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CYCLE STRATIFIED HARVEST POLCIES FOR A SUB-POPULATION OF BARREN LAND CARIBOU

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BACKGROUND

Migratory barren-land caribou (*Rangifer tarandus groenlandicus*) are a cyclic species that is highly valued by Northern Residents, and are a keystone species for North America's vast barren-lands. It is well documented in both TEK (traditional ecological knowledge) and scientific studies that barren-land caribou are the only ungulate to experience large periodic fluctuations in population abundance (Government of Yukon, 2015; Gunn, 2003; Russell *et al.*, 2002; Ferguson *et al.*, 1998; Meldgaard, 1986). These periodic shifts from times of abundance to subsequent periods of scarcity play a vital role in shaping the overall ecology of North America's barren lands, while also influencing the relationship of Indigenous peoples and the land (Kendrick *et al.*, 2005; Ashley, 2000; Stenton, 1991). Research has suggested that the caribou cycle is driven by forage availability and regeneration, while climate interactions, decadal winter severity, predation and pathogens influence demographic rates (Bastille-Rousseau *et al.*, 2013; Gunn *et al.*, 2010; Gunn, 2003; Bergerud, 1974).

Typically, when populations are abundant or rapidly increasing the pooled maximum resident, sport and commercial removals of barren-land caribou are not sufficient to pose a conservation risk. When populations become scarce, effective harvest management is of greater concern. The cyclic nature of barren-land caribou populations requires a more flexible approach to harvest management than the usual maximum sustained yield (MSY) or total allowable harvest (TAH) approaches. I have developed one approach to this management issue by identifying a time-stratified harvest regime. Stratifying harvest policies by qualitatively distinct cycle periods associated with times of increase, decline, abundance or low densities, allows harvesting throughout the cycle in a manner that is sustainable and negotiable.

The maximum and minimum rates of population growth or decline varies across all herds, but does not exceed +/- 0.17, and subpopulation cycle periods range from 40-70 years (Gunn, 2003). This implies all barren-land herds share similar rates of demographic change despite covering an extensive and variable geographic and ecological range. In addition to the harvest model, eleven distinct barren land herds were examined by means of a cycle analysis exploring variables such as sine fit parameters, a cluster analysis, and green vegetation indices.

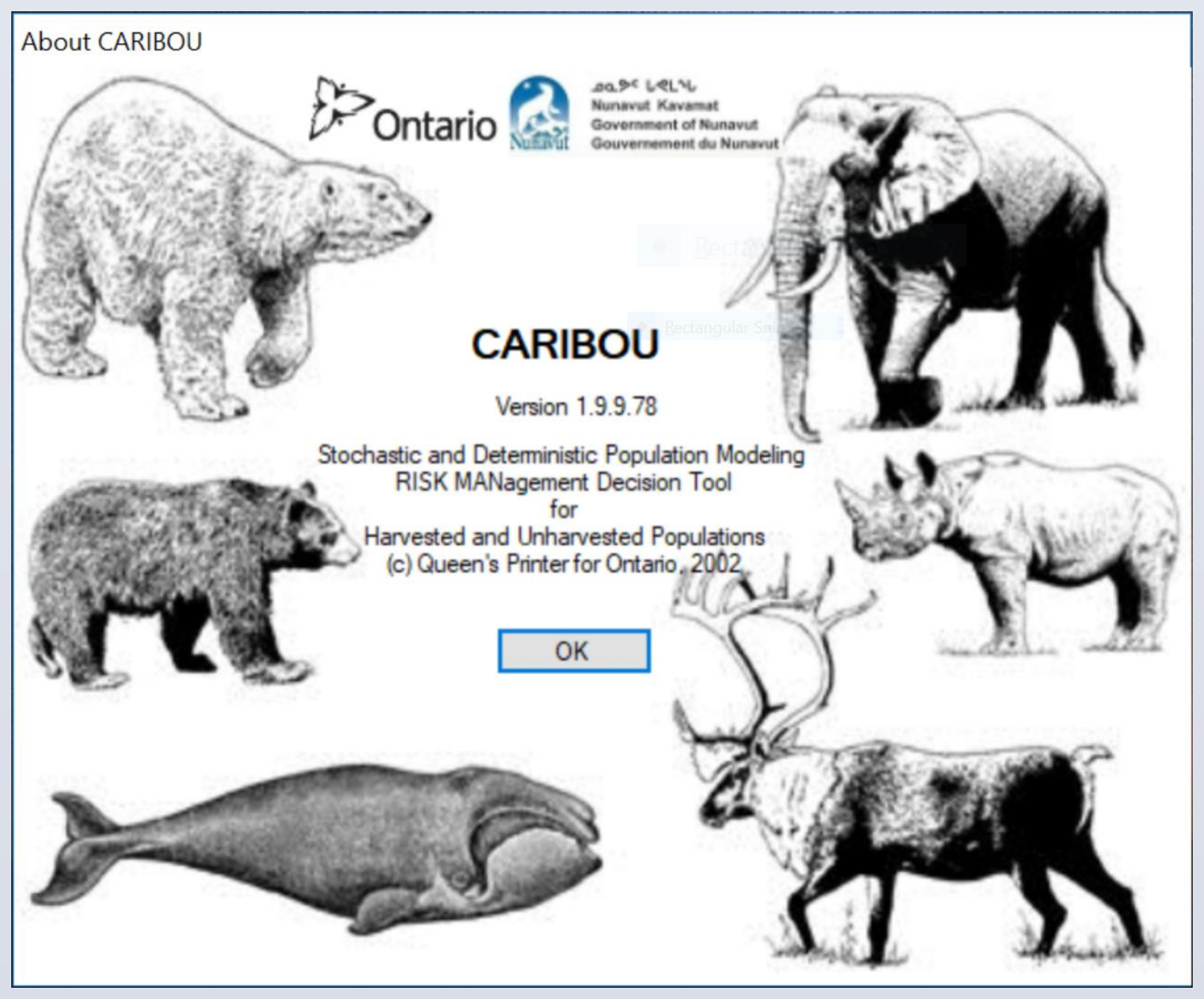
MATERIALS & METHODS

Harvest simulations were conducted using program CARIBOU (*Figure 1*), a modified version of RISKMAN 2.0 software. CARIBOU is an individual-based deterministic single species harvest model with population numbers regulated by density effects. The final model was developed in stepwise stages with the simplest models developed and tested first.

1) ~~Combination of linear and non-linear density effects~~

2) ~~Linear and non-linear density effects, plus lag times~~

3) Linear and non-linear density effects, plus a cyclic carrying capacity



About CARIBOU

CARIBOU

Version 1.9.9.78

Stochastic and Deterministic Population Modeling
RISK MANagement Decision Tool
for
Harvested and Unharvested Populations
(c) Queen's Printer for Ontario, 2002

Figure 1 – The opening screen to the new modified version of RISKMAN software, now known as program CARIBOU.

Simulation models were developed empirically through a trial and error process. Models were evaluated based on their ability to reproduce cycle numbers and vital rates observed for the Qamanirjuaq population in nature (i.e.. period = 53 years, maximum = 500,000, minimum number = 30,000 (Campbell *et al.*, 2010; Campbell, 2007)). Using the identified best choice model, harvest iterations were performed by indicating a specific level of harvest for each cycle strata and threshold (*Figure* 2). Several harvest options were identified which included options that maximized the number taken per cycle, maximized the number of years that the maximum number can be taken (unrestricted harvesting), and minimized the number of years with imposed restrictions when only token harvesting is allowed.

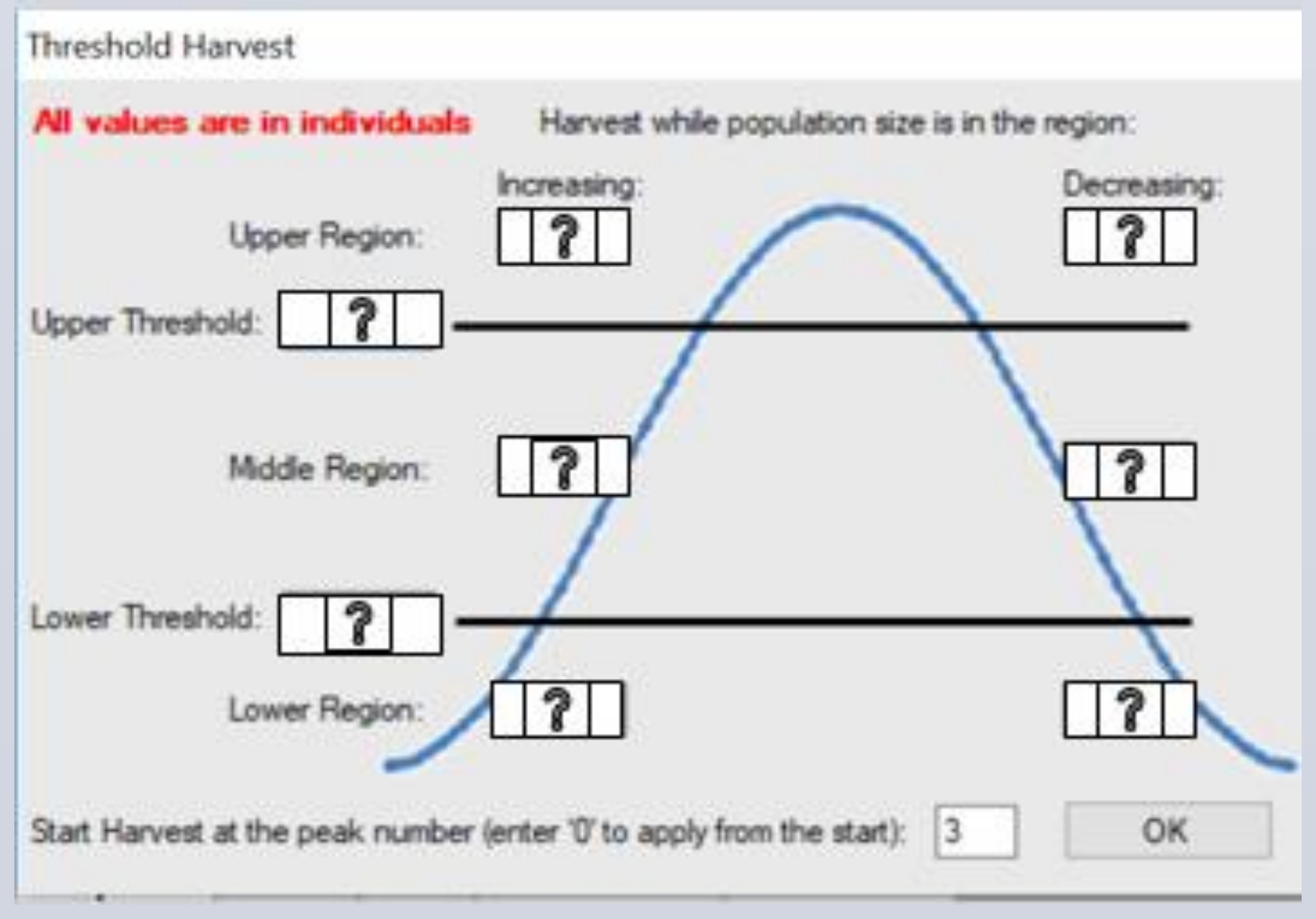
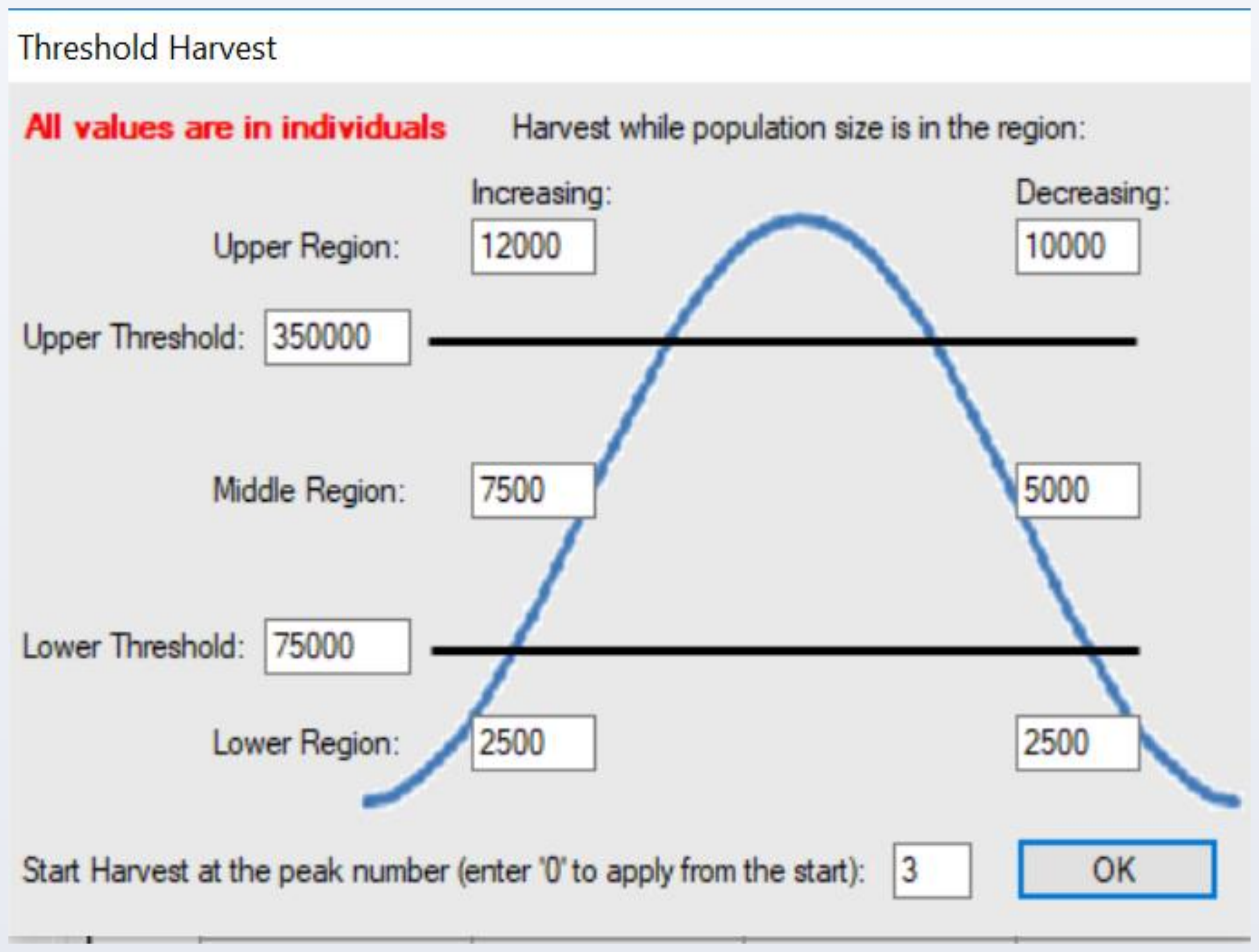


Figure 2 – A screenshot of the user-defined harvest parameter option from program CARIBOU. The question marks delineate user-defined inputs

RESULTS: HARVEST MODEL

Program CARIBOU offers an essentially infinite number of harvest options. All options are sustainable if the program runs. Harvest options are not suggested to be prescriptive, rather they are meant as a decision support tool that should be accompanied by frequent surveying to ensure the reliability of the model. The harvest regimes and corresponding cycle reports are not comprehensive. Their purpose is to illustrate the range of harvest option possibilities.

User-defined Harvest Parameters



Threshold Harvest

All values are in individuals

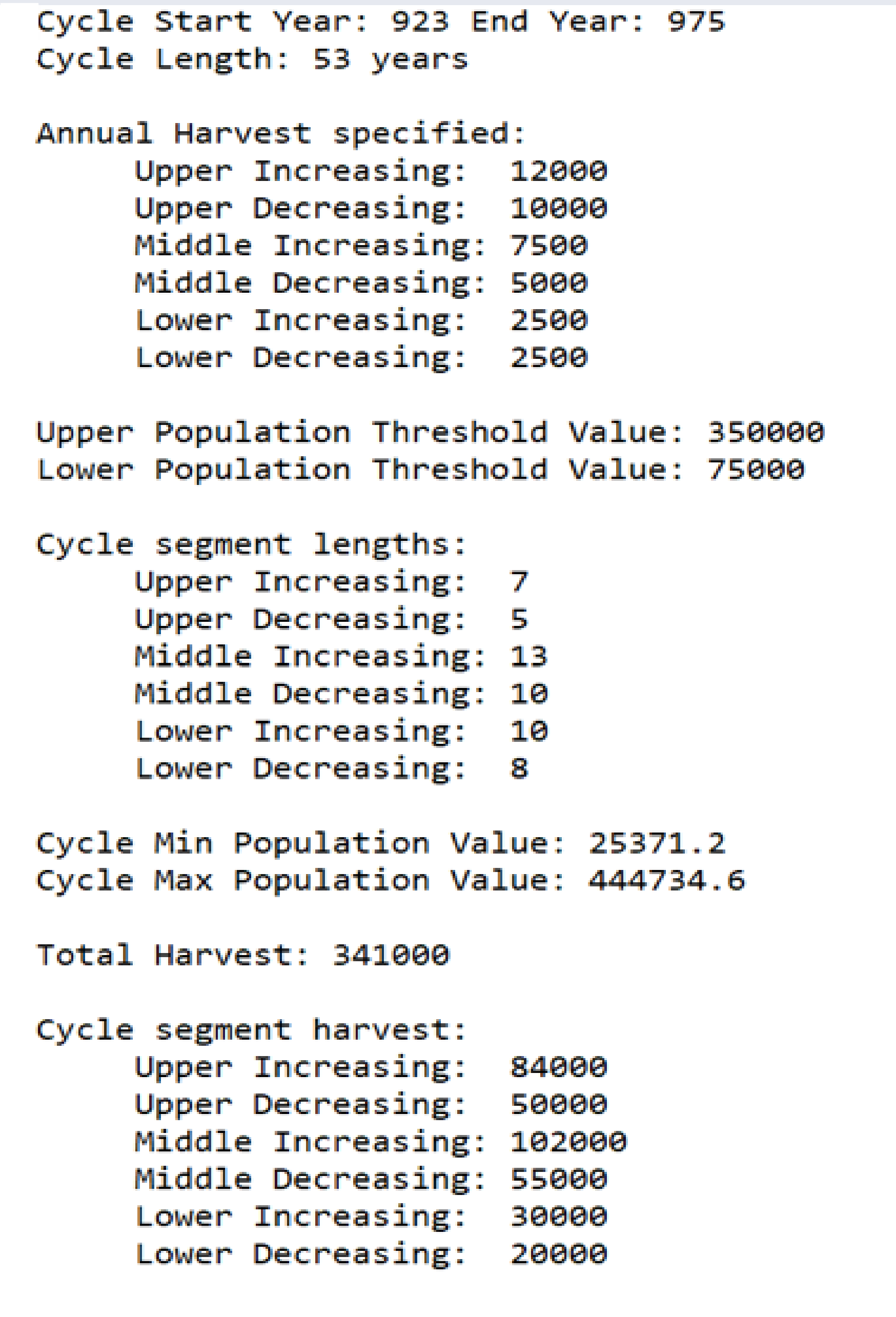
Harvest while population size is in the region:

	Increasing:	Decreasing:
Upper Region:	12000	10000
Upper Threshold:	350000	
Middle Region:	7500	5000
Lower Threshold:	75000	
Lower Region:	2500	2500

Start Harvest at the peak number (enter '0' to apply from the start): 3

Figure 3 – An example of the user-defined harvest parameters for a harvest option that minimizes the number of years with restrictions (<2500)

Harvest Cycle Report



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Cycle Start Year: 923 End Year: 975
Cycle Length: 53 years

Annual Harvest specified:
     Upper Increasing:  12000
     Upper Decreasing:  10000
     Middle Increasing: 7500
     Middle Decreasing: 5000
     Lower Increasing:  2500
     Lower Decreasing:  2500

Upper Population Threshold Value: 350000
Lower Population Threshold Value: 75000

Cycle segment lengths:
     Upper Increasing:  7
     Upper Decreasing:  5
     Middle Increasing: 13
     Middle Decreasing: 10
     Lower Increasing:  10
     Lower Decreasing:  8

Cycle Min Population Value: 25371.2
Cycle Max Population Value: 444734.6

Total Harvest: 341000

Cycle segment harvest:
     Upper Increasing:  84000
     Upper Decreasing:  50000
     Middle Increasing: 102000
     Middle Decreasing: 55000
     Lower Increasing:  30000
     Lower Decreasing:  20000
```

Figure 4 – The cycle report for the above harvest option that minimizes restrictions

RESULTS: CYCLE ANALYSIS

A substantial amount of research and analysis of caribou cycles has been conducted (i.e.. Crete & Payette, 1990; Valkenburg et al. 1994; Whitten, 1996) as single herd case studies. Over approximately the last decade the population trend for the majority of barren-land herds has been negative (CARMA, 2016; Gunn *et al.*, 2010; Sarkadi, 2007). Although this may imply synchrony, differing period lengths for each herd indicates that an asynchronous relationship exists. Respectively *Figure 3* and *Table 1* illustrate the sine curve cycle fit, and the statistical analysis based on the available scientific and government population abundance estimates for eleven distinct barren land herds.

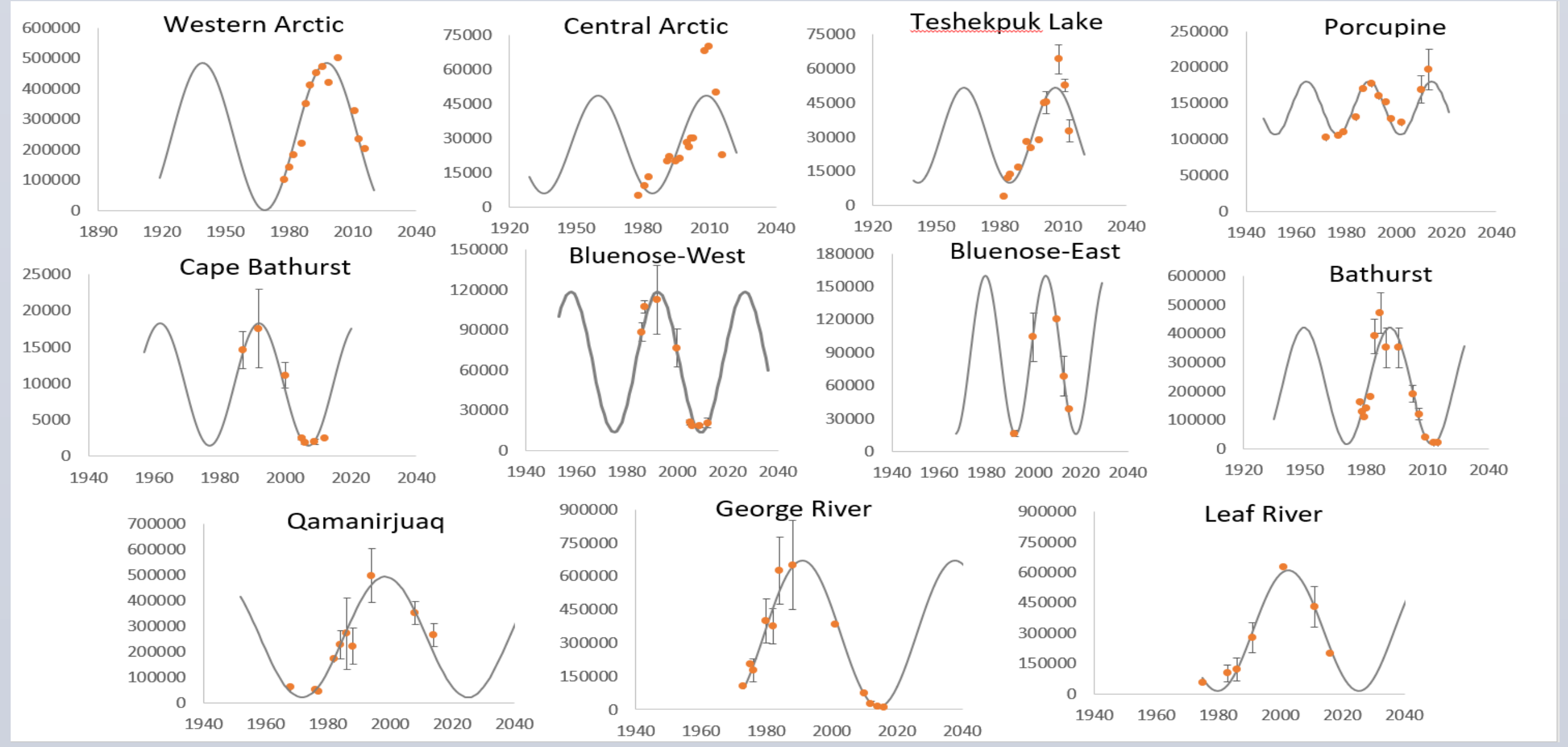

Figure 5 – Sine curve fit from scientific and government population abundance estimates from eleven distinct barren land herds

Table 1 – Statistical results of the non-linear regression dynamic curve fit.

Herd	Period	SE	Amplitude	SE	R sq.
Western Arctic	59	16.3	240953	85188	0.9449
Central Arctic	49	10	21400	5084.5	0.6433
Teshekpuk Lake	43	8.3	20905	3260.2	0.8487
Porcupine	25	1.5	37143	6113	0.8319
Cape Bathurst	30	1.7	8394	447.5	0.9954
Bluenose-West	34	1.9	52408	3942	0.8226
Bluenose-East	26	0.13	71723	354.8	1
Bathurst	42	3.4	203081	24520.3	0.874
Qamanirjuaq	52	3.3	230897	25872.4	0.9334
George River	45	2.4	354413	21653.5	0.9677
Leaf River	46	2	297784	26124.2	0.9779

A cluster analysis is an explorative analysis tool that aims to identify homogeneous cases with respect to variables of interest (i.e.. period and amplitude), such that each group has similar characteristics that separate it from other groups (Tryfos, 1998). *Figure 4* below identifies two distinct clusters that were formed based on period and amplitude values. Clustering based on high amplitude and long period vs. small amplitude and short period suggests that all herds experience similar population growth and decline rates throughout their cycle. Interestingly, there is a strong East-West correlation between these clusters suggesting that period and amplitude may be a function of a climatic variable.

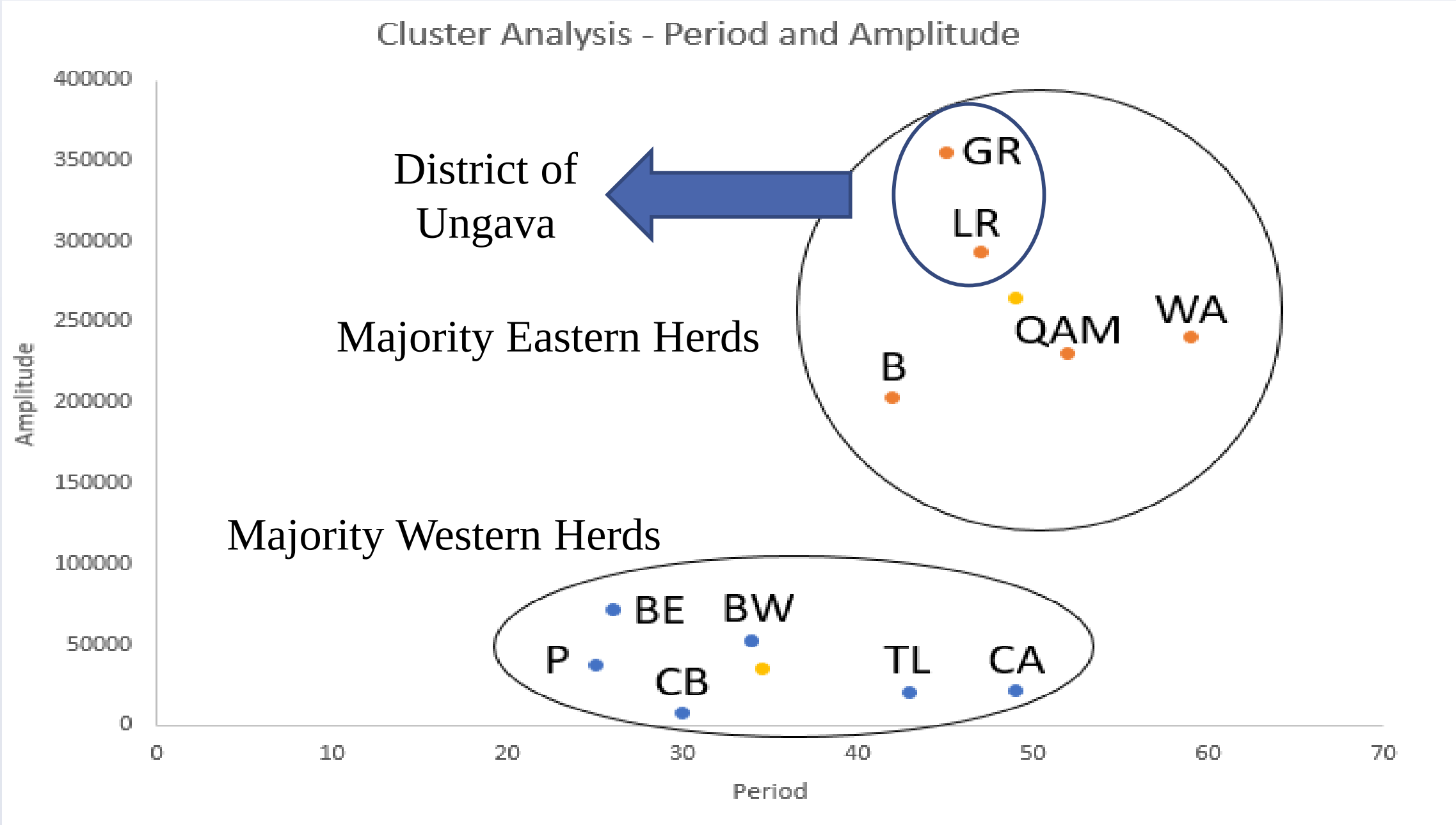

Figure – 6 A cluster analysis based on the period and amplitude values derived from the best fit sine solutions.

MGVF (maximum green vegetation fraction) was used to assess the trend in the abundance of green vegetation from 2001-2012 within the migratory range of each herd. Linear regression results indicated that there was no significant increase in MGVF in nine of the eleven herds. The George River and Leaf River herds respectively showed a statistical increase in MGVF over the same time period to a significance of 0.99.

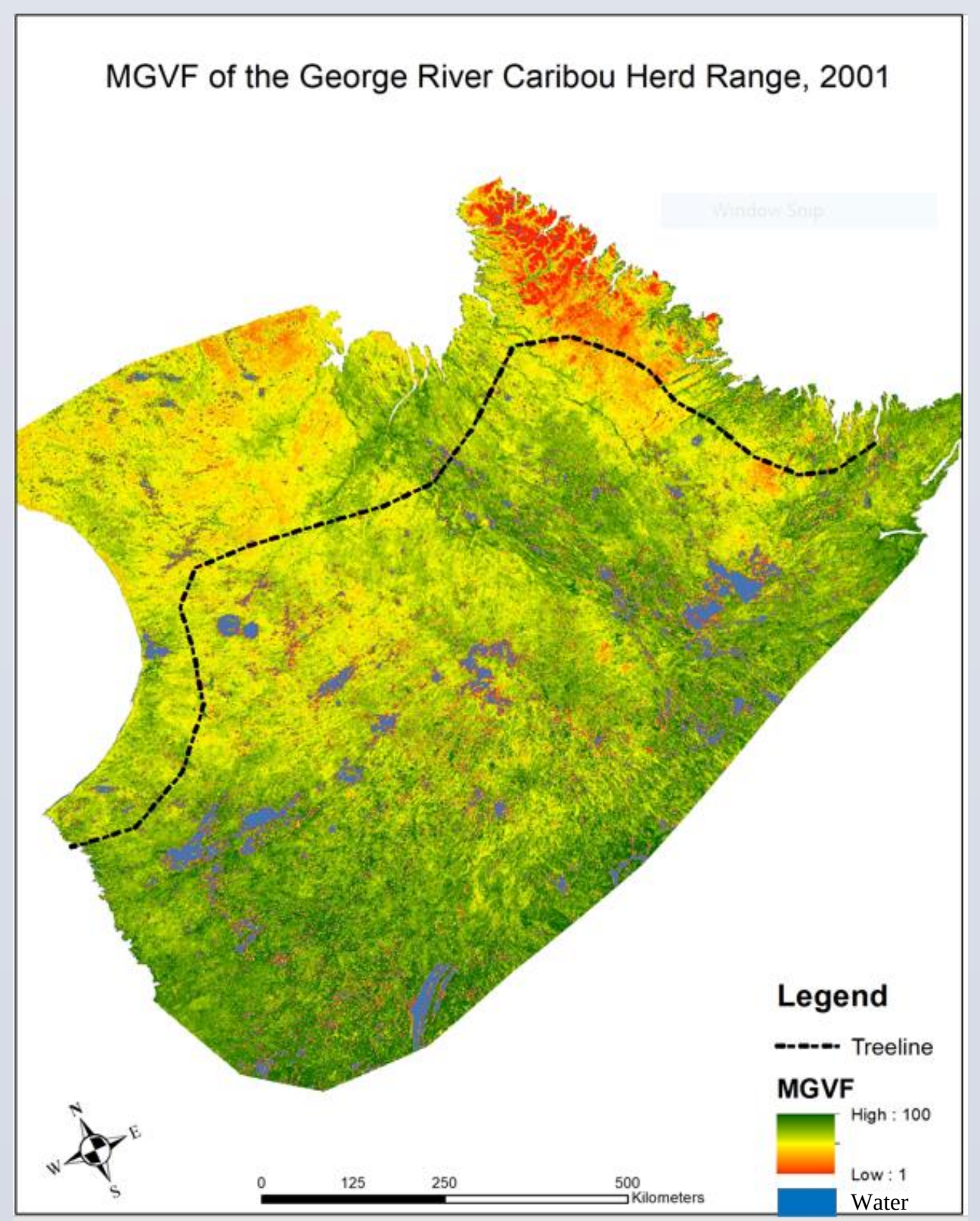

Figure 7 – 10m resolution MGVF raster data for the George River migratory caribou range, 2001.

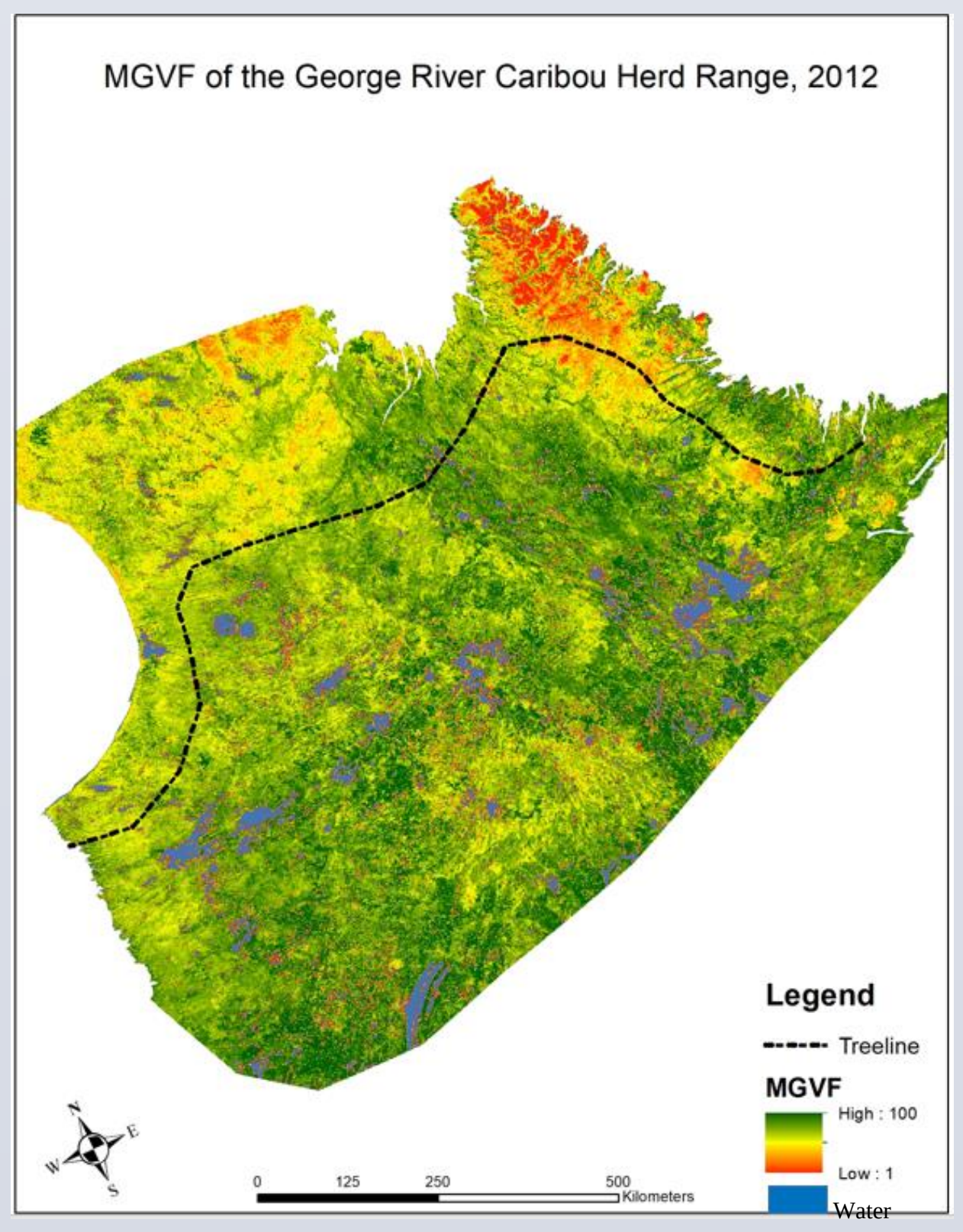

Figure 8 – 10m resolution MGVF raster data for the George River migratory caribou range, 2012.

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