Wildlife Areas Habitat Conservation Plan
Deliverable 3 for Task # 3
Contract # E-41-HP-3
WDFW # 08-1534

Initial results of prototyping and beta testing of the draft effects model

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1.0 INTRODUCTION

The WDFW is developing a multi-species HCP to more fully assess and account for the impacts of recreation and management activities on at-risk species, and provide conservation measures and strategies to compensate for any negative impacts to federally and state listed and other at-risk species that use, or could potentially use, WDFW lands. As a result, implementation of the HCP will ensure that WDFW conducts land management activities, and permits recreation activities, in ways that meet the requirements of both the WDFW's legislative mandate and the ESA. The HCP will apply to approximately 900,000 acres of WDFW owned and managed lands statewide.

An integral component of such a plan is the development of a model or process for assessing the impacts, conservation opportunities and conservation benefits of WDFW management, operational, maintenance and recreational activities on listed species. The purpose of this document is to review the HCP predictive effects model, and describe model geoprocessing, model inputs and initial model results. This information focuses on one covered species (Sharp-tailed Grouse) but the process will be applied to all covered species. The information presented here builds upon the HCP Datamodel Design (GeoNorth 2007), and the Preliminary Predictive Model (Sutter and Quan 2008). **This document is considered a working draft, which means that the model itself is still in the conceptual design phase, and the data presented here is subject to change.**

2.0 WILDLIFE AREAS HCP PREDICTIVE EFFECTS MODEL CONCEPT

The Preliminary Predictive Model (Figure 1) identified the process that WDFW would use to determine effects in support of its development of an HCP and its associated Incidental Take Permit (ITP).

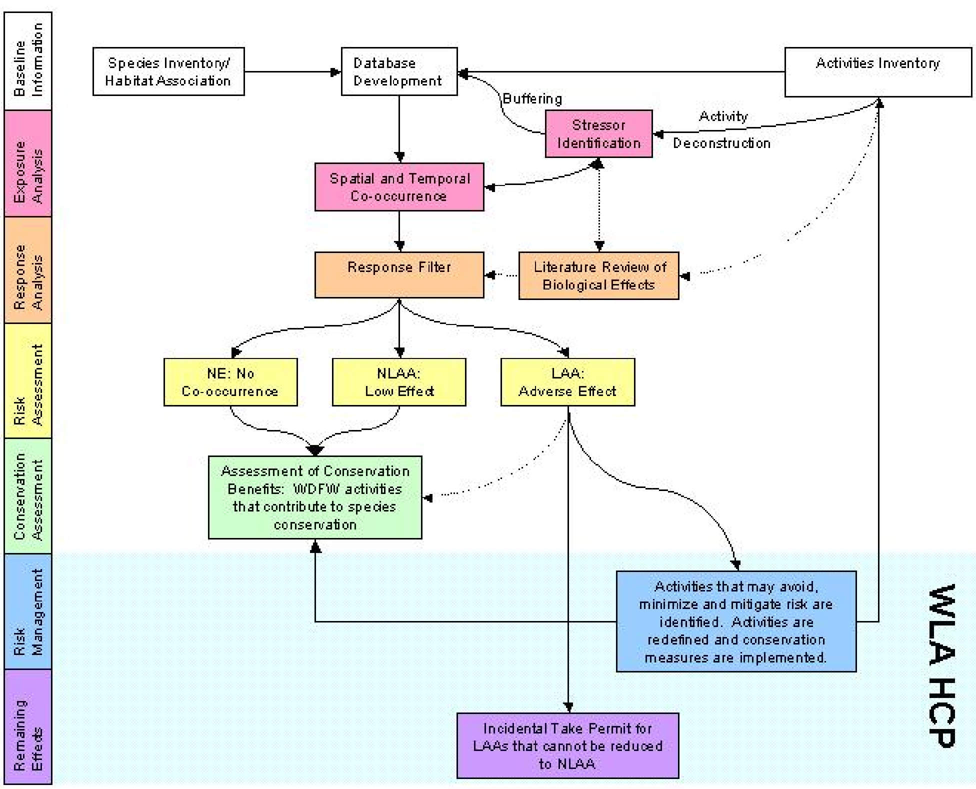

Figure 1. Conceptual diagram of Predictive Effects Model

The basic concept behind the HCP Predictive Effects Model is creating a database and process that is able to reveal the spatial and temporal coincidence or exposure of individual species profiles (species/lifestage/behavior combinations) and activity-generated stressors. Exposure scenarios are used to model the response of the species to the stress based upon assumptions captured in an internal knowledgebase. Once these stress-response effects are made spatially and temporally explicit, various conservation actions can applied and the spatial-temporal exposure and stress-response modeling can be re-initiated.

3.0 MODEL INPUTS

The HCP Draft Sharp-tailed Grouse Predictive Effects Model's goal is to investigate the spatial and temporal extent of Sharp-tailed Grouse habitats affected by activity generated stressors (co-occurence) and to begin the process of determining significant critical thresholds for individual species (response). This process requires activity inputs, species inputs, and response criteria.

3.1 Activity Data

Activity information is assembled from GIS data and normalized database tables. This information represents the following basic activity metrics:

1. Activity name (what);
2. Spatial footprint (where);
3. Start and end dates (when);
4. Duration (how long);
5. Frequency (how often);
6. Time of day; and
7. Effort quantity (how much).

Activity metrics are more fully described in Gorrell and Foisy (2009).

Through the process of activity deconstruction (see *Deliverable 2a Initial Set of Model Assumptions*), each activity is assigned one or more components, and each component is assigned one or more stressors. Components represent all potential "elements" of an activity that may result in a stressor. Stressors are defined as the biological, physical, or chemical outcome of a component that may result in a response by a covered species. Activity deconstruction is a process recommended by USFWS in Advanced Section 7 Training, as it reveals more fully the suite of effects, and the sources of those effects, that may occur.

The assignment of each activity to components and each component to stressors is recorded in the HCP Stress-response database via user input forms (Figure 2). The HCP Predictive Effects Model is applied statewide, meaning every polygon of a similar activity is assigned the same components and stressors. Basic assumptions regarding activity implementation are identified in *Deliverable 2a Initial Set of Model Assumptions.*

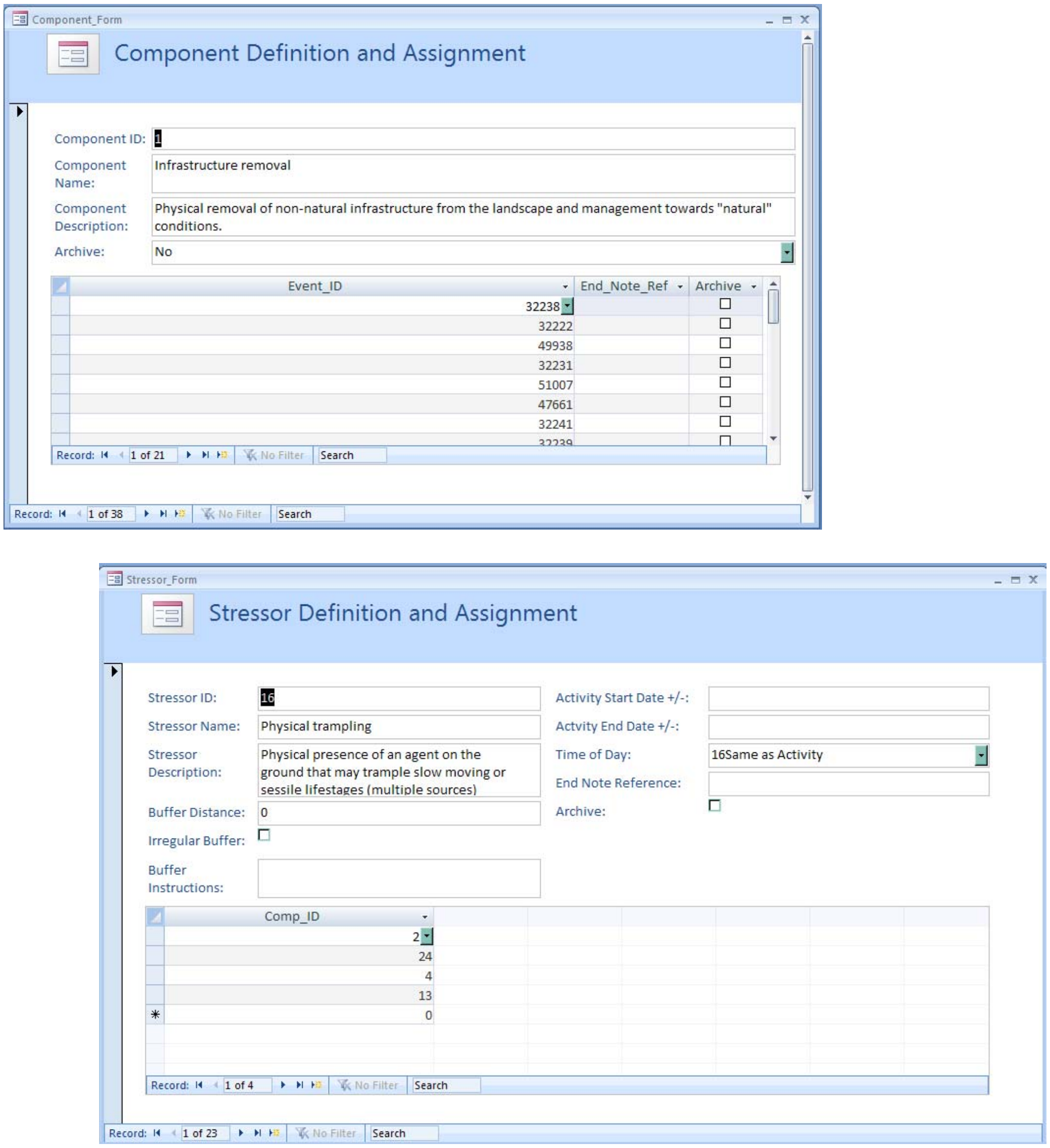

Figure 2. Component and Stressor Input Form.

Stressors inherit the base activity metrics listed above. However, a stressor may modify those inherited metrics by increasing/decreasing the size or modifying the shape of the spatial footprint as well as adding/subtracting days to the activity start and/or end dates and/or changing the time of day. Stressors may be buffered in space and time to more accurately reflect our understanding of stressor "behavior" on the landscape. This process modifies WDFW's area of influence by increasing it beyond the temporal and spatial footprint of our activities, allowing us to more accurately evaluate potential effects.

A series of SQL database queries counts and uniquely identifies each activity in an activity event/component and component/stressor relationship table. This table is used as parameter in geoprocessing scripts, which clones and modifies activities, attributing each new feature with its individual activity, event, component and stressor lineage.

To run the model, some activity data requires preprocessing, in that spatial (GIS) data must be convered to polygonal data if it was collected as points or lines; point and line spatial attributed have no area and cannot be used in a co-occurrence analysis. An activity buffering matrix (containing the real-world areas of activity points and lines, based on information from Wildlife Area Managers) allows the Spatial Analysts to convert the activity point and line features to polygons. The default buffer distance equals ten feet for activities not represented in the matrix.

3.2 Species Data

Species information is assembled from GIS data and normalized database tables. This information represents the following basic species metrics:

1. Species profile name (what);
2. Spatial footprint (where);
3. Start and end dates (when);
4. Duration (how long);
5. Frequency (how often); and
6. Time of day.

Species metrics are more fully described in Gorrell and Foisy (2009).

No preprocessing of the habitat-species data is required for the co-occurrence modeling (all habitat-species spatial data was collected as polygons). Similar to activities, the critical habitat-species metrics used as inputs into the draft modeling process(s) include the species profile (what); spatial footprint; start and end dates; duration; frequency; and time of day. Activity and species metrics are more fully addressed in Gorrell and Foisy (2009).

3.3 Co-occurrence and Response Criteria

The Predictive Effects Model effectively identifies in space and time where anticipated species responses may due to species co-occurrence with stressors, integrating the outcomes of activity deconstruction with species response matrices. While Figure 1 depicts the application of the Predictive Effects Model in the entire process of HCP development, the model, and the relationships between activities and species responses, are simplified in Figure 2. These relationships are more fully described in *Deliverable 2a Initial Set of Model Assumptions.*

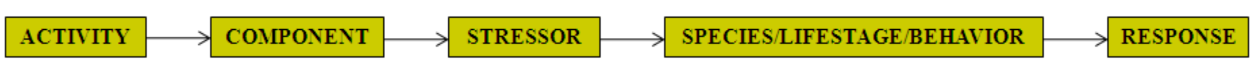

Figure 2. Predictive Effects Model.

The draft Sharp-tailed Grouse predictive effects model is divided into three submodels:

1) Partially described above, the first submodel includes the assignment of components and stressors to activities and the one (activity) to many (stressor) extraction. Generation of stressor features and buffering in space and time allow exposure or co-occurrence analyses to be conducted.

2) The second submodel is the exposure analysis. Similar to component/stressor assignment, the exposure analysis involves both SQL database queries and geoprocessing scripts. A basic GIS

union is used to reveal spatial co-occurrence, and a more elaborate SQL query identifies temporal co-occurrence. The resulting dataset is best envisioned as a three-dimensional structure with many layers of like and unlike activity-generated stressors from discrete spatial sources overlapping Sharp-tailed grouse habitat. To summarize results, overlapping stressors of identical attributes are flattened or planarized.

3) The third submodel is response assignment. The HCP Stress-Response database translates co-occurrence of a species profile with an activity-generated stressor into an anticipated individual response. Response assignment is based on populated species response matrices (see *Deliverable 2a Initial Model Assumptions* for examples). Response assignment takes place in an output personal geodatabase and a series of SQL queries.

Exposure records are compared against four criteria, which, excluding effort quantity, are calculated values (Figure 3).

1) Percent Area: The ratio of species profile habitat (acres) exposed to a specific stressor to the total amount of species profile habitat within that polygon. This is a straightforward calculation deriving the percentage of a species polygon that may be affected.

2) Percent Duration: The ratio of species profile time (days) exposed to a specific stressor to the total species profile time within that polygon. Duration is autocalculated for species (end date minus start date), but activity duration can be entered as the maximum number of days an activity takes place within a given start/end date window. If the assigned activity duration is less than the temporal co-occurrence duration, percent duration is calculated using that smaller assigned activity duration rather than co-occurrence duration. This ultimately results in a more realistic estimate of effects.

3) Quantity: The effort quantity (how much) of a stressor that co-occurs with a species profile. Quantity requires the identification of a quantitative threshold that triggers a response. Such values were not identified for the draft Sharp-tailed Grouse Predictive Effects Model.

4) Proximity: the straight line distance to the source of the stressor. Proximity requires additional geoprocessing scripts and was not used for the draft Sharp-tailed Grouse Predictive Effects Model.

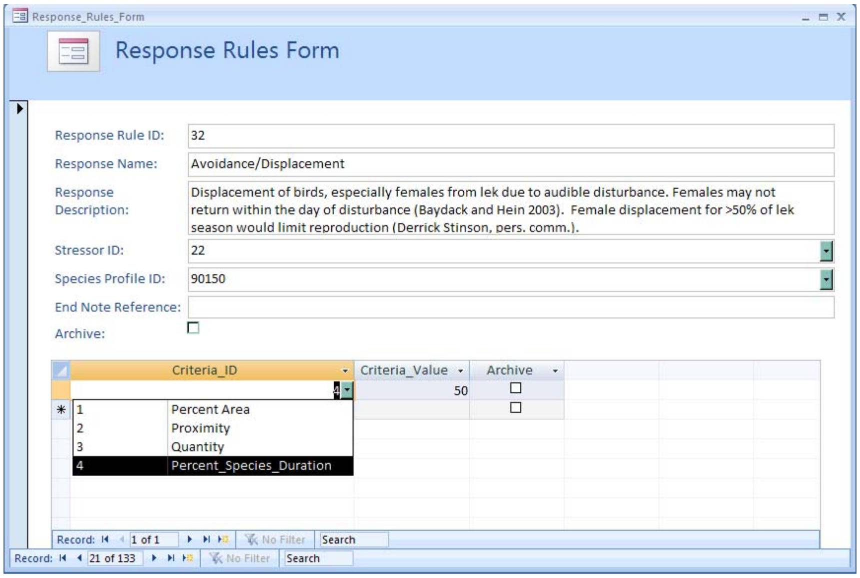

Figure 3. Response Rules Form Showing Evaluation Criteria

4.0 SHARP-TAILED GROUSE MODEL RESULTS

Response modeling identified 3,837 spatially and attributionally unique co-occurrences with an assigned response. Additional co-occurrences are likely but were probably assigned the response "no effect." No effect responses are not considered in reporting because they are not considered take. Of those 3,837 co-occurrences:

- 480 (≈12.5%) were ≥1% species profile area (i.e., the stressor occurred on 1% or more of the acres occupied by the species profile).
- 1,705 (≈44%) were ≥1% species profile days (i.e., the stressor occurred on 1% or more of the days the species profile was assumed to be present).
- 201 (≈5%) were both ≥1% species profile acres and ≥1% species profile days

The 201 co-occurrences that were considered "significant" (i.e., more than 1% species profile days, more than 1% species profile acres) were distributed on 12 of the 19 Wildlife Area Units on which Sharp-tailed Grouse occur. All significant co-occurrences were with stressors generated by grazing and infrastructure maintenance. Model results are presented as percent acres and percent days that a potential response is expected to occur at the species profile level on each Wildlife Area Unit. In addition, the source activity (i.e., grazing or infrastructure operations and maintenance) is identified. These results are presented in Table 1. The data in table 1 was exported from a database query, which summarizes all records by the uniques combination of Activity ID, Species Habitat ID, Response ID, WLA Unit ID, Stress Acres, and Overlap ID. The report structure has been modified for ease of reporting in this document.

Predictive Effects Model outputs include quantified percent acres and days of a pre-determined list of individual responses, based on co-occurrence of a species profile and a stressor, as described above. The WDFW HCP Development Team has made substantial effort to develop a response list that may accommodate the categorization of direct and indirect effects by the Federal Services for their Section 7 consultation. Accordingly, stressors have also been identified that either directly affect individuals (e.g., avoidance), or affect them indirectly through habitat modification (e.g, habitat degradation).

The following discussion provides details on example outputs identified in Table 1. This discussion relates the numbers in Table 1 to the response matrix assumptions in Appendix 1.

> Example 1. Grazing on the Chiliwist Wildlife Area Unit occurs for 22 percent of adult feeding acres and 27 percent of adult feeding days. We anticipate no physical harm or mortality of feeding adult grouse because they are mobile and can avoid grazing cattle. However, any source of potential physical trampling (in this case cattle) may result in avoidance by adults.
>
> Example 2. On the Washburn Island Unit, road maintenance occurs over 100 percent of adult wintering acres, but only 2 percent of adult wintering days. The use of heavy equipment during road maintenance results in noise that is likely to attenuate away from the maintenance site and possibly cause disturbance and result in avoidance by wintering Sharp-tailed Grouse. Road corridors are not considered habitat for Sharp-tailed grouse and maintenance of an existing road does not impact habitat quality. In addition, assuming wintering adults are mobile and will likely avoid the activity center, we do not anticipate any direct harm or mortality from road maintenance activities.

Table 1. Initial Draft Sharp-tailed Grouse Predictive Effects Results

	Response					
	Avoidance		Habitat Degradation		Physical harm or mortality	
	Percent Acres	Percent Days	Percent Acres	Percent Days	Percent Acres	Percent Days
Adult						
Feeding						
Chiliwist						
Grazing permits						
Grazing[1]			22	27		
Physical trampling	22	27				
Golden Doe						
Infrastructure O & M						
Heavy equipment noise	33	59				
Scotch Creek						
Grazing permits						
Grazing			7	15		
Physical trampling	7	15				
Nesting						
Chiliwist						
Grazing permits						
Grazing			76	40		
Physical trampling					76	40
Scotch Creek						
Grazing permits						
Physical trampling					7	25
Infrastructure O & M						
Heavy equipment noise	43	2				
Sinlahekin						
Infrastructure O & M						
Heavy equipment noise	4	2				
Swanson Lakes						
Infrastructure O & M						
Heavy equipment noise	100	2				
Wintering						
Bridgeport Bar						
Infrastructure O & M						
Heavy equipment noise	61	2				
Scotch Creek						
Infrastructure O & M						
Fence presence					2	6
Tunk Valley						
Infrastructure O & M						
Fence presence					1	1
Washburn Island						
Infrastructure O & M						
Heavy equipment noise[2]	100	2				
West Foster Creek						
Infrastructure O & M						
Fence presence					3	2

All Lifestages						
Feeding						
Big Buck						
Grazing permits						
Grazing			42	53		
Infrastructure O & M						
Heavy equipment noise	10	59				
Methow						
Grazing permits						
Grazing			5	45		
Infrastructure O & M						
Heavy equipment noise	7	59				
Rendezvous						
Grazing permits						
Grazing			21	45		
Infrastructure O & M						
Heavy equipment noise	22	59				

[1]Example 1; [2] Example 2

5.0 APPLICATION OF MODEL RESULTS TO CONSERVATION MEASURE DEVELOPMENT

5.1 Baseline effects and conservation measures

The draft Sharp-tailed Grouse Predictive Effects Model results indicate that possible effects of WDFW's covered HCP activities on Sharp-tailed Grouse Sharp-tailed Grouse are currently limited primarily to grazing and infrastructure maintenance. According to the model, baseline effects of WDFW's land management activities are limited to potential avoidance of cattle and maintenance activities, habitat degradation caused by grazing, and physical harm caused structure presence.

The following information is a subset of that which will be used to initiate the development of conservation measures for these two activities that will benefit sharp-tailed grouse. We provide example conservation measures that WDFW could employ to avoid or minimize the specific effect. These measures are drawn from existing sources and, if utilized, will be detailed by species experts in the Wildlife Areas HCP.

Infrastructure Operation and Maintenance (Noise)

Anticipated sharp-tailed grouse responses to operation and maintenance include disturbance and avoidance in adults, and theoretically to physical harm in eggs if nests are situated close to existing infrastructure, which seems unlikely. The avoidance associated with infrastructure operation and maintenance in Table 1 is associated with noise generated by heavy equipment used in road maintenance. Potential conservation measures that will minimize this response include:

- Avoidance or minimization of audible disturbances within a specified distance from active habitat. Giesen and Connelly (1993) recommend a buffer distance for audible disturbances of 2 km (1.2 mi) for active lek sites. The Sharp-tailed Grouse Predictive Effects Model, however, reflects no co-occurrence of grouse leks on wildlife areas and noise-generating activities. Because noise sensitivity of other life stages has not been found in the literature, this will have to be assessed by species experts. to Sensitivity of other life stages will

Infrastructure Operation and Maintenance (Fence Presence)

Fences bisect Sharp-tailed Grouse wintering habitat on the Scotch Creek, Tunk Valley, West Foster Creek Wildlife Area units (Table 1). On Wildlife Areas are used primarily for boundary delineation and habitat protection, and while these values are important, fences do represent an important source of mortality for sharp-tailed grouse. Sharp-tailed grouse may be injured or killed by flying into fences (Aldous 1943). Wolfe et al. (2007) reported that fences accounted for 33% of 260 mortalities of radio-tagged lesser prairie chickens where cause of death could be determined over a 5 year period in Oklahoma and New Mexico, and fence density may be positively associated with mortality from collision (Patten et al. 2005). In addition, fences provide artificial perches for avian predators.

Potential conservation measures that will avoid or minimize the potential for mortality from fence collision and avian predation caused by fence presence include:

- Remove dilapidated and unnecessary fencing, avoid construction of new fences and modify existing but necessary fencing to improve visibility (Stinson and Schroeder 2010). Existing but necessary fence modifications may include attachment of vinyl markers (Christiansen 2009), as well perch guards (Stinson and Schroeder 2010).

Grazing

The Wildlife Areas HCP approach to grazing is very conservative in that grazing is identified, as according to the literature, as a habitat improvement or degradation for individual species. Vegetation removal occurs due to grazing both through trampling and herbivory, the results of which are important in multiple Sharp-tailed Grouse habitats. High levels of livestock grazing may 1) affect sharptail reproductive success through reduction of key food plants and insects available to hens and broods (Hoffman and Thomas 2007); 2) reduce residual cover making hens, nests and chicks vulnerable to predation (Schroeder and Baydack 2001, Flanders-Wanner et al. 2004, Manzer 2004) and 3) degrade riparian and upland shrub winter habitat. In the species response matrix, grazing was assessed to cause habitat degradation for all life stages.

Potential conservation measures that will avoid or minimize degradation of Sharp-tailed grouse habitats include:

- Exclude cattle from verified Sharp-tailed grouse habitat.
- Exclude cattle from within 100m of streams, including seasonally dry and intermittent secondary drainages to minimize the loss of associated trees and shrubs (Giesen and Connelly 1993).
- Maintain light grazing levels (25% removal of annual herbaceous growth) if grazing occurs in Sharp-tailed grouse nesting habitat. Utilization levels should be based on predicted use during periods of drought (Stinson and Schroeder 2010).
- Modify existing grazing leases to achieve habitat characteristics required to maintain sharp-tailed grouse. Stinson and Schroeder (2010) define optimal nesting habitat as having a visual obstruction reading (VOR) of >25 cm.

Direct effects of cattle presence due to grazing activities include physical trampling of nesting females and eggs, as well as behavioral avoidance by adult grouse (Stinson et al. 2009; McDonald 1998). Cattle on lek sites may interfere with courtship displays and breeding (Giesen and Connelly 1993; D. Stinson pers. comm.), but the HCP data do not reflect spatial and temporal co-occurrence of any sharp-tailed grouse leks and grazing. Potential conservation measures to avoid or minimize such direct effects include:

- Defer grazing until after the nesting and brood rearing seasons in sharp-tailed grouse nesting habitat (McDonald 1998; Stinson and Schroeder 2010).
- Avoid grazing on established leks during the lekking season.

5.2 Potential additional measures

While the predictive effects model quantifies baseline effects as response acres or response days, the model is limited to co-occurrences of stressors and activities that are reflected in current data. However, the species response matrix identify potential responses to theoretical co-occurrences (while the model reflects true co-occurrences), and over the lifetime of the plan, there is certainly potential to realize additional co-occurrences and responses that are currently unpredictable. Therefore, it is WDFW's intention to develop conservation measures for all species/activity or species/stressor interactions that result in a defined response (excluding no effect) identified in the species response matrix. For the sharp-tailed grouse, based on Appendix 1, these will include:

- Dog training and field trials
- Chemical weed control

- Non-chemical weed control
- Infrastructure construction
- Infrastructure removal
- Grazing and associated activities
- Maintenance of CRP
- Resource provisioning for upland game birds
- Stocking of upland game birds
- Habitat restoration (stream, riparian, wetland, agricultural land conversion, shrubsteppe)
- Structure Presence (fence, roads, guzzlers, livestock troughs)
- Any activity resulting in the following stressors (Noise, Human disturbance, Physical trampling, reduction of woody debris, dog presence, chemical inputs)

6.0 NEXT STEPS

1) Make necessary model modifications
In future iterations of the model, the HCP Spatial Analyst will make use of SQL Server 2008 spatial support to perform spatial co-occurrence modeling (current modeling process requires passing tabular results between ArcMap and SQL server several times). This adjustment may support proximity calculations.

2) Determine methods for assessing cumulative effects
Activity deconstruction has identified component and stressor commonalities among activities, and accordingly, multiple activities could have similar effects on a covered species (e.g., multiple covered activites include the use of heavy equipment). While contribution of individual activities to species responses may be small (for example, as above, only 12.5% of co-occurring stressors overlapped more than one percent of a species profile polygon), multiples of such small contributions may diminish the value of individual polygons. As additional species models are run in spring and summer 2010, WDFW will determine a way to assess cumulative effects of multiple activities.

3) Update Sharp-tailed Grouse response data entry to current response matrix template
The Response Matrix template has been updated to reflect the broader suite of potential stressors that have been identified through activity deconstruction. The matrix provided in Appendix 1 is based on a previous draft, but an updated version appears in *Deliverable 2a Initial Set of Model Assumptions.* The Sharp-tailed Grouse response assumptions will be updated in the stress-response database, and the model will be rerun to reflect changes in stressor and response categories by June 30, 2010.

4) Run the model for all covered species
The Predictive Effects Model requires population of the Stressor Response Database, including components and stressors which are identified through the activity deconstruction process, and species responses that are identified during Species Response Matrix population. WDFW will finalize these processes and products for both activities and species no later than June 30, 2010. As species models are run, conservation measures can be applied.

5) Develop and apply conservation measures to model
Conservation measures are being developed in response to information in the Species Response Matrix and model outcomes. Currently in the absence of model outputs for each species, WDFW is working

with the Federal Services to identify "programmatic" measures applied to activity types that address potential responses identified in species response matrices. As the databases are populated and models are run, those programmatic measures can be applied to the model to assess the effects of the HCP (as opposed to baseline effects). We anticipate that measure integration into the Predictive Effects Model will occur in the second half of 2010.

LITERATURE CITED

Aldous, S. E.1943. Sharp-tailed grouse in the sand dune country of north-central North Dakota. Journal of Wildlife Management 7: 23-31.

Christiansen, T. 2009. Fence marking to reduce Greater Sage-grouse (Centrocercus urophasianus) collisions and mortality near Farson, Wyoming – Summary of Interim Results. Wyoming Game & Fish Dept.

Giesen, K. M. and J. W. Connelly. 1993. Guidelines for management of Columbian sharp-tailed grouse habitats. Wildlife Society Bulletin 21:325-333.

Gorrell, J. V. and J. S. Foisy. 2009. Washington's Wildlife Areas Habitat Conservation Plan Predictive Effects Model: Update on Modeling Components. Washington Department of Fish and Wildlife. 19pps.

Hoffman, R.W., and A.E. Thomas. 2007. Columbian Sharp-tailed Grouse (*Tympanuchas phasianellus columbianus*): A Technical Conservation Assessment. Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project. 131 pp.

Manzer, D.L. 2004. Sharp-tailed grouse breeding success, survival, and site selection in relation to habitat measured at multiple scales. Ph.D. Dissertation, University of Alberta. 158 pp.

McDonald, M. W. 1998. Ecology of Columbian Sharp-tailed Grouse in eastern Washington. M. S. Thesis. University of Idaho, Moscow. 125 pp.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005. Habitat fragmentation, rapid evolution and population persistence. Evolutionary Ecology Research 7:235-249.

Schroeder , M.A., and R.K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.

Stinson, D. W., and M. A. Schroeder. 2009. Draft Washington State Recovery Plan for the Columbian Sharp-tailed Grouse. Washington Department of Fish and Wildlife, Olympia. 147+ viii pp.

Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens *Tympanuchus palladicinctus* and implications for management. Wildlife Biology 13 (Supplement 1): 95-104.

APPENDIX 1. SHARP-TAILED GROUSE DRAFT RESPONSE MATRIX

Sharp-tailed Grouse

Response Code Key:

NE: No Effect

AD: Avoidance/displacement of individuals to an extent that impacts fitness

HM: Direct physical harm or mortality of individuals

MB: Migration barriers to individuals

PP: Possible increase in predation

PC: Possible increase in competition

DT: Disease transmission

FE: Food effects; impacts to prey

HA: Short-term habitat alteration

HD: Habitat degredation

HL: Habitat loss

HI: Habitat improvement

				Adult			Eggs	
				Leking	Nesting	Feeding	None	Justification/Source
				A	**B**	**C**	**D**	
ACTIVITY	**Recreation**	Horseback Riding	**1**	NE	NE	NE	NE	
		Dog training and field trials	**2**	AD	AD	AD	NE	
	Operations and Maintenance	Chemical weed control	**3**	HI	HI, HD	HI, HD	HI	
		Non-chemical weed control	**4**	HI	HI	HI	HI	
		Infrastructure maintenance	**5**	NE	NE	NE	NE	
		Infrastructure construction	**6**	AD	AD	AD	HM	
		Infrastructure removal	**7**	HI	HI	HI	HI	
		Grazing	**8**	HD	HD	HD	HD	Hoffman and Thomas 2007; Schroeder and Baydack 2001; Flanders-Wanner et al. 2004; Manzer 2004)

		Agriculture	**9**	NE	NE	NE	NE	
		Maintenance of CRP	**10**	HI	HI	HI	HI	D. Stinson, pers. comm.
		Irrigation	**11**	NE	NE	NE	NE	
		Resource provisioning for big game (winter feed, salt licks)	**12**	NE	NE	NE	NE	
		Resource provisioning for upland game birds	**13**	NE	PP, PC, DT	PP, PC, DT	NE	M. Schroeder, pers. comm; D. Stinson, pers. comm.
		Forest thinning and logging	**14**	NE	NE	NE	NE	
		Salvage logging	**15**	NE	NE	NE	NE	
		Firewood cutting	**16**	NE	NE	NE	NE	
		Moist soil management	**17**	NE	NE	NE	NE	
	Habitat Restoration	Stream	**18**	NE	NE	HA, HI	NE	
		Riparian	**19**	HA, HI	HA, HI	HA, HI	HA, HI	
		Wetland	**20**	NE	NE	HA, HI	NE	
		Agricultural land conversion	**21**	NE	HA, HI	HA, HI	HA, HI	
		Shrub steppe	**22**	HA, HI	HA, HI	HA, HI	HA, HI	
		White oak and prairie	**23**	NE	NE	NE	NE	
		Estuary	**24**	NE	NE	NE	NE	
		Flood plain	**25**	NE	NE	NE	NE	
		Tide plain	**26**	NE	NE	NE	NE	
		Nearshore	**27**	NE	NE	NE	NE	
STRESSOR	**Structure Presence/Operation**	Fence	**28**	HM	HM	HM	NE	Aldous 1943; Wolfe et al. 2007; Patten et al. 2005
		Road	**29**	AD, HM	HM	HM	NE	Aldous 1943; Brown 1961; Stinson et al. 2009
		Parking area	**30**	NE	NE	NE	NE	
		Bridge	**31**	NE	NE	NE	NE	
		Culvert	**32**	NE	NE	NE	NE	
		Building	**33**	NE	NE	NE	NE	
		Restroom	**34**	NE	NE	NE	NE	
		Guzzler	**35**	PC	PC, DT	PC, DT	NE	
		Campsite	**36**	NE	NE	NE	NE	
		Livestock trough	**37**	PC	PC, DT	PC, DT	NE	
		Hunting blind	**38**	NE	NE	NE	NE	

		Educational kiosk	**39**	NE	NE	NE	NE	
		Irrigation equipment	**40**	NE	NE	NE	NE	
		Trail	**41**	NE	NE	NE	NE	
		Boat launch	**42**	NE	NE	NE	NE	
		Dock	**43**	NE	NE	NE	NE	
		Dike	**44**	NE	NE	NE	NE	
		Ditch	**45**	NE	NE	NE	NE	
		Artificial nesting/roosting structures	**46**	NE	NE	NE	NE	
		Fish screens	**47**	NE	NE	NE	NE	
		Seep/spring enhancements	**48**	NE	NE	NE	NE	
		Water impoundment	**49**	NE	NE	NE	NE	
	Disturbance-related Stressors	Noise	**50**	AD	AD	AD	NE	
		Human Disturbance	**51**	AD	AD	AD	NE	Baydack and Hein 1987; Connelly et al. 1998; D. Stinson, pers. comm.;
		Cattle Disturbance	**52**	AD	NE	NE	NE	
		Horse Disturbance	**53**	AD	NE	NE	NE	
		Sediment	**54**	NE	NE	NE	NE	
		Physical Trampling/Direct contact (people, heavy equipment, cattle, horses, terrestrial motorized vehicles)	**55**	NE	HM	NE	HM	Meints 1991; Beisen 1997; McDonald 1998; Stinson et al. 2009
		Smoke	**56**	NE	NE	NE	NE	
		Reduction of woody debris	**57**	HD, HI	HD, HI	HD, HI	NE	
		Dog presence/disturbance	**58**	AD	AD, HM	AD	HM	Leupin 2003; Baydack and Hein 1987
		Change in nutrient cycling/pollution loading	**59**	NE	HM	NE	NE	
		Chemical inputs (weed control, fertilizer use)	**60**	NE	HD, HM	HD, HM	HM	
		Reduction in water quantity	**61**	NE	NE	NE	NE	
		Changes in soil chemistry	**62**	NE	NE	NE	NE	
	Introduced Wildlife	Turkey	**63**	NE	PC	PC	NE	M. Schroeder, pers. comm; D. Stinson, pers. comm.
		Quail	**64**	NE	NE	NE	NE	

		Pheasant	**65**	PC, DT	PC, DT	PC, DT	NE	Giudice and Ratti 2001; Vance and Westerneier 1979; Stinson et al. 2009