on Habitat Importance, multiply the baseline score by the following percentage if one of the conditions apply.

Adverse impact to species of special concern and/or species susceptible to disturbance. The habitat is altered or indirectly affected such that it can no longer sustain such species. Species tolerant of human disturbance are likely to inhabit the area. Multiply by 75% and subtract from baseline score.

Species of special concern unlikely to inhabit area due to stenotypic habitat requirements. Sedentary species not able to persist. Habitat is fragmented and no connectivity to similar habitat exists. Multiply by 50% and subtract from baseline score.

Moderate impacts to species of special concern and/or species susceptible to disturbance. Habitat still provides for life history requirements. Connectivity to similar habitat maintained to allow dispersal. Edge may influence core habitat as a result of the project. Multiply by 25% and subtract from baseline score.

Low impacts to species of special concern and/or species susceptible to disturbance. Project does not directly intrude on habitat patch. Influences only the edge type. Multiply by 10% and subtract from baseline score.

No impact. Species of special concern and/or species susceptible to disturbance are able to still inhabit the area. Habitat provides for life history requirements. Sedentary species unaffected. Score is same as baseline.

The habitat importance assessment also needs to consider the consequences of secondary development. These impacts should be included in the final scoring for post-project conditions.

Rarity B The rarity metric is based on the natural ecological community classification developed by the Pennsylvania Natural Diversity Inventory-East, Pennsylvania Science Office of the Nature Conservancy (Smith, 1991). It utilizes the classification of ecological communities in Pennsylvania and the element ranks developed by the Nature Conservancy=s Heritage Program. Element refers to the community of interest. Each community is assigned a global rank (G) and a state rank (S). The global rank indicates the rarity of the community throughout the world and the state rank reflects the rarity within Pennsylvania. The ranks for this metric are based on the Nature Conservancy=s Natural Heritage Program and are as follows:

- G1: Critically imperiled throughout its range due to extreme rarity (5 or fewer occurrences or very few remaining individuals, acres or miles of stream) or extremely vulnerable to extinction due to biological factors.
- G2: Imperiled throughout its range due to rarity (6 to 20 occurrences or few remaining individuals, acres or miles of stream) or highly vulnerable to extinction due to biological factors.
- S1: Typically 5 or fewer occurrences, very few remaining individuals, acres or miles of stream or some factor of biology making it especially vulnerable to extirpation in Pennsylvania.
- S2: Typically 6 to 20 occurrences, few remaining individuals, acres or miles of stream or factors demonstrably making it very vulnerable to extirpation in Pennsylvania.
- G3: Either very rare or local throughout its range (21-100) occurrences), with a restricted range (but possibly locally abundant), or vulnerable to extinction due to biological factors.
- S4: Apparently secure in Pennsylvania.
- S5: Demonstrably secure in Pennsylvania.

These are listed such that imperiled communities receive the greatest score and the scoring decreases as these communities become more secure within Pennsylvania. Thus the emphasis is placed on those communities that need protection.

For baseline scoring purposes, the highest appropriate value is scored if more than one type of community is present in each habitat evaluated.

Rank	**Points**
G1	20
G2	18
S1	16
S2	14
G3	13
S3	10
S4	8
S5	4

Impacts should be scored a minimum of 50% of their baseline score (i.e. G1 = 20 for baseline and 10 for project impacts) if G1, G2, S1 and S2 communities are affected to any extent by the proposed project. For G3, S4, and S5 communities, it should be determined whether the impacts will change their ranking (i.e. G3 to a G2 or G1). If they change to a G1, G2, S1 or S2 then they should be scored as described above. If the rankings for G3, S4 and S5 communities do not change, then they should be scored based on the best professional judgement of the evaluator. The percent decrease in scoring by the evaluator needs to consider the magnitude of the impact and whether the remaining portions or the community are functional.

Stewardship B This metric identifies the ownership of the habitat that affords that habitat varying levels of protection. Habitat owned by public agencies receives the highest score and those owned by private entities, the lowest score. It is assumed that private ownership provides little, if any, protection.

The baseline scoring for each habitat is based on the following:

Stewardship Category	**Points**
Federal or State Resource Agency	15
National or State Private Conservation Organization	13
Federal or State Non-resource Agency	10
Local Conservation Organization	8
Legal Conservation Statement	6
Local Government	4
Private Ownership	2

If a particular habitat compartment has more than one owner within the evaluation limits, then each component of ownership must be averaged in the scoring. For example, if 50% of the habitat is in federal ownership and 50% in local government, the score would be 15 (.50) + 4 (.50) = 9.5. The impact scoring should be assessed based on the magnitude of the impact (i.e. 20%, 50% of habitat area impacted). The percent impacted is multiplied by the baseline score to arrive at an impact score. If the habitat contains more than one owner, then each baseline score for each parcel owner needs to be multiplied by the percentage impact and then added to arrive at an impact score.

Habitat Patch Size B The metric, size, is related to the theory of how species increase in direct relation to the size of the area and the effects of fragmentation. The species-area relationship has been investigated for islands (MacArthur and Wilson, 1967) and fragmented interior habitats (Galli, Leck and Forman, 1976). It has been found to apply to a broad range of taxa (Blake and Karr, 1982; Lomolino, 1982; Jones, Kepner and Martin, 1985; Laan and Verboom, 1990; and Murphy and Wilcox, 1986). Habitat fragmentation can negatively influence species populations by reducing the size of the patch below a minimal threshold; exposing individuals to increased rates of predation, competition, and parasitism; changing the temperature and moisture regimes within the habitat patch; and reducing rates of recolonization (Harris, 1984; Small and Hunter, 1988; Yahner, 1988; Saunders et al., 1991; Robinson et al., 1995; Paton, 1994; and Morrison et al., 1992). Forest interior dwelling and landscape dependent species are particularly sensitive to the reduction in habitat patch size and land use changes (Lynch and Wigham, 1984; Robbins, 1980; Robbins et al., 1989; Whitcomb et al., 1981).

The scoring for baseline patch size conditions is as follows:

Patch Size	**Points**
350 + acres	13
275 + acres	12
200 + acres	11
150 + acres	10
100 + acres	9
80 + acres	8
60 + acres	7
40 + acres	6
25 + acres	5
15 + acres	4
9 + acres	3
4 + acres	2
<4 acres	1

The impact scoring is based on the remaining patch sizes after the project is constructed. Scoring for both baseline and impact conditions is completed for each contiguous patch within the study corridor. These scores are added to arrive at an aggregate score for each condition. It should be noted that small patches within a larger patch might occur. These should be treated as part of the larger patch. For example, there may be small coniferous stands within a deciduous forest patch.

Habitat Connectivity B This metric assigns higher values to habitats which comprise one part of a naturalistic matrix. Some habitats are, by their nature limited in size. Examples of these might include side-hill seep wetlands or other habitats based upon outcroppings of a particular lithology. These habitats, while small, form important parts of a mosaic landscape. This metric also accounts for the ability of a community array to meet the varied life requirements of species that must move between communities to accommodate such needs. It is scored identically to Habitat Size, but instead of considering only one community parcel it includes all natural communities adjacent to the evaluation compartment as well as all natural communities adjacent to those compartments until the entire parcel is bounded by anthropogenic habitats.

The scoring for this metric is as follows:

Total Size of Linked Compartments	**Points**
350 + acres	13
275 + acres	12
200 + acres	11
150 + acres	10
100 + acres	9
80 + acres	8
60 + acres	7
40 + acres	6
25 + acres	5
15 + acres	4
9 + acres	3
4 + acres	2
<4 acres	1

Proximal Land Use B Natural habitat areas that remain undisturbed but are surrounded by anthropogenic land uses may be unsuitable for certain species, such as interior forest dwellers. The core area of the habitat patch may be affected by edge species that can penetrate that patch. It has been reported that edge effects can penetrate a habitat patch up to at least 200 meters (m) for forested areas (Brittingham and Temple, 1983; Csuti, 1991; Noss and Cooperrider, 1984; Paton, 1994; and Rich et al., 1991). Proximal land use also affects the permeability of that habitat patch. This refers to the ability of the adjacent habitat to be traversed by species to enter habitat patch in question (Schroeder, 1996). It is related to characteristic of the edge boundary, intervening habitat patches and their structure and the characteristics of the species.

The natural communities used in this metric refer to communities that are unaltered or not currently disturbed by human interaction. These areas are predominated by wetlands, streams, lakes, ponds, forests and rangelands. Typically, housing density is limited to one unit per five or more acres. Low intensity anthropogenic uses includes agricultural activities and limited residential and commercial development with some areas of natural communities. High intensity anthropogenic land uses are areas where residential, commercial, industrial and/or institutional development is dominant and there are very few natural communities.

The proximal land use metric for baseline conditions is calculated as follows:

Proximal Land Use Score = $(L_N *0.12) + (L_L *0.07) + (L_H *0.02)$

Where:

L_N = Percentage of community perimeter bordered by natural Communities;
L_L = Percentage of community perimeter bordered by low intensity anthropogenic land uses; and,
L_H = Percentage of community perimeter bordered by high intensity anthropogenic land uses.

This metric should be calculated for each patch within the study area and the scores totaled for the baseline condition. Impacts should be estimated by including the percentage of the community perimeter that is bordered by the highway. If the highway has a low maintenance vegetated right-of-way then it should be considered a low intensity land use. If it does not have a vegetated right-of-way (i.e. retaining walls) then it should be considered high intensity land use. The impact scores are calculated in the same manner as the baseline score.

Relative Significance B This metric identifies the relative significance of a particular community in reference to land use within the study area. That community becomes more significant as the natural areas within the study area becomes less. This community may represent a refuge of biological diversity, sensitive communities etc. in an area that is undergoing increasing development. It is of less significance if natural communities are predominant in the study area and/or if it comprises a large percentage of the natural communities within the study area.

The metric for this is calculated as follows:

Significance score = $(7-[C_N *0.07]) + (3-[C_s *0.03])$

Where:

C_N = Percentage of study area in natural communities; and
C_s = Percentage of study area in the specific community types

The metric score for impacts is based on the changes in the natural communities after the project has been constructed. This will change the percentage of natural communities within the study area as well as specific community types. Certain community types may not be affected by the project and as a result increase in relative significance compared to the overall natural community composition within the study area.

Habitat Patch Shape B The underlying premise for this metric is that changes in patch shape are due to habitat fragmentation and can potentially increase the influence of edge effects on that patch. Generally, smaller habitat patches have a longer margin or edge relative to the area of the patch. A long narrow patch will be influenced by edge effects compared to a patch of the same area, but more circular in shape. (Forman and Godron, 1986).

The baseline calculation for this metric is as follows:

Fragmentation Score = $10(A_H)A_C$

Where:

A_H = Area of the habitat compartment; and
A_C = Area of a circle with a circumference equal to the perimeter of the Habitat compartment.

The metric is based on the area of a circle since it is assumed to have a higher core area to support species than an elongated patch. The score should be calculated for each patch and then totaled for the study area.

Scores for impact assessment will be based on changed in patch shape from the proposed project and totaled as before.

Natural Processes B Natural processes maintain and influence ecosystems as well as the biological communities they contain. These processes interact within and between the land cover patches in the landscape mosaic. The edges at the patch interface will influence the interaction of these processes between patches based on the definition of the edge (i.e. agriculture field-woodland edge vs. transitional shrub/scrub/woodland edge.) Natural processes include energy and material transfers, biotic movement, hydrologic cycles and disturbance regimes.

Natural disturbance regimes are essential to maintaining the integrity of biological communities. Such disturbances can be a result of fires, flooding, windstorms, rockslides, etc. In general, species have adapted to a particular disturbance regime (Noss and Cooperrider, 1994) and in some instances depend on them for continued existence. Anthropogenic disturbances can introduce a new disturbance regime or change the frequency/intensity of natural disturbance regimes that will impact the natural diversity of the community and make it susceptible to the invasion of exotics. The literature suggests that natural disturbance regimes at some intermediate frequency/intensity of disturbance will support a higher species diversity than less and more frequent/intensity disturbances (Sousa, 1984; Huston, 1996; Reice, 1994).

This metric considers the influence of both natural and anthropogenic disturbances and the frequency of such disturbances. The scoring is based on how both natural and anthropogenic disturbances affect systems. This includes the frequency of natural disturbance which can affect the development and diversity of the habitat as well as man-made disturbances that interfere with natural processes. This metric is scored by determining the number of points to subtract from the overall score (no more than 8 points can be subtracted). Those factors that have a negative influence receive the highest number for subtraction. This evaluation will be based on the best professional judgement of the evaluator.

The scoring system is as follows:

Current anthropogenic influences (i.e. timbering, local ordinances, existing development) preclude the functioning of natural processes (i.e. snag production, barriers to movement) B **Subtract 5**

Current natural influences (faunal imbalance, invasive species, etc.) severely limit the functioning of natural process B **Subtract 4**

Current anthropogenic influences adversely impact the functioning of natural processes B **Subtract 3**

Current natural influences limit the functioning of natural processes B **Subtract 2**

Impacts from the project will be based on how the construction will influence natural disturbance regimes and natural processes. It should be decided whether the project will exacerbate the process described in the metric. For example, will the project introduce and/or promote the invasion of non-native species that will out-compete native species.

Diversity B Diverse landscapes are able to provide for a broader range of life requisites for resident species. However there is a point beyond which a landscape in extreme diversity becomes so fragmented a mosaic that core habitat is unavailable o meet life requisites of resident species. This metric attempts to evaluate and balance these issues by using two measurements of diversity, the Shannon-Weiner Diversity Index (Shannon & Weiner 1963) and community richness. Diversity divided by richness provides a measurement called evenness, which has been used by entomologists to establish the stability of insect populations. But, when considering landscapes with highly equal community compartments tend to be either highly mosaic or have relatively poor interface between natural communities. On a landscape level the diversity divided by richness (the inverse of evenness, or hegemony) is highly desirable. High hegemony levels are indicative of a landscape dominated by one natural community with good access to many other types of natural communities.

This metric is scored as follows:

Diversity Score = 5 x (R) I)

Where:

R = The number of different types of natural communities present; and,

I = The computed Shannon-Weiner Diversity Index (a unitless number representing the degree of uncertainty of predicting a community type selected at random from the universe of community types present.

Anthropic Use B The metric is based on whether the habitat area is utilized by the public for passive and/or active recreational uses. The type and frequency of use by the public may influence the quality of the habitat as well as species diversity. The habitat may also present unique educational and research objectives. It is scored as follows:

Site has an established management plan - 2 points
1 point for each of the following:
- Site is open to public
- Site admittance is free
- Site has a maintained public access
- Site is within 25 miles of an urbanized area

Points should be added for each applicable condition for a possible seven (7) points. The impact scoring for the proposed project needs to consider whether the established management plan is affected and how the project changes, interferes with or enhances the use of the site.

Intangibles B The evaluator in coordination with the U.S. Fish and Wildlife Service, Pennsylvania Game Commission and the Pennsylvania Fish and Boat Commission may have identified other features that should be considered. These receive a score for a maximum of 5 points. The feature should be identified and a score assigned. The reasoning and assumptions for the feature should be documented. The impact analysis should consider the effect on that feature and the resultant score.

Interpreting VARMINT Scores

Each natural compartment is scored for each of the above metrics. Compartment scores are then compared against the range of previously evaluated compartments to establish a comparative habitat quality. Current practice is to rank habitats as excellent (greater than one standard deviation above the mean of all evaluated compartments), good (above the mean to one standard deviation above the mean of all evaluated compartments), fair (below the mean to one standard deviation below the mean of all evaluated compartments), or poor (less than one standard deviation below the mean of all evaluated compartments).

Additionally, the VARMINT scores for each compartment are totaled for the project area and divided by the total acreage of the study area.

Both of these exercises are performed for existing conditions and all alternatives reaching the level of detailed alternatives analysis. The amount of impact by habitat category is helpful in avoidance and minimization efforts and, where impacts are unavoidable in setting goals for mitigation. The general acreage based habitat quality is used to assist in determining reasonableness. Additionally, for focused mitigation efforts each total metric score can be evaluated to establish what the most detrimental impact of the project is and target efforts to mitigate that habitat component. In the absence of established regional habitat management plans, this evaluation is critical in establishing a logical nexus between project impacts and mitigation efforts.

Establishing Reasonability from Impact Assessment

The proposed model for decision-making considers four factors in establishing a basis for reasonability: nexus to impact, need for mitigation, willingness to provide mitigation independent of cost, and cost dependent willingness to provide mitigation.

Nexus to Impact B Project managers should seek to mitigate ecological functions that their projects are responsible for impairing. Projects that fragment existing habitat should target efforts to reduce fragmentation in the compensatory mitigation effort. Projects that impact certain types of rare habitats should undertake efforts to preserve such habitats from future impacts.

Need for Mitigation B This evaluation establishes whether or not compensatory mitigation is appropriate. Compensatory mitigation efforts for projects with small-scale impacts are appropriately similarly small in scale. This particular evaluation takes into account the ability of the environment for a certain degree of self-repair. In general the relationship between the scale of impact and the need to provide compensatory mitigation is geometric as shown in figure 1 below.

Willingness to provide mitigation independent of cost B This consideration is one factor in the reasonableness of compensatory decision-making. It provides a somewhat objective (although not a sole) measure of reasonableness. In making a decision on this parameter alone the decision-maker is likely to overestimate need at the lower levels of impact and discount mitigation at the upper levels of mitigation due to a poor understanding of the nature of diminishing returns in habitat enhancement/restoration. The relationship between impact and willingness independent of cost is shown on figure 2.

Willingness to Mitigate Considering Cost B This evaluation takes into account both increasing costs per unit of impact and diminishing marginal utility in providing compensatory mitigation. Although this relationship is at the heart of reasonability, it would be improper to make decisions on the basis of this relationship alone. This relationship is portrayed in figure 3.

Establishing Composite Reasonableness B The product of economic and beneficent willingness is established as composite willingness. The mathematical relationship of composite willingness with mitigation need is best accomplished heuristically. To date I have attempted to define this relationship as the weighted average of an arithmetic and geometric relationship defined as:

$$\frac{[1.5(C + N)] + [M(C \times N)]}{2.5}$$

Where:

C = Composite Willingness

N = Need for Mitigation

M = A dimensionless factor that ensures numerical values within the range of those developed based on an arithmetic relationship and that composite reasonableness always increases with increased impacts.

To complete the computation of reasonableness a maximum cost per acre of mitigation must be established. This dollar figure is then multiplied by the figure for composite reasonableness and discounted based upon habitat quality as established above. Dollar figures can then be targeted to compensatory mitigation designs able to achieve goals that are directly related to project impacts.

Further Efforts

It should be recognized that this methodology is an initial attempt to establish a framework for terrestrial mitigation decision-making as it relates to the delivery of transportation infrastructure. It is not, nor is it intended to be a finalized methodology at this time. Recommendations for further work associated with the proposed framework include the following.

Metric Scoring - The scoring of VARMINT metrics have been established based upon the authors understanding of ecological processes as the currently function in Pennsylvania. When a preponderance of empirical evidence did not point in one particular direction, which it often did not, the author's biases based upon existing evidence are strongly reflected.

Metric Weighting - The author developed this methodology in the absence of a comprehensive statewide species conservation policy. As a result the metrics are weighted strongly towards a program which would prioritize the conservation of at risk (but not threatened or endangered) non-game species. Others wishing to adapt this approach will want to carefully examine the weighting system to ensure that it supports any conservation goals they may already have established.

Additional Field Testing B VARMINT has been tested on only two sites in Pennsylvania. Neither of these projects used this methodology to establish goals for or levels of terrestrial mitigation. One key element in using this approach is comparison of evaluation compartments with a universe of previously evaluated compartments. The model would be additionally validated by a larger universe of reference sites both within and outside of Pennsylvania.

Economic Analyses B Economic considerations are a key component of reasonability analyses, which have been, to date, excluded from the decision-making process. Although included here, they are broadly based upon generalized economic principles. Additional studies to validate inherent economic assumptions are warranted. This effort would be additionally bolstered by a rigorous public survey effort to more quantitatively factor in public willingness to foot the bill for compensatory mitigation costs.

Questions or comments regarding these procedures should be referred to the author at 124 E. Keller Street, Mechanicsburg, PA 17055 or via e-mail at memaurer@yahoo.com.

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Figure 1 - Need for Mitigation

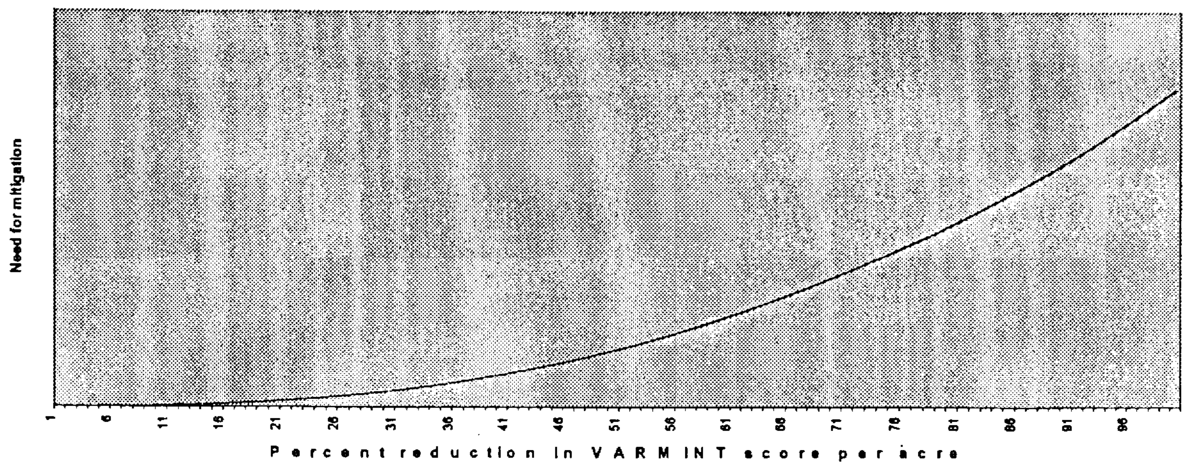

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Figure 2 - Willingness Independent of Cost

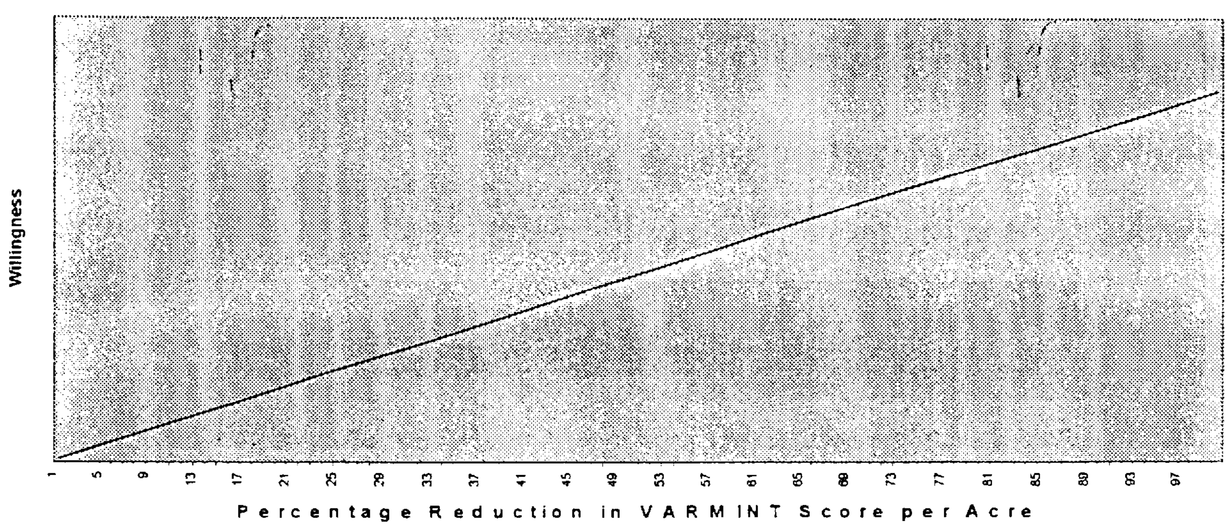

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Figure 3 - Willingness per Unit Cost

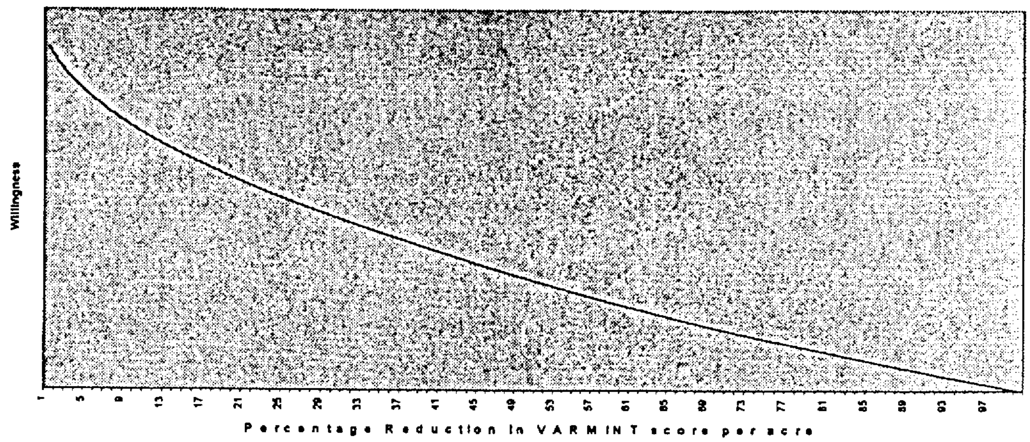

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Figure 4 - Reasonable Expenditures per Impact