Resource Use of Arctic Peregrine Falcons along the Colville River, Alaska[1]

2012 Annual Report

16 January 2013

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Abstract: To improve knowledge about the ecology, life history, and behavior of arctic peregrine falcons (*Falco peregrinus tundrius*) on the Colville River Special Area (CRSA), we propose to (1) summarize and evaluate existing CRSA peregrine nesting data to assess trends in territory occupancy and abundance, and assist in summary and evaluation of nesting habitat use and related productivity, (2) implement additional data collection efforts focused on assessing factors related to the probability a territory is occupied, and (3) identify disturbance thresholds for arctic peregrine falcons from different types of human activity. In 2011, we assisted in 2 U.S. Fish and Wildlife Service/Bureau of Land Management surveys (1 during nesting and 1 during the fledgling period) of peregrine falcons on the Colville River that documented 56 pairs and 3 singles occupying 59 sites. During 2012, the Ph.D. student originally hired to lead this project left the University of Minnesota. Following that departure, we recruited a postdoctoral research associate (JEB) to take over as the lead in addressing research objective 1, beginning in September 2012. In addition, Ted Swem (U.S. Fish and Wildlife Service) spent the 2011-2012 academic year at the Minnesota Cooperative Fish and Wildlife Research Unit at the University of Minnesota, and updated and formatted the long-term arctic peregrine falcon database. Based on that historical database, we have acquired data sources related to characteristics of nest locations along the Colville River. We are currently developing models relating habitat, topography, climate, prey availability,

competition, and site quality covariates to occupancy and abundance of breeding peregrines. We anticipate using the results of those models to help identify what factors have the most influence on peregrines nesting along the Colville River, and to help identify critical information needs.

Introduction

The Colville River Special Area (CRSA) was designated in 1977 to protect nesting and foraging habitat of the then-endangered arctic peregrine falcon (*Falco peregrinus tundrius*). The CRSA is approximately 2.44 million acres, and provides nesting habitat for approximately one-fourth of Alaska's arctic peregrine falcon population. In 2008, the Bureau of Land Management (BLM) Arctic Field Office revised the CRSA Management Plan (CRSAMP) designed to protect nesting and foraging habitat of the arctic peregrine falcon (USDOI BLM 2008). This plan addressed the following specific issues:

1. The need for additional measures to protect arctic peregrine falcon nesting habitat,
2. Consistency of protection measures for arctic peregrine falcon across the NPR-A,
3. Needed research on arctic peregrine falcons,
4. Impacts of energy exploration and extraction activities on arctic peregrine ecology, behavior and demography,
5. Planning maps for inventory of arctic peregrine falcon features (nest sites, preferred habitat, etc.),
6. Impacts of recreationists and subsistence users on arctic peregrine ecology, behavior and demography, and
7. Long-term monitoring of the ecology of arctic peregrine falcons in the CRSA.

One objective of the CRSAMP was to improve knowledge about the ecology, life history, and behavior of arctic peregrine falcons to help decision makers and managers make informed decisions on proposals that could impact falcons. To address that information need, we propose to (1) summarize and evaluate existing CRSA peregrine nesting data to assess trends in territory occupancy and abundance, (2) assist in summary and evaluation of existing data on nesting habitat use and related productivity, and (3) implement additional data collection efforts focused on assessing factors related to the probability a territory is occupied. The purpose of the first objective is to identify high suitability sites (consistently occupied), low suitability sites (inconsistently occupied sites), and unsuitable habitat (no evidence of occupancy) and evaluate factors, including past anthropogenic influences, associated with occupancy. Based in part on the results of these efforts, we also intend to develop a research proposal to implement additional data collection to better understand the potential impacts of increased human activity associated with energy exploration and extraction on peregrines breeding along the Colville River. Herein, we describe progress toward these objectives in 2011 and 2012.

Study Area

The Colville River is the largest river north of the Brooks Range (North Slope) and provides the North Slope's single most important peregrine falcon nesting area with approximately one quarter of arctic peregrine falcons in Alaska nesting there (Nigro and Ritchie 2004, Swem 2007, USDOI BLM 2008). In 1977, the CRSA was designated specifically to conserve peregrine falcon nesting and foraging habitat. This portion of Alaska contains numerous wetlands and the entire area is underlain by continuous permafrost. The vegetation is characterized by tundra plant communities except for the zone directly adjacent to the Colville River floodplain where relatively short (~5-10 m in height) willow (*Salix spp*.) and alder (*Alnus spp.*) communities coincide with perennial-herb pioneer communities (Bliss and Cantlon 1957). The climate is dry with low levels of annual precipitation (12-20 cm) and is dominated by long winters (~ 9 mo) of subzero temperatures and approximately 50 cm of snow and high winds (National Research Council 2003). Summers are short with extreme variations in temperature (~0 to – 35 C°) and frequent storms. Peregrine falcons nest on cliffs and silt-loam bluffs that occur on one or both sides of the floodplain of the Colville River and several tributaries during summer months between May and August. The CRSA is contained within the National Petroleum Reserve-Alaska (NPR-A), which is managed by the BLM. Protections for peregrine falcons also extend into a conservation easement outside of the CRSA on Native corporate lands within the Colville River floodplain. Oil and gas development will continue to be a primary land use in the NPR-A.

Methods

Historical Breeding Surveys: Surveys for breeding peregrine falcons were conducted annually along the Colville River between 1978 and 2003. After 2003, surveys were conducted every 3 years resulting in data collected in 2005, 2008 and 2011. Surveys were primarily conducted by Ted Swem, U.S. Fish and Wildlife Service, except for surveys in 5 years (1983, 1984, 1986, 2003, 2008), when surveys were conducted by other raptor biologists. Surveyors documented paired adults, single adults, and nest status each year, once during egg-laying and incubation in June and again during the fledgling period in late July and early August. Nest success and productivity were evaluated during the fledging period. Each nest location was mapped onto a topographical map and later digitized into a GIS layer.

Statistical Analysis and Modeling: We will use the long-term dataset resulting from breeding peregrine surveys to evaluate how habitat, topography, climate, prey availability, competition, and site quality covariates influenced peregrine occupancy and abundance through time. Specifically, we will assess covariates that influenced peregrine occupancy on large (i.e., entire cliffs/escarpments) and small (i.e., individual nest sites) spatial scales, and total peregrine abundance on large scales. Covariates to be used in the analyses will be derived and calculated from multiple sources. The GIS layers used in deriving habitat, topography, and prey availability covariates include layers for elevation, streams, lakes, land cover, and surficial geology (Karlstrom 1964). We will calculate competition and site quality covariates from the peregrine survey database and historical CRSA gyrfalcon (*Falco rusticolus*) nesting database. Climate covariates will be determined from a combination of data from the Umiat NOAA station and Sagwon SNOTEL station, and National Snow and Ice Data Center MODIS satellite imagery. Another separate analysis that may be possible involves assessing whether historical BLM-permitted human activity is related to peregrine occupancy or abundance in certain areas of the CRSA.

Results (2012 Accomplishments)

In 2010 and 2011, we established the agreements between BLM and the USGS, and between the USGS and the University of Minnesota (Research Work Order No. 90) that support this project. In 2011, we selected a Ph.D. student to lead this project (Stephanie Jenkins was selected in early 2011 and she formally began her Ph.D. program the fall of 2011). The Ph.D. student assisted in peregrine-monitoring surveys coordinated by BLM and the USFWS (Ted Swem) in summer 2011, and DEA assisted in a portion of the second survey that summer. Ted Swem spent the 2011-2012 academic year as a visiting scientist at the Minnesota Cooperative Fish and Wildlife Research Unit at the University of Minnesota, where he collaborated with project personnel and University of Minnesota faculty to update and finalize the historical database and begin analyses related to peregrine population ecology. In early 2012, Stephanie Jenkins withdrew from the Ph.D. program at the University of Minnesota and from this project. DEA and PLK met with Ted Swem in Minnesota in March 2012 to update project status and decide how best to proceed. Based on that discussion and following a teleconference with Debbie Nigro in June 2012, we advertised for a postdoc to conduct analyses of historical data and help define a program for addressing additional information needs. JEB was hired in that position starting in September 2012. Since September 2012, JEB has been working to compile existing data and GIS layers, calculate covariates, and develop candidate *a priori* models for the three separate analyses (see below).

Statistical Analysis and Modeling:

Beginning in September 2012, we have taken the necessary steps to begin analyses of the long-term peregrine database. First, we evaluated data sources and GIS layers available for analyses and obtained those relevant to peregrine ecology. Second, we used aerial imagery of the CRSA and a GIS layer of streams to define cliff/escarpment segments along the Colville River. Third, we developed a list of covariates to be derived from the data sources and GIS layers that will be used in *a priori* modeling analyses and exploratory analyses. The covariates are arranged into categories of habitat, topography, climate, prey availability, competition, and nest site quality. Fourth, we decided on conducting three separate modeling analyses to evaluate factors affecting peregrine occupancy on large scales along cliff/escarpment segments, peregrine occupancy on small scales at individual nest sites, and total peregrine abundance along cliff/escarpment segments. Fifth, we developed suites of *a priori* models for each of the three analyses. Table 1 provides a list of covariates to be used in the *a priori* and exploratory analyses. Tables 2, 3, and 4 provide a listing of the *a priori* models for the large-scale occupancy analysis, small-scale occupancy analysis, and large-scale abundance analysis, respectively. Finally, we have begun deriving and calculating covariates to be used in the 3 analyses.

Plans for 2013

Our first goal for 2013 work is to complete the 3 *a priori* and exploratory analyses of the long-term peregrine survey data. We have started calculating covariates and expect to be finished with this task in late January 2013. We will then conduct the 3 *a priori* analyses with an expected completion date of mid-February 2013 at which point we will provide a summary of the results to USFWS and BLM. Finally, we will complete the exploratory analyses and provide a summary of results to USFWS and BLM. We expect this task to be completed by late February 2013.

The second goal for 2013 will be to use the results of the modeling analyses to identify potential additional research and field work objectives for 2013 and beyond. Specifically, we will assess limitations in the covariate data available for the analyses and identify how those limitations could be improved through additional data collection efforts on habitat, topography, climate, prey availability, competition, and nest site quality factors. We will also address how new field efforts can be used to best assess how these factors are related to the probability that an individual nest site or cliff/escarpment segment is occupied along with peregrine abundance on cliff/escarpment segments. A teleconference meeting between DEA, PLK, JEB, Ted Swem of USFWS, and Debbie Negro of BLM regarding these matters should occur within 1 month of completion of analyses. Based on our modeling results and subsequent discussions, we anticipate developing a research plan, to be written by JEB, DEA, and PLK.

Our third goal is to use the results of the modeling analyses and write and submit at least 1 manuscript to a management-related peer-reviewed journal (e.g., Journal of Wildlife Management, Ecological Applications) that details findings of the occupancy and/or abundance analyses. The actual choice of journal will be determined based on the significance of the results.

A fourth goal will be to assess whether BLM-permitted human activity is related to peregrine occupancy or abundance in certain areas of the CRSA. BLM-permitted human activity data have been partially compiled to date and additional data are available to add to the database to conduct this analysis.

Literature Cited

Bliss, L. C. and J.E. Cantlon. 1957. Succession on river alluvium in northern Alaska. American Midland Naturalist 58:452-469.

Karlstrom, T. 1964. Surficial geology map of Alaska. 1:1,586,000. US Geological Survey. Anchorage, Alaska, USA.

National Research Council 2003. Cumulative environmental effects of oil and gas activities on Alaska's North Slope. The National Academies Press. Washington D.C., USA.

Nigro, D. and Ritchie, R. 2004. River cliff-nesting raptor survey, 2003. Unpublished report by the U.S. Department of Interior, Bureau of Land Management, Arctic Field Office, Fairbanks, Alaska, USA.

Swem, T. 2007. Arctic Peregrine Falcon, species of special concern. Alaska Departmentof Fish and Game Conservation. <http://www.wc.adfg.state.ak.us/index.cfm?adfg=concern.ar_falcon>

USDOI BLM. 2008. Colville River special area management plan and environmental assessment. BLM/AK/PL08/022+20. Bureau of Land Management Arctic Field Office, Fairbanks, Alaska, USA.

Table 1. A list of *a priori* and exploratory covariates to be used in the 3 analyses examining large-scale and small-scale factors affecting peregrine occupancy and abundance in the CRSA.

Covariate	Covariate abbreviation	Covariate usage
Habitat/topography category		
Aspect of nest site or average aspect of cliff segment	aspect	*a priori*
Surficial geology category of cliff segment or nest site location	geology	*a priori* / exploratory
Height of nest site above drainage / average height of all nest sites on cliff segment above drainage	height	*a priori* / exploratory
Slope of nest site / average slope of cliff segment	slope	exploratory
Maximum elevation gain around nest site or cliff segment	elevgain	exploratory
Average elevation difference around nest site or cliff segment	elevdiff	exploratory
Climate category		
Date of snow melt	meltdate	*a priori*
Total precipitation during nesting period	precip	*a priori*
Average daily maximum temperature during nesting period	tmax	exploratory
Winter PDO index	pdo	exploratory
Prey availability category		
Total area of wetland, lake, and riparian habitat within 3 km of nest site or cliff segment	waterarea	*a priori*
Distance to nearest water (wetland, lake, riparian area)	waterdistance	exploratory
Competition category		
Number of peregrines along cliff segment during previous year	abundance(t-1)	*a priori*
Distance to nearest neighboring occupied peregrine nest	peregrinedistance	*a priori*
Distance to nearest neighboring occupied peregrine nest from previous year	peregrinedistance(t-1)	exploratory
Distance to nearest gyrfalcon nest	gyrdistance	exploratory
Total number of peregrines in study area for that year	totalabundance	exploratory
Total number of peregrines in study area during previous year	totalabundance(t-1)	exploratory
Site quality category		
Productivity of nest site or average productivity for cliff segment from previous year	productivity(t-1)	*a priori*
Productivity of nest site or average productivity for cliff segment from that year	productivity	exploratory

Table 2. The list of *a priori* models to be evaluated in the analysis examining large-scale factors affecting peregrine occupancy of cliff/escarpment segments for each year in the CRSA. The response variable is binary with a "1" representing 1 or more peregrines occupying a segment and a "0" representing 0 birds occupying a segment. Covariates are defined in Table 1.

Model No.	Model Structure
1	aspect + meltdate
2	aspect + meltdate + aspect*meltdate
3	waterarea
4	productivity(t-1)
5	aspect + meltdate + geology + aspect*meltdate
6	aspect + meltdate + precip + aspect*meltdate
7	aspect + meltdate + waterarea + aspect*meltdate
8	aspect + meltdate + productivity(t-1) + aspect*meltdate
9	geology + waterarea
10	geology + productivity(t-1)
11	precip + waterarea
12	precip + productivity(t-1)
13	waterarea + productivity(t-1)
14	aspect + meltdate + geology + precip + aspect*meltdate
15	aspect + meltdate + geology + waterarea + aspect*meltdate
16	aspect + meltdate + geology + productivity(t-1) + aspect*meltdate
17	aspect + meltdate + precip + waterarea + aspect*meltdate
18	aspect + meltdate + precip + productivity(t-1) + aspect*meltdate
19	aspect + meltdate + waterarea + productivity(t-1) + aspect*meltdate
20	geology + precip + waterarea
21	geology + precip + productivity(t-1)
22	geology + waterarea + productivity(t-1)
23	precip + waterarea + productivity(t-1)
24	aspect + meltdate + geology + precip + waterarea + aspect*meltdate
25	aspect + meltdate + geology + precip + productivity(t-1) + aspect*meltdate
26	aspect + meltdate + geology + waterarea + productivity(t-1) + aspect*meltdate
27	aspect + meltdate + precip + waterarea + productivity(t-1) + aspect*meltdate
28	geology + precip + waterarea + productivity(t-1)
29	aspect + meltdate + geology + precip + waterarea + productivity(t-1) + aspect*meltdate

Table 3. The list of *a priori* models to be evaluated in the analysis examining small-scale factors affecting peregrine occupancy of nest sites each year in the CRSA. The response variable is binary with a "1" representing 1 or more peregrines occupying a nest site and a "0" representing 0 birds occupying a nest site. Covariates are defined in Table 1.

Model No.	Model Structure
1	aspect + meltdate
2	aspect + meltdate + aspect*meltdate
3	waterarea
4	productivity(t-1)
5	peregrinedistance
6	aspect + meltdate + height + aspect*meltdate
7	aspect + meltdate + precip + aspect*meltdate
8	aspect + meltdate + waterarea + aspect*meltdate
9	aspect + meltdate + peregrinedistance + aspect*meltdate
10	aspect + meltdate + productivity(t-1) + aspect*meltdate
11	height + waterarea
12	height + peregrinedistance
13	height + productivity(t-1)
14	precip + waterarea
15	precip + peregrinedistance
16	precip + productivity(t-1)
17	waterarea + peregrinedistance
18	waterarea + productivity(t-1)
19	peregrinedistance + productivity(t-1)
20	aspect + meltdate + height + precip + aspect*meltdate
21	aspect + meltdate + height + waterarea + aspect*meltdate
22	aspect + meltdate + height + peregrinedistance + aspect*meltdate
23	aspect + meltdate + height + productivity(t-1) + aspect*meltdate
24	aspect + meltdate + precip + waterarea + aspect*meltdate
25	aspect + meltdate + precip + peregrinedistance + aspect*meltdate
26	aspect + meltdate + precip + productivity(t-1) + aspect*meltdate
27	aspect + meltdate + waterarea + peregrinedistance + aspect*meltdate
28	aspect + meltdate + waterarea + productivity(t-1) + aspect*meltdate
29	aspect + meltdate + peregrinedistance + productivity(t-1) + aspect*meltdate
30	height + precip + waterarea
31	height + precip + peregrinedistance
32	height + precip + productivity(t-1)
33	height + waterarea + peregrinedistance
34	height + waterarea + productivity(t-1)
35	height + peregrinedistance + productivity(t-1)
36	precip + waterarea + peregrinedistance

37	precip + waterarea + productivity(t-1)
38	precip + peregrinedistance + productivity(t-1)
39	waterarea + peregrinedistance + productivity(t-1)
40	aspect + meltdate + height + precip + waterarea + aspect*meltdate
41	aspect + meltdate + height + precip + peregrinedistance + aspect*meltdate
42	aspect + meltdate + height + precip + productivity(t-1) + aspect*meltdate
43	aspect + meltdate + height + waterarea + peregrinedistance + aspect*meltdate
44	aspect + meltdate + height + waterarea + productivity(t-1) + aspect*meltdate
45	aspect + meltdate + height + peregrinedistance + productivity(t-1) + aspect*meltdate
46	aspect + meltdate + precip + waterarea + peregrinedistance + aspect*meltdate
47	aspect + meltdate + precip + waterarea + productivity(t-1) + aspect*meltdate
48	aspect + meltdate + precip + peregrinedistance + productivity(t-1) + aspect*meltdate
49	aspect + meltdate + waterarea + peregrinedistance + productivity(t-1) + aspect*meltdate
50	height + precip + waterarea + peregrinedistance
51	height + precip + waterarea + productivity(t-1)
52	height + precip + peregrinedistance + productivity(t-1)
53	height + waterarea + peregrinedistance + productivity(t-1)
54	precip + waterarea + peregrinedistance + productivity(t-1)
55	aspect + meltdate + height + precip + waterarea + peregrinedistance + aspect*meltdate
56	aspect + meltdate + height + precip + waterarea + productivity(t-1) + aspect*meltdate
57	aspect + meltdate + height + precip + peregrinedistance + productivity(t-1) + aspect*meltdate
58	aspect + meltdate + height + waterarea + peregrinedistance + productivity(t-1) + aspect*meltdate
59	aspect + meltdate + precip + waterarea + peregrinedistance + productivity(t-1) + aspect*meltdate
60	height + precip + waterarea + peregrinedistance + productivity(t-1)
61	aspect + meltdate + height + precip + waterarea + peregrinedistance + productivity(t-1) + aspect*meltdate
62	peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
63	aspect + meltdate + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
64	height + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
65	precip + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
66	waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)

67	aspect + meltdate + height + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
68	aspect + meltdate + precip + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
69	aspect + meltdate + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
70	height + precip + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
71	height + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
72	precip + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
73	aspect + meltdate + height + precip + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
74	aspect + meltdate + height + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
75	aspect + meltdate + precip + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
76	height + precip + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)
77	aspect + meltdate + height + precip + waterarea + peregrinedistance + productivity(t-1) + peregrinedistance*productivity(t-1)

Table 4. The list of *a priori* models to be evaluated in the analysis examining large-scale factors affecting total abundance of peregrines on cliff/escarpment segments for each year. The response variable is the maximum total number of adult peregrines counted on each segment during surveys. Covariates are defined in Table 1.

Model No.	Model Structure
1	aspect + meltdate
2	aspect + meltdate + aspect*meltdate
3	waterarea
4	productivity(t-1)
5	abundance(t-1)
6	aspect + meltdate + geology + aspect*meltdate
7	aspect + meltdate + precip + aspect*meltdate
8	aspect + meltdate + waterarea + aspect*meltdate
9	aspect + meltdate + abundance(t-1) + aspect*meltdate
10	aspect + meltdate + productivity(t-1) + aspect*meltdate
11	geology + waterarea
12	geology + abundance(t-1)
13	geology + productivity(t-1)
14	precip + waterarea
15	precip + abundance(t-1)
16	precip + productivity(t-1)
17	waterarea + abundance(t-1)
18	waterarea + productivity(t-1)
19	abundance(t-1) + productivity(t-1)
20	aspect + meltdate + geology + precip + aspect*meltdate
21	aspect + meltdate + geology + waterarea + aspect*meltdate
22	aspect + meltdate + geology + abundance(t-1) + aspect*meltdate
23	aspect + meltdate + geology + productivity(t-1) + aspect*meltdate
24	aspect + meltdate + precip + waterarea + aspect*meltdate
25	aspect + meltdate + precip + abundance(t-1) + aspect*meltdate
26	aspect + meltdate + precip + productivity(t-1) + aspect*meltdate
27	aspect + meltdate + waterarea + abundance(t-1) + aspect*meltdate
28	aspect + meltdate + waterarea + productivity(t-1) + aspect*meltdate
29	aspect + meltdate + abundance(t-1) + productivity(t-1) + aspect*meltdate
30	geology + precip + waterarea
31	geology + precip + abundance(t-1)
32	geology + precip + productivity(t-1)
33	geology + waterarea + abundance(t-1)
34	geology + waterarea + productivity(t-1)
35	geology + abundance(t-1) + productivity(t-1)
36	precip + waterarea + abundance(t-1)

37	precip + waterarea + productivity(t-1)
38	precip + abundance(t-1) + productivity(t-1)
39	waterarea + abundance(t-1) + productivity(t-1)
40	aspect + meltdate + geology + precip + waterarea + aspect*meltdate
41	aspect + meltdate + geology + precip + abundance(t-1) + aspect*meltdate
42	aspect + meltdate + geology + precip + productivity(t-1) + aspect*meltdate
43	aspect + meltdate + geology + waterarea + abundance(t-1) + aspect*meltdate
44	aspect + meltdate + geology + waterarea + productivity(t-1) + aspect*meltdate
45	aspect + meltdate + geology + abundance(t-1) + productivity(t-1) + aspect*meltdate
46	aspect + meltdate + precip + waterarea + abundance(t-1) + aspect*meltdate
47	aspect + meltdate + precip + waterarea + productivity(t-1) + aspect*meltdate
48	aspect + meltdate + precip + abundance(t-1) + productivity(t-1) + aspect*meltdate
49	aspect + meltdate + waterarea + abundance(t-1) + productivity(t-1) + aspect*meltdate
50	geology + precip + waterarea + abundance(t-1)
51	geology + precip + waterarea + productivity(t-1)
52	geology + precip + abundance(t-1) + productivity(t-1)
53	geology + waterarea + abundance(t-1) + productivity(t-1)
54	precip + waterarea + abundance(t-1) + productivity(t-1)
55	aspect + meltdate + geology + precip + waterarea + abundance(t-1) + aspect*meltdate
56	aspect + meltdate + geology + precip + waterarea + productivity(t-1) + aspect*meltdate
57	aspect + meltdate + geology + precip + abundance(t-1) + productivity(t-1) + aspect*meltdate
58	aspect + meltdate + geology + waterarea + abundance(t-1) + productivity(t-1) + aspect*meltdate
59	aspect + meltdate + precip + waterarea + abundance(t-1) + productivity(t-1) + aspect*meltdate
60	geology + precip + waterarea + abundance(t-1) + productivity(t-1)
61	aspect + meltdate + geology + precip + waterarea + abundance(t-1) + productivity(t-1) + aspect*meltdate