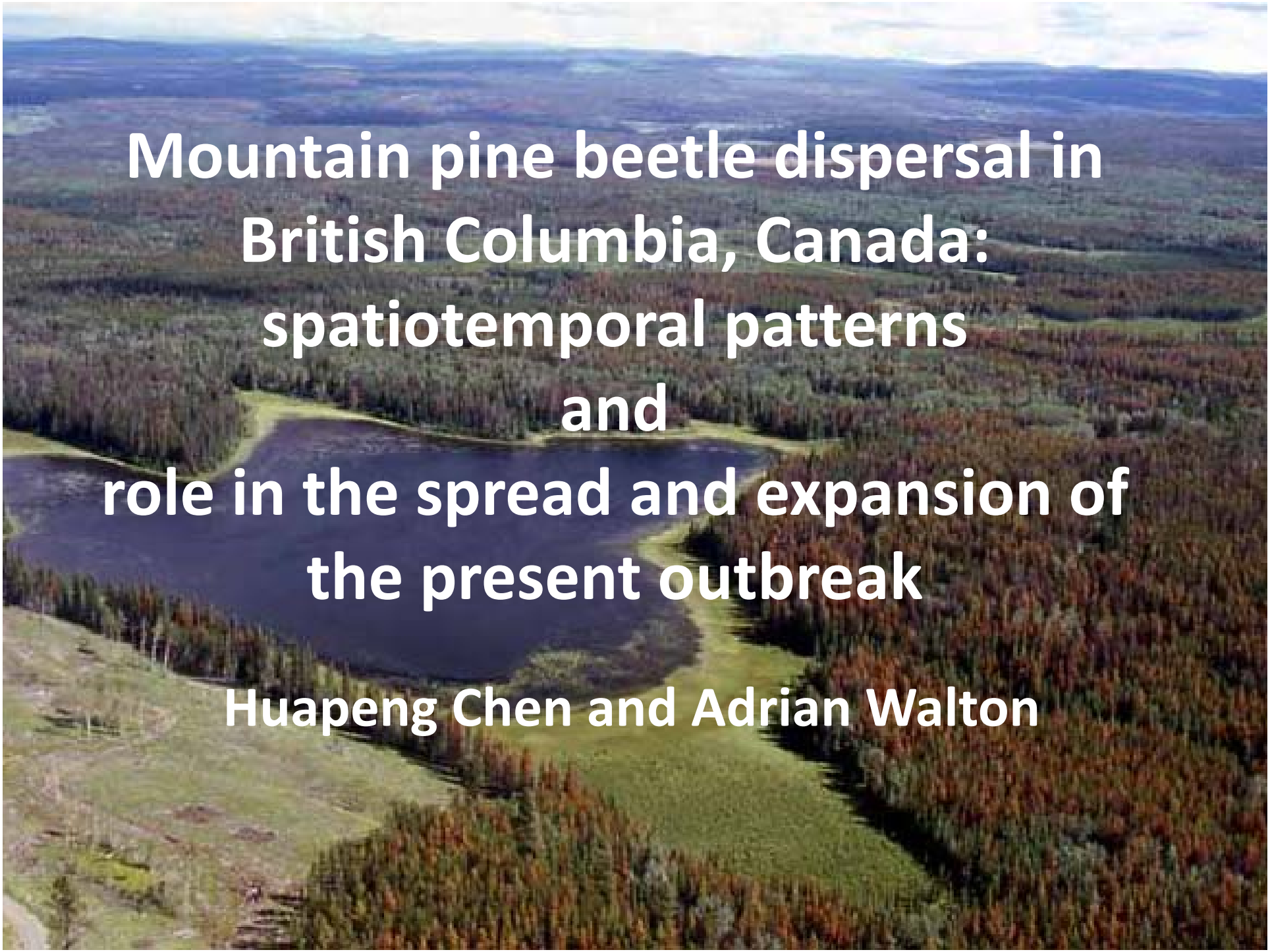


# Mountain pine beetle dispersal in British Columbia, Canada: spatiotemporal patterns and role in the spread and expansion of the present outbreak

Huapeng Chen and Adrian Walton

# Outline

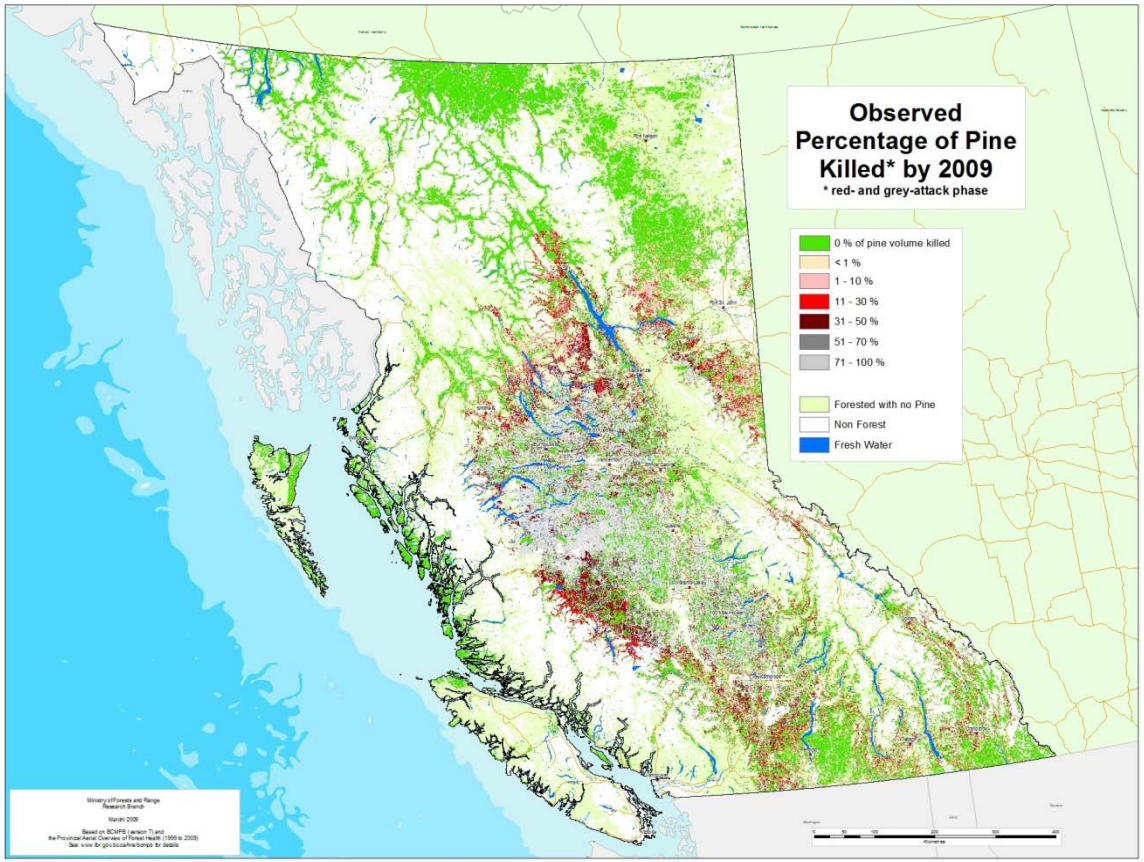


- Introduction
- Objectives
- Study area
- Data and method
- Results
- Discussion
- Conclusions

# Introduction



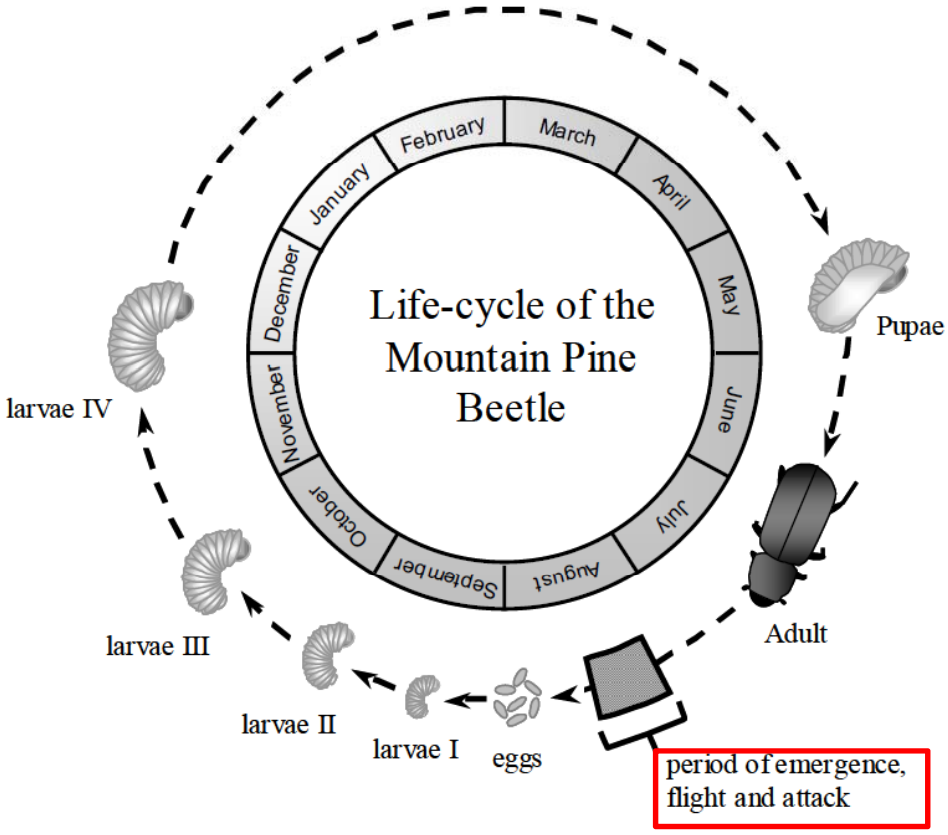
- BC Mountain Pine Beetle (MPB) infestations
  - As of 2009, 47% or 630 million $m^3$ of merchantable pines



# Introduction



- Life cycle of MPB



# Introduction



- Dispersal is a key stage in the life circle of MPB
- Dispersal is a key population process in MPB

- A better understanding of dispersal:
  - Valuable insights into MPB outbreak dynamics
  - Help to minimize outbreak impacts, achieving sustainable forest management goals

- **However, dispersal is least understood in MPB**

# Objectives



- What are the spatiotemporal patterns of short-distance dispersal (SDD) and long-distance dispersal (LDD)?
- What are the roles of SDD and especially LDD in the spread and expansion of the current MPB outbreak?

# Objectives

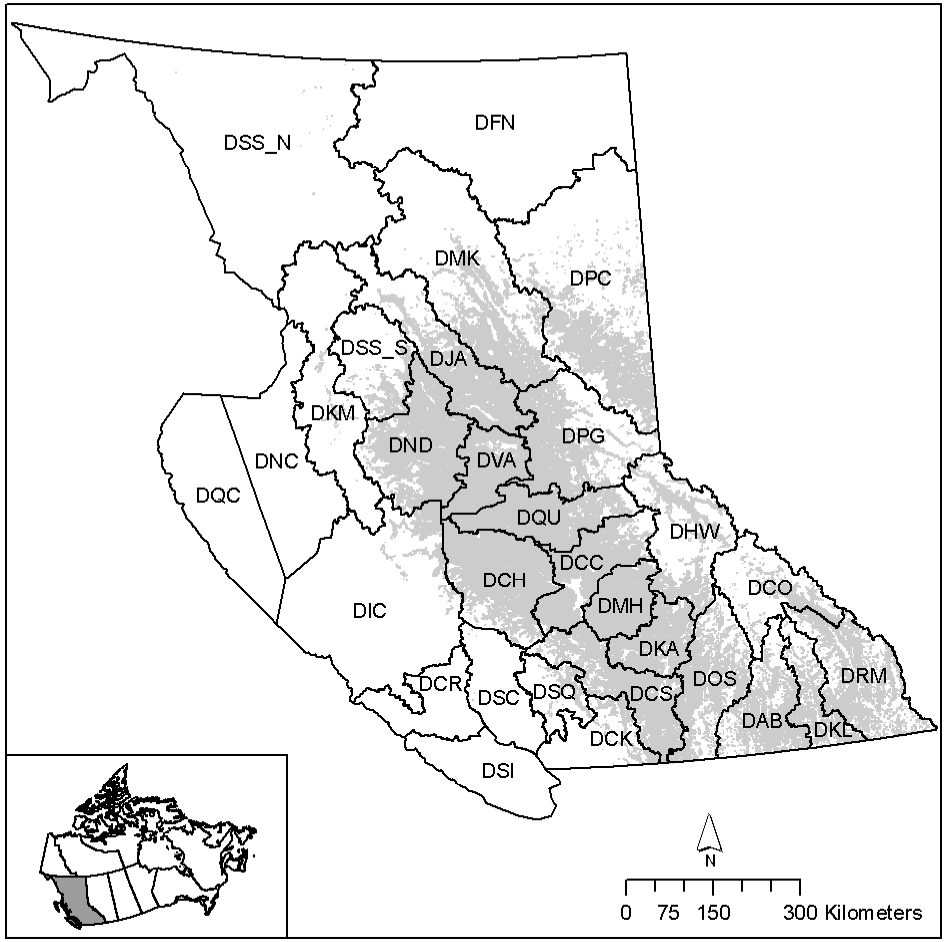


- Hypotheses to be tested:
  - SDD is a dominant factor in the spread and expansion of the MPB outbreak
  - LDD is a key factor to initiate new infestations in remote areas
  - The occurrence of LDD is random, and if not, its occurrence is positively correlated to severity and patchiness of the MPB infestations

# Study area



- Defined as the cumulative annual MPB infestation areas from 1999 to 2008



# Data



- BC Provincial-Level MPB Model output raster datasets (1999 – 2008)
  - Produced using the BC aerial overview survey data
  - 400x400 meter cell size

# Data

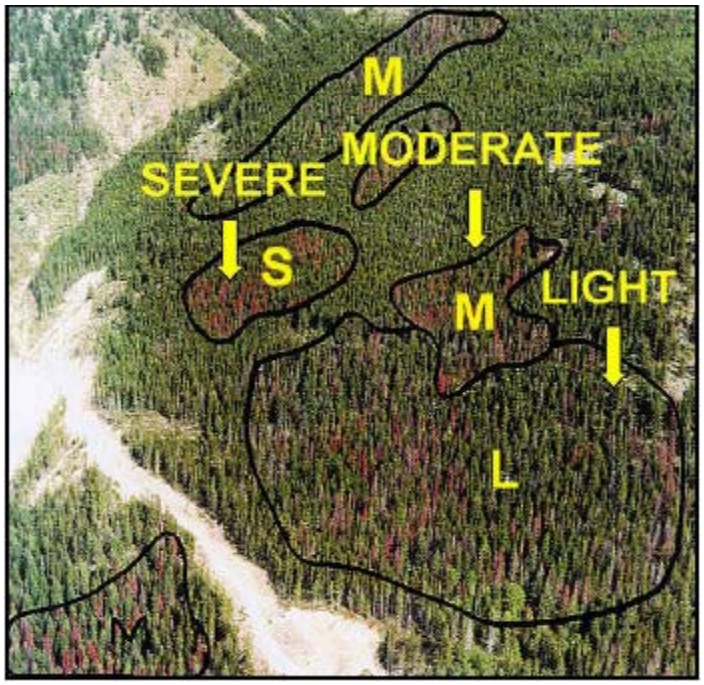


- Aerial overview (sketch mapping) survey data
  - Spatial extent (coverage): province
  - Temporal scale: 1914 up to present
  - Spatial scale: 1: 100, 000 to 1: 250, 000
  - Severity estimation: yes, based on a representative polygon drawn on a topographic map

# Data



- Aerial overview survey data




Severity classes
- T (Trace, < 1%)
- L (Light, 1 – 10%)
- M (Moderate, 11 – 30%)
- S (Severe, 31 – 50%)
- V (Very severe, 51 – 100%)

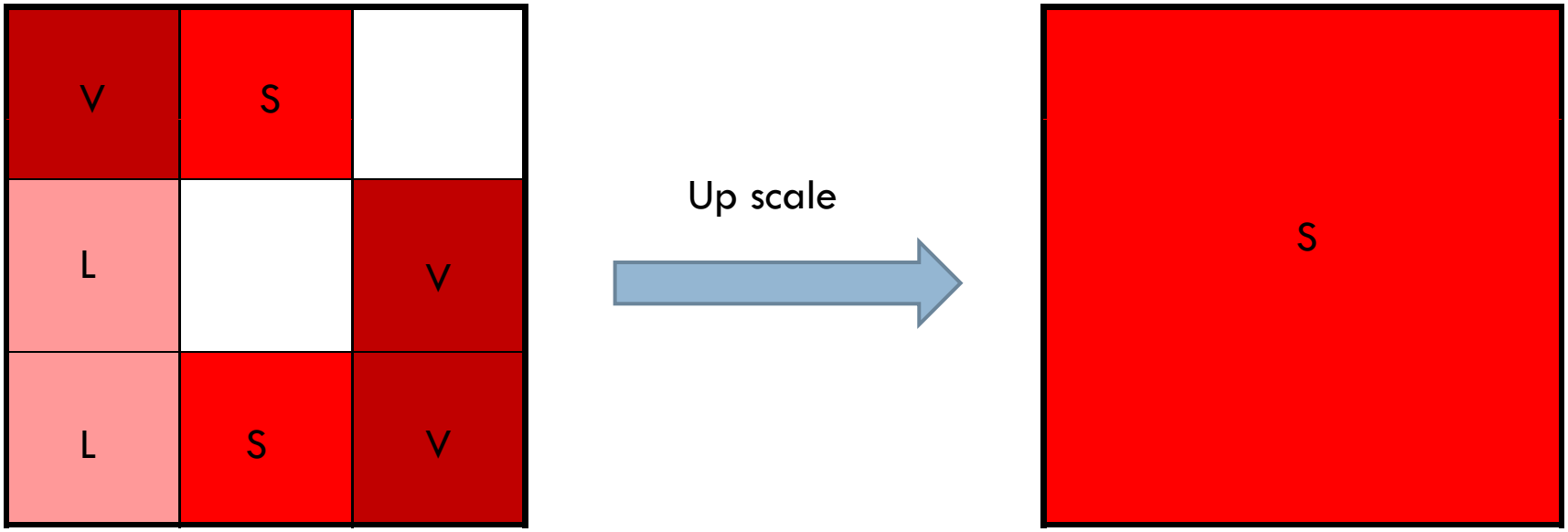
# Data



- Data processing
  - Scaled the raster datasets to 1200 meters because a grid of the same size was used in the correction procedures
  - Combined to create a master grid
  - Severity of a grid cell were calculated from 9 cells of the raster datasets using an area weighted average
  - Severities of the grid cells were re-grouped into two general classes: light infestation (L), combining T, L, and M, and severe infestation (S), combining S and V
  - Total number of master grid cells: 165, 731

# Data





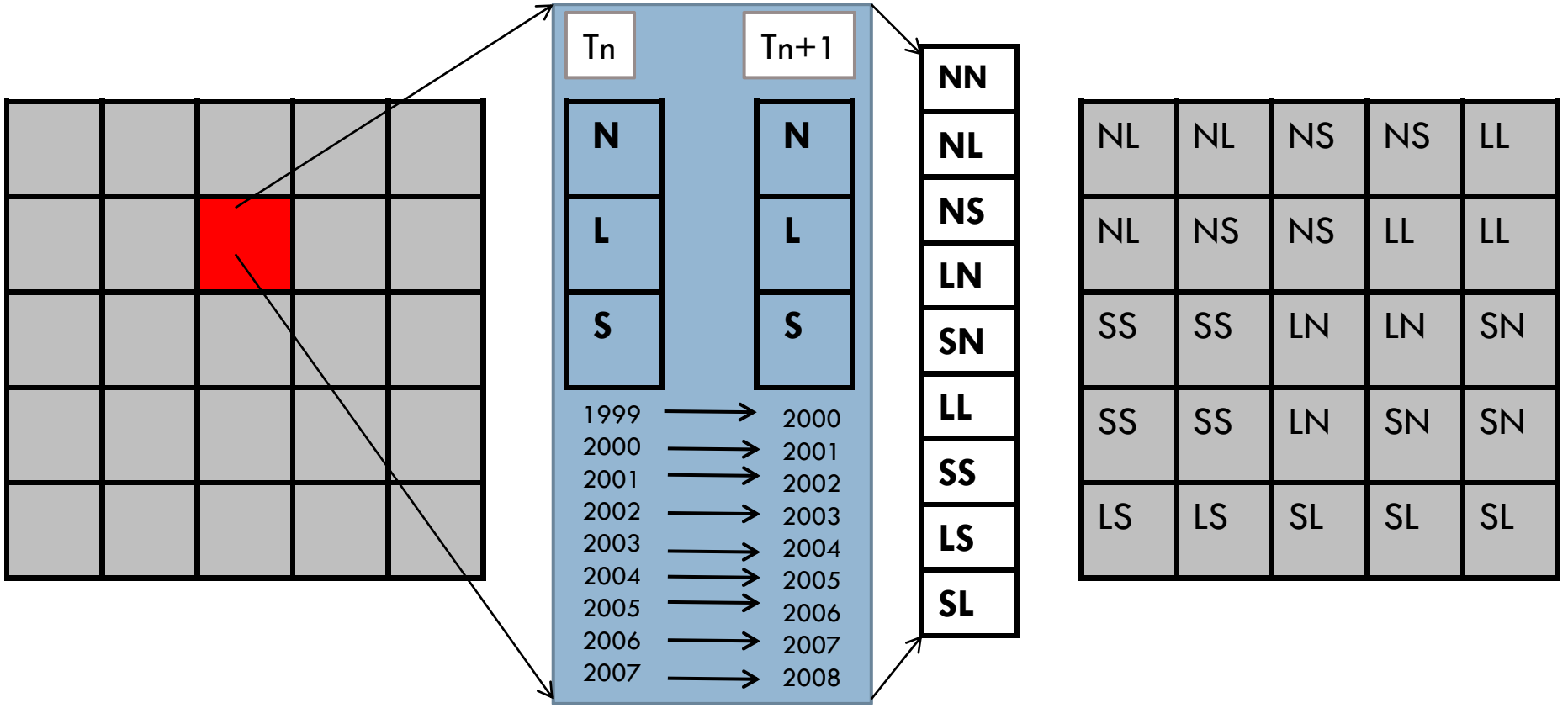

Raster datasets

Master grid

# Method



- Conceptual model of MPB infestations



# Method



- Conceptual model of MPB infestations

| | | |
|---|---|---|
| | SINK, NL and NS | Beetles only fly into the cell |
| | SOURCE, LN and SN | Beetles only fly out of the cell |
| | TRANSFORMER, LL and SS, LS, and SL | Beetles fly into and out of the cell, being a SINK and SOURCE |

| | | | | |
|---|---|---|---|---|
| NL | NL | NS | NS | LL |
| NL | NS | NS | LL | LL |
| SS | SS | LN | LN | SN |
| SS | SS | LN | SN | SN |
| LS | LS | SL | SL | SL |

| | | | | |
|---|---|---|---|---|
| NL | NL | NS | NS | LL |
| NL | NS | NS | LL | LL |
| SS | SS | LN | LN | SN |
| SS | SS | LN | SN | SN |
| LS | LS | SL | SL | SL |

# Method

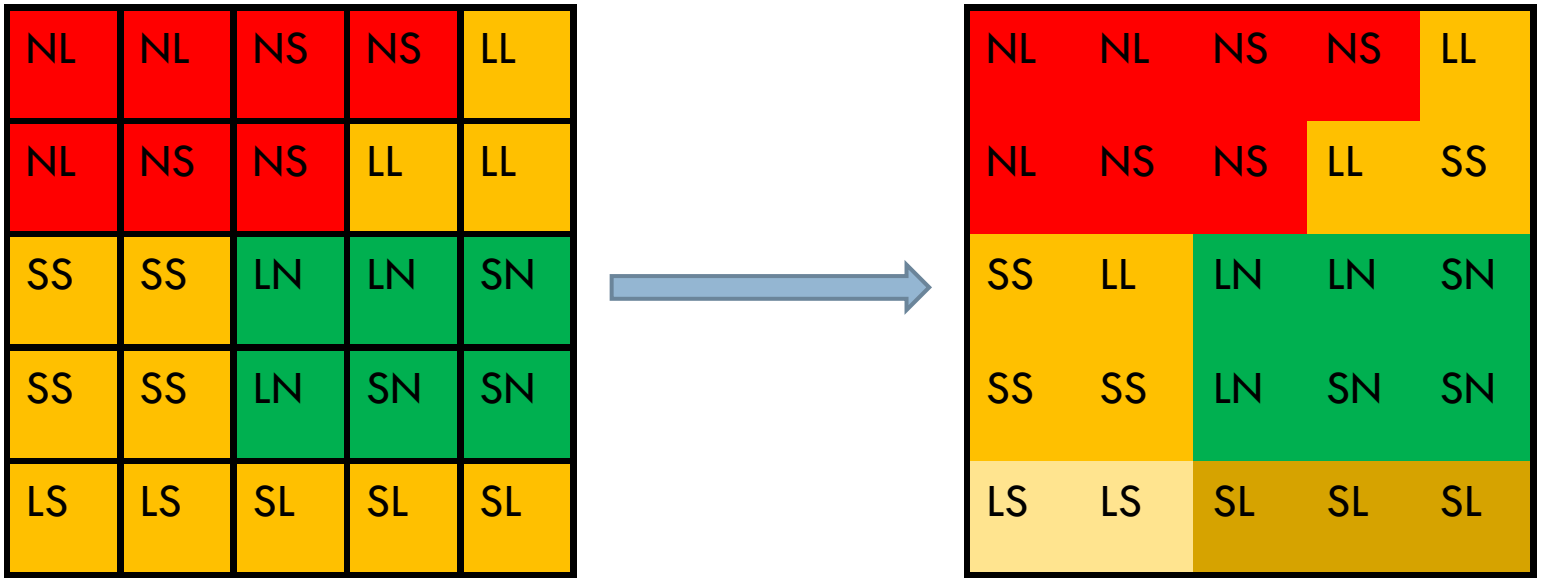


- Key assumptions for the conceptual model of MPB infestations
  - The beetles fly from a source to a sink
  - The infestation severity is a good proxy of beetle population abundance
  - It takes a year for infested trees to fade from green to red attack they have been attacked
  - The infested trees always produce a brood of beetles in the next year

# Method



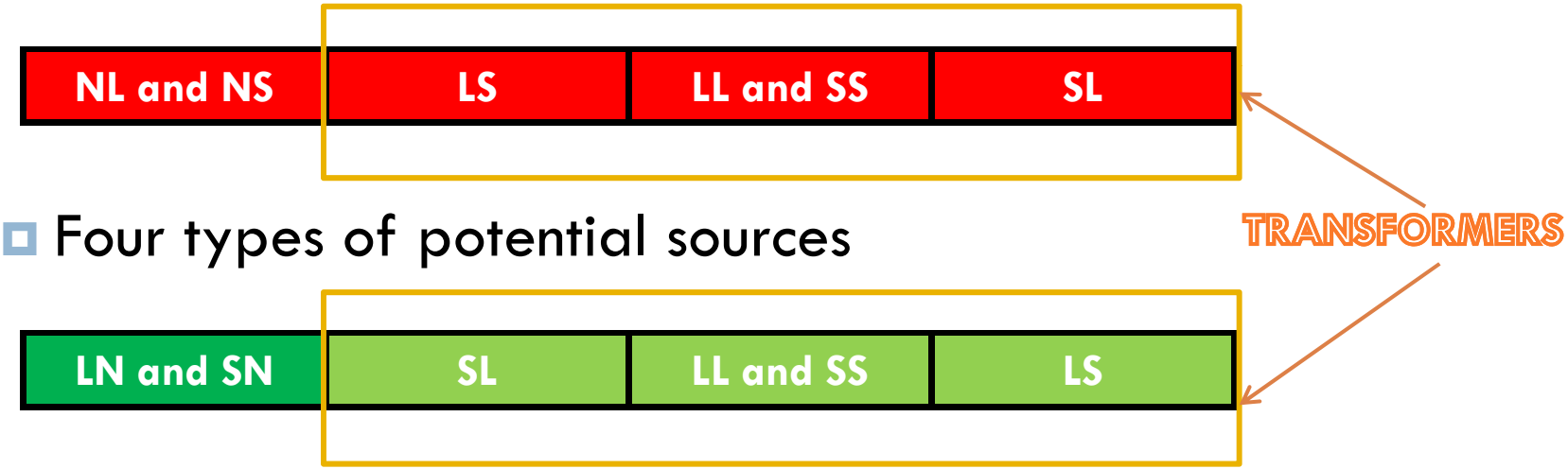
- Characterize dispersal patterns
  - Grid cells were grouped into five types: (1) sink NL and NS; (2) source LN and SN; (3) transformer LL and SS; (4) transformer LS; and (5) transformer SL.



# Method



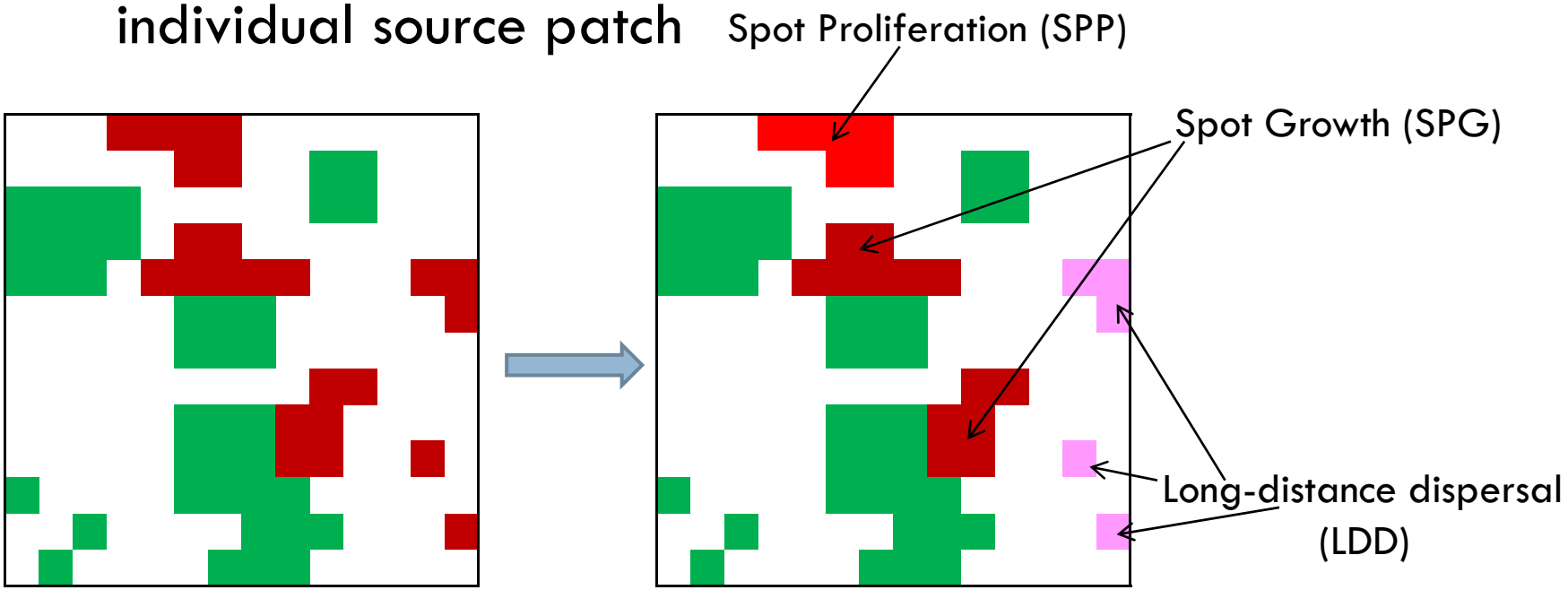
- Characterize dispersal patterns
  - Four types of potential sinks
  - Four types of potential sources



# Method



- Characterize dispersal patterns
  - Measured the distance from the edge of each individual sink patch to the edge of the nearest individual source patch



# Method



- Characterize dispersal patterns
  - Percentage of three modes of dispersal used to characterize dispersal pattern
  - Results only reported for:
    - Sink type NL and NS, dispersal to non-infested areas, ie., new infestations
    - Sink type LL and SS, dispersal to infested areas, ie., old infestations

# Method

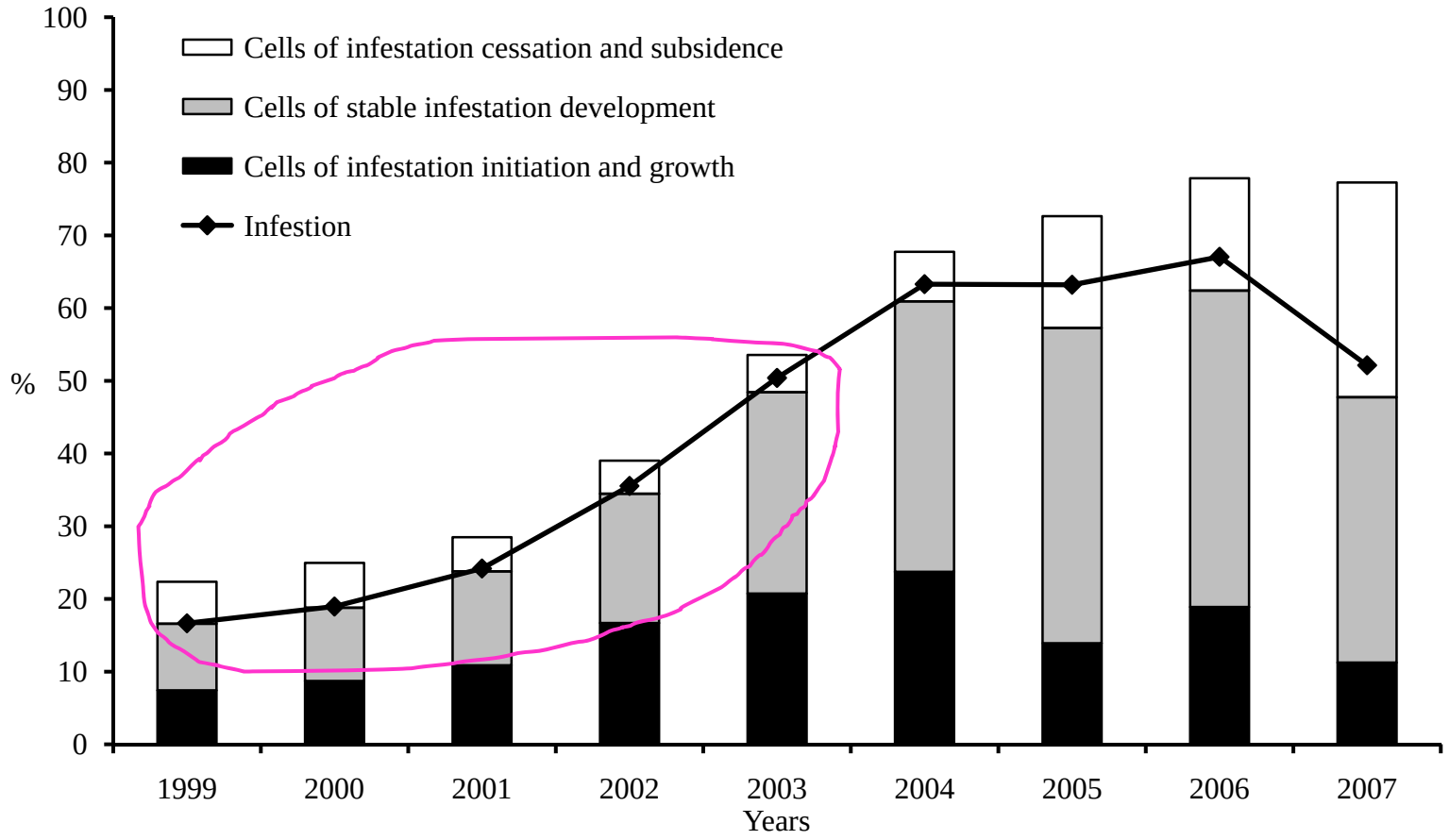


- Statistical analyses
  - The chi-square goodness fit was used to test if the occurrences of three modes of dispersal to both non-infested and infested areas are random
  - If the test was rejected for LDD, the Spearman rank correlation coefficients between the occurrences of LDD and the total number of infested grid cells as well as landscape aggregation indices

# Results



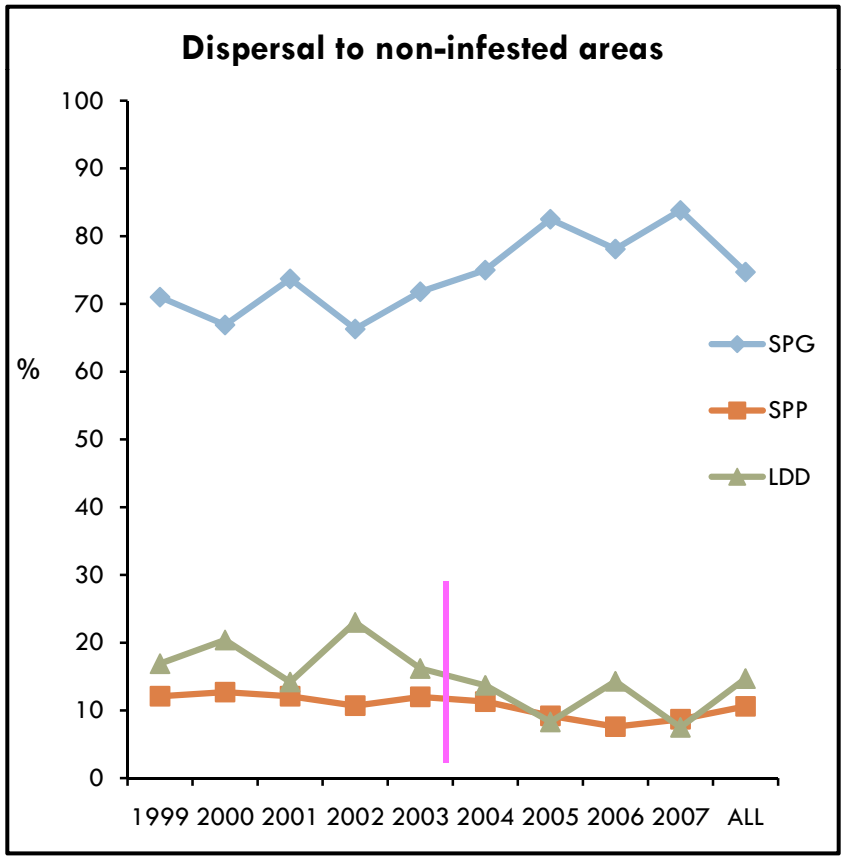
- Dynamics of the mountain pine beetle outbreak

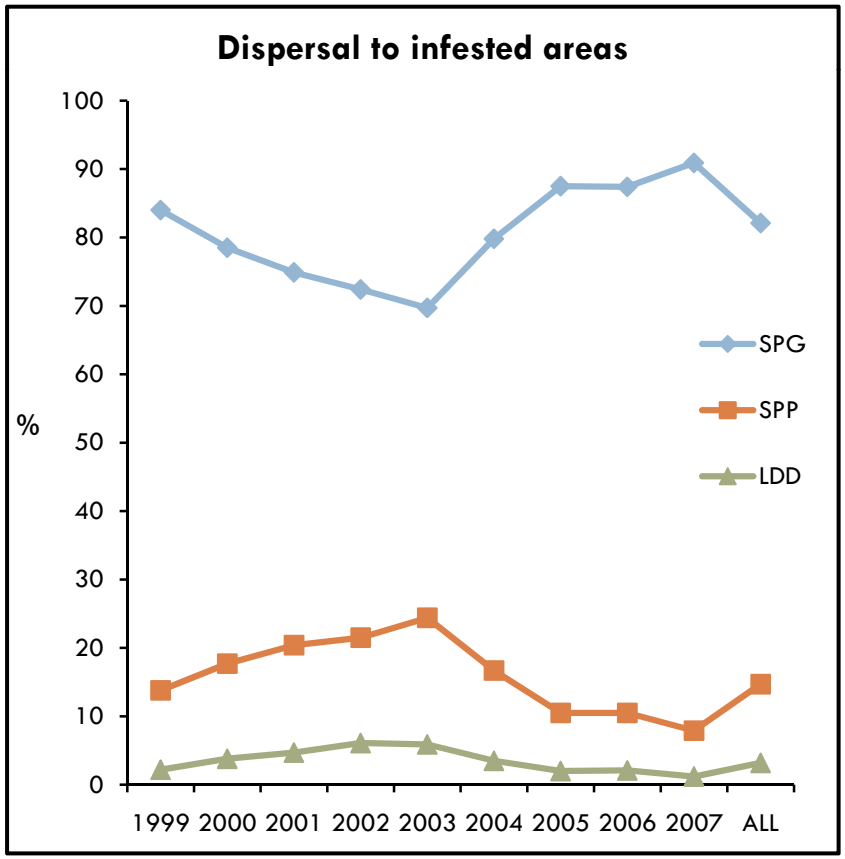


# Results



- Dispersal at the regional (provincial) scale

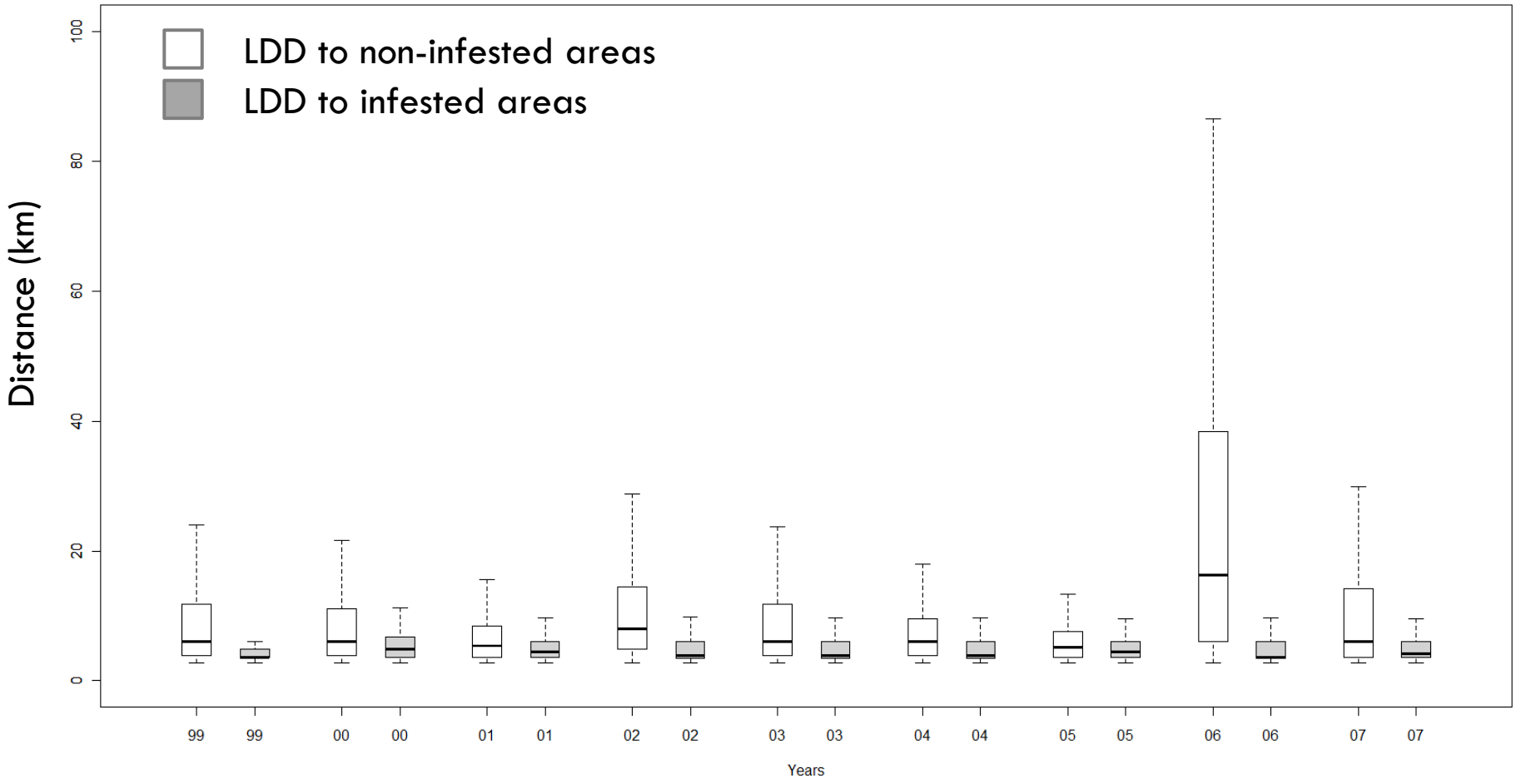


# Results



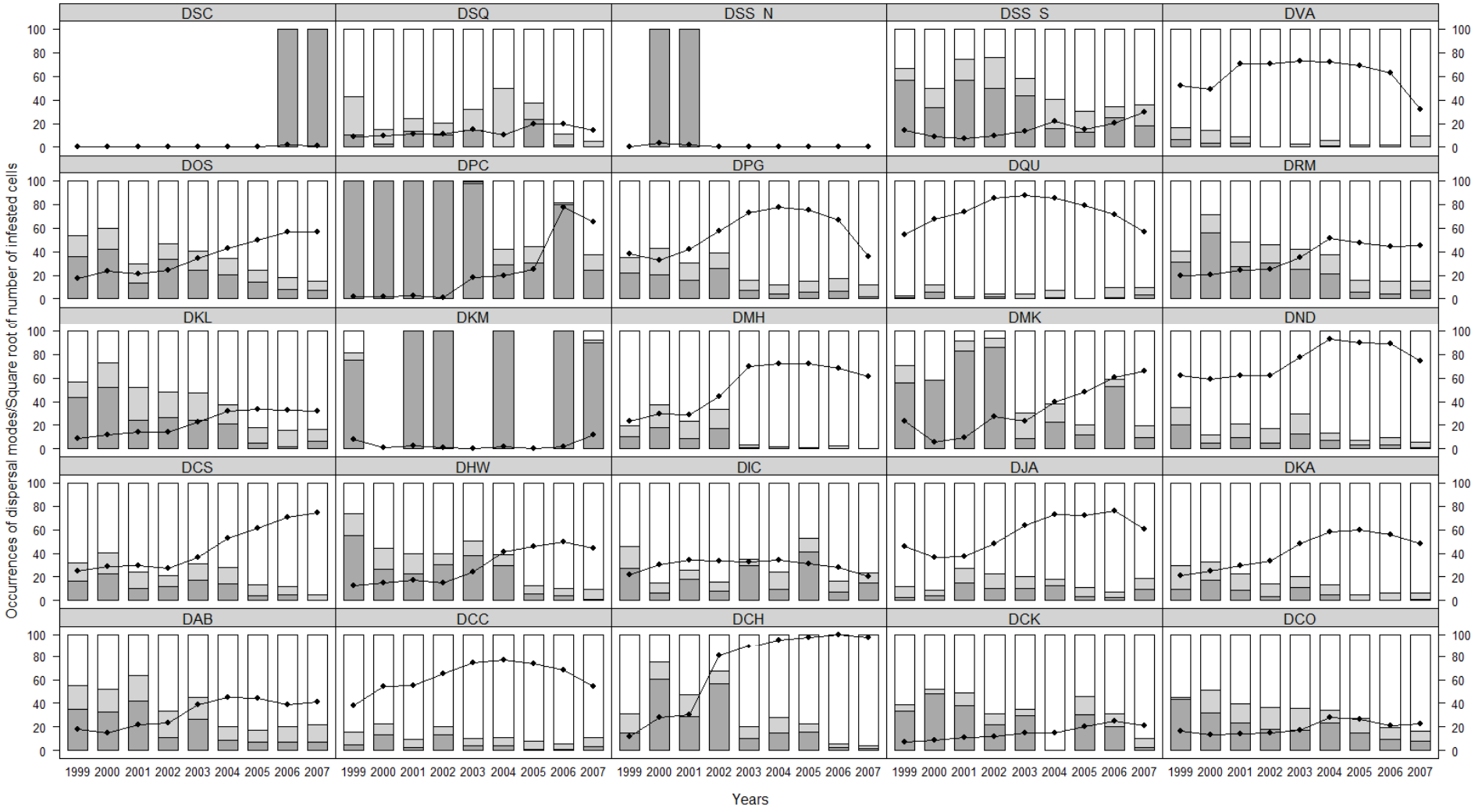
- LDD distance distribution

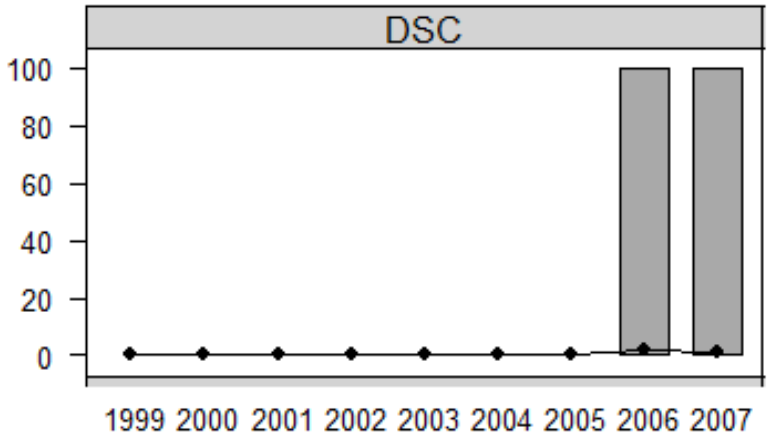


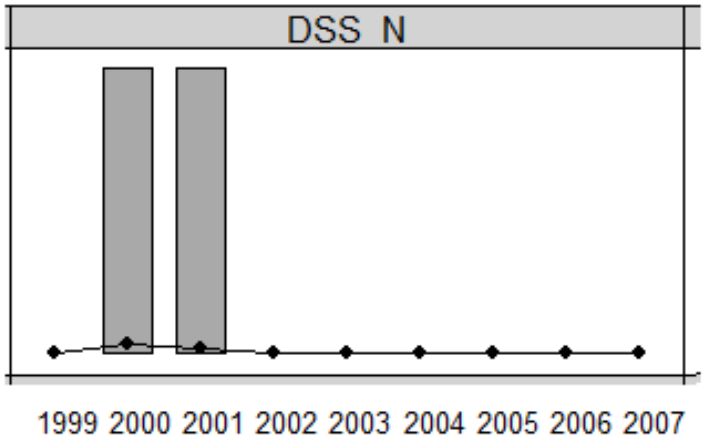
# Results

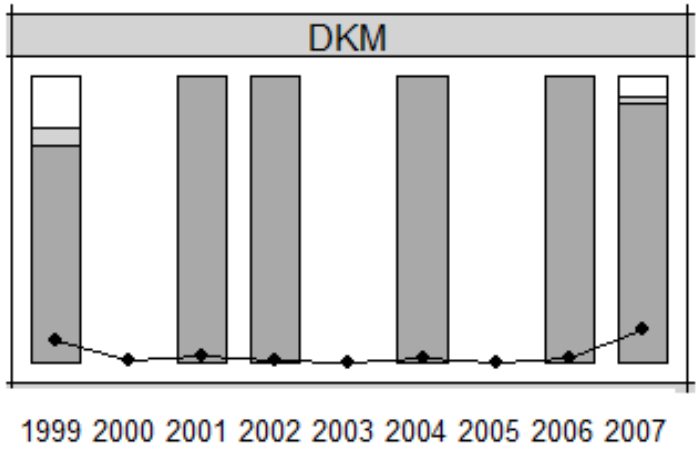


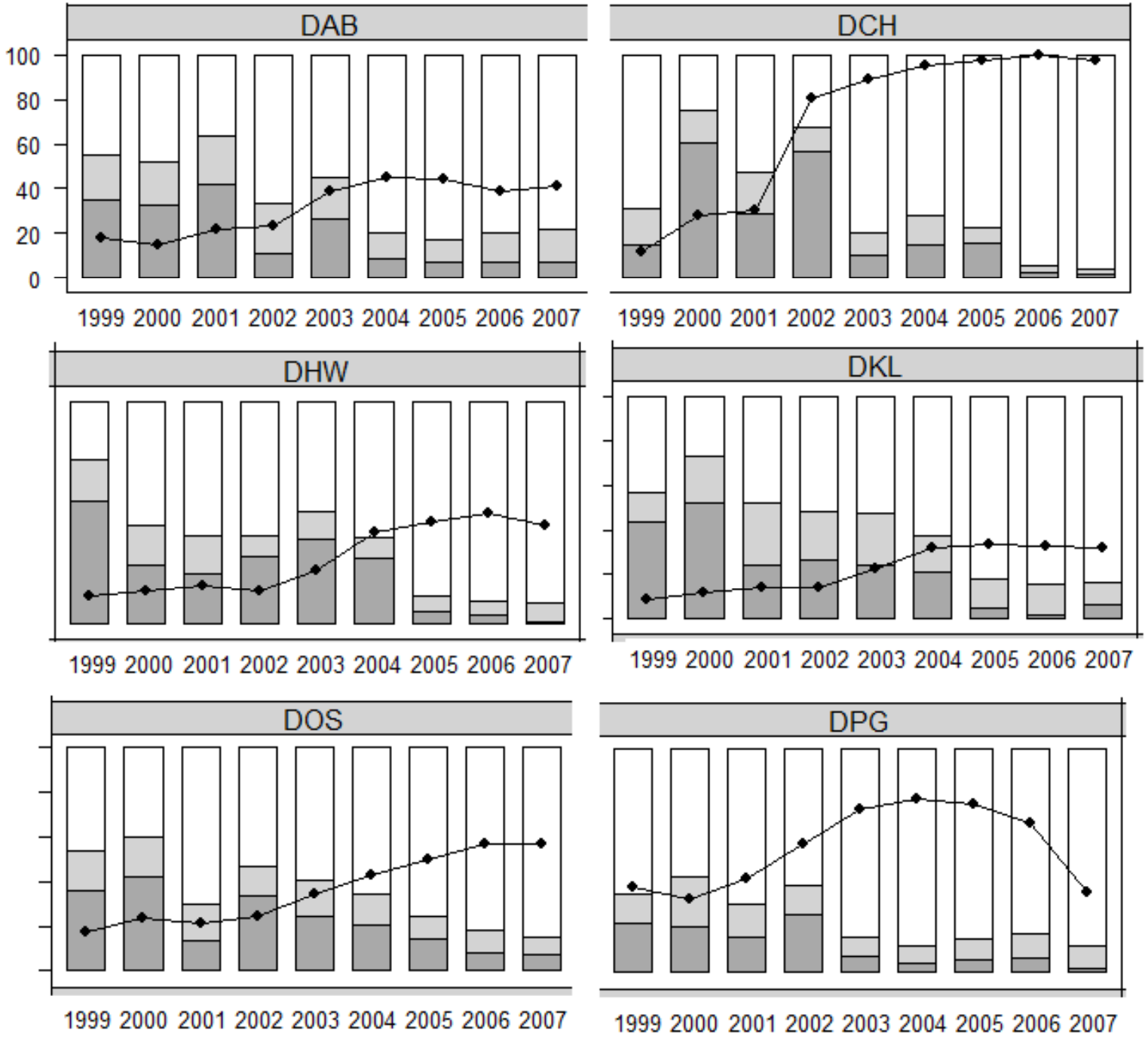
- Dispersal at the local (district) scale
  - The occurrences of three modes of mountain pine beetle dispersal to non-infested areas

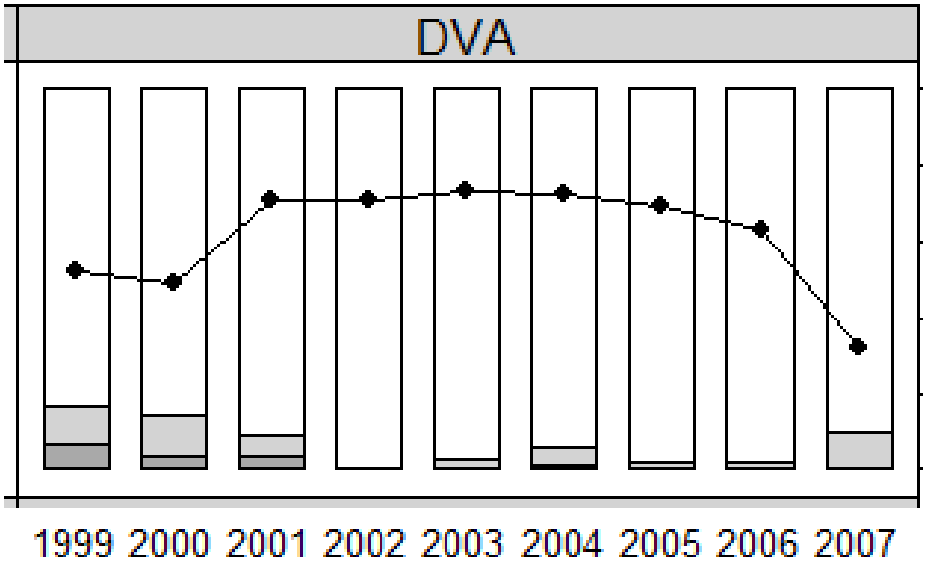

DSC
DSQ
DSS_N
DSS_S
DVA
DOS
DPC
DPG
DQU
DRM
DKL
DKM
DMH
DMK
DND
DCS
DHW
DIC
DJA
DKA
DAB
DCC
DCH
DCK
DCO
Occurrences of dispersal modes/Square root of number of infested cells
Years
0
20
40
60
80
100
1999 2000 2001 2002 2003 2004 2005 2006 2007

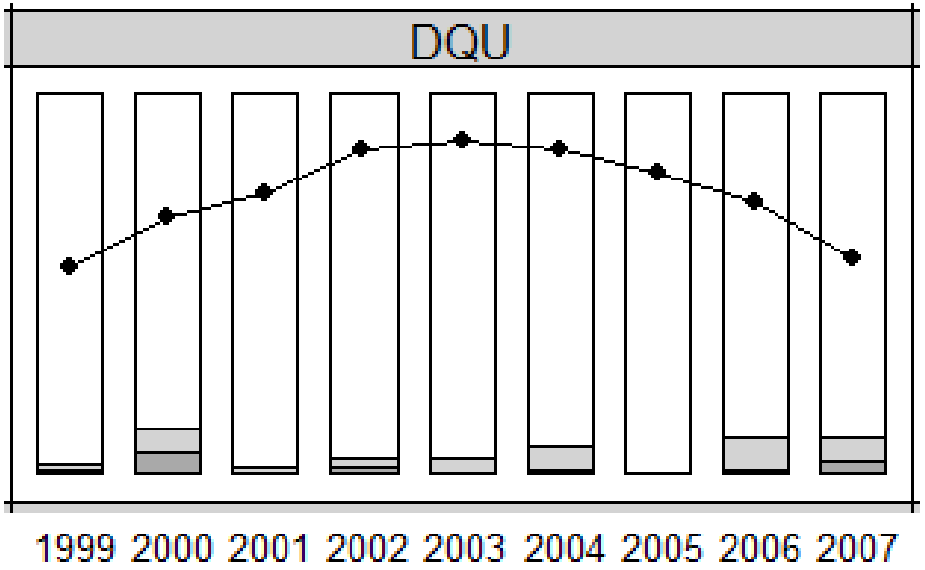

DSC
100
80
60
40
20
0
1999 2000 2001 2002 2003 2004 2005 2006 2007

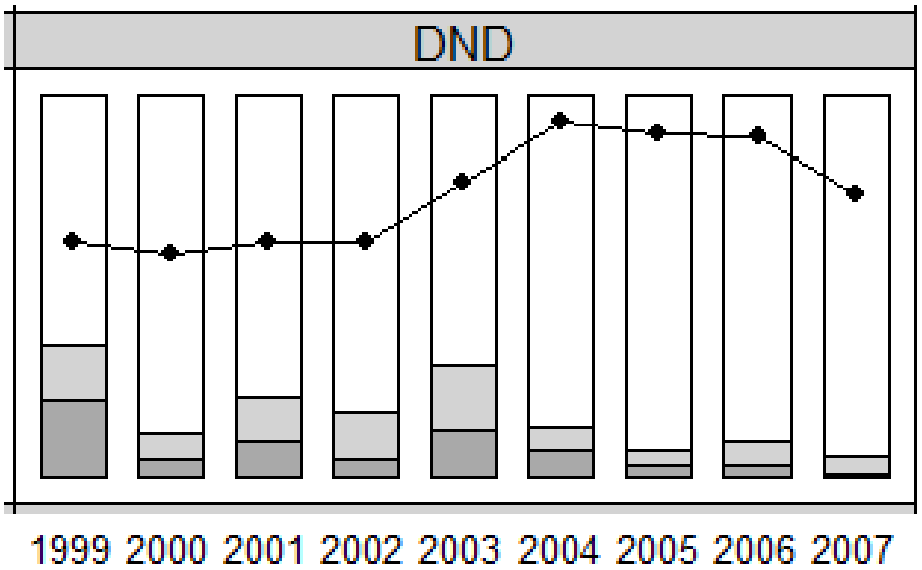

DSS N
1999 2000 2001 2002 2003 2004 2005 2006 2007

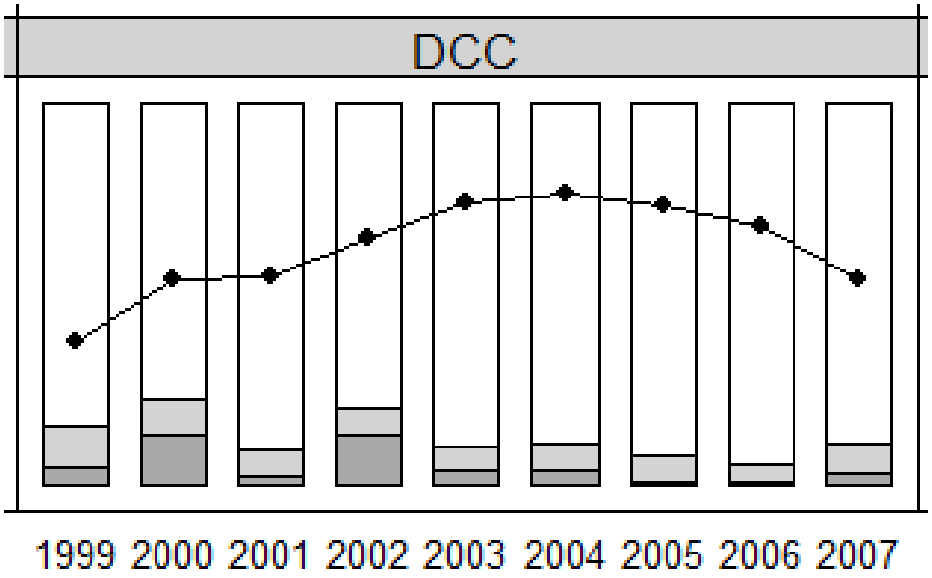

DKM
1999 2000 2001 2002 2003 2004 2005 2006 2007

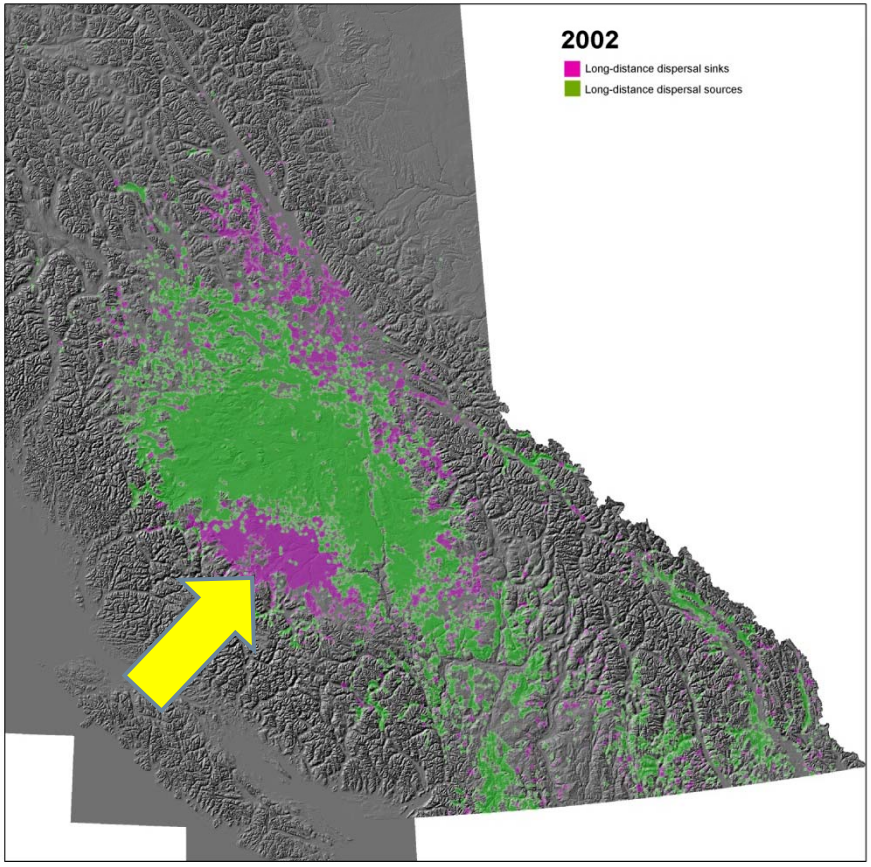

DAB
100
80
60
40
20
0
1999 2000 2001 2002 2003 2004 2005 2006 2007
DCH
1999 2000 2001 2002 2003 2004 2005 2006 2007
DHW
1999 2000 2001 2002 2003 2004 2005 2006 2007
DKL
1999 2000 2001 2002 2003 2004 2005 2006 2007
DOS
1999 2000 2001 2002 2003 2004 2005 2006 2007
DPG
1999 2000 2001 2002 2003 2004 2005 2006 2007

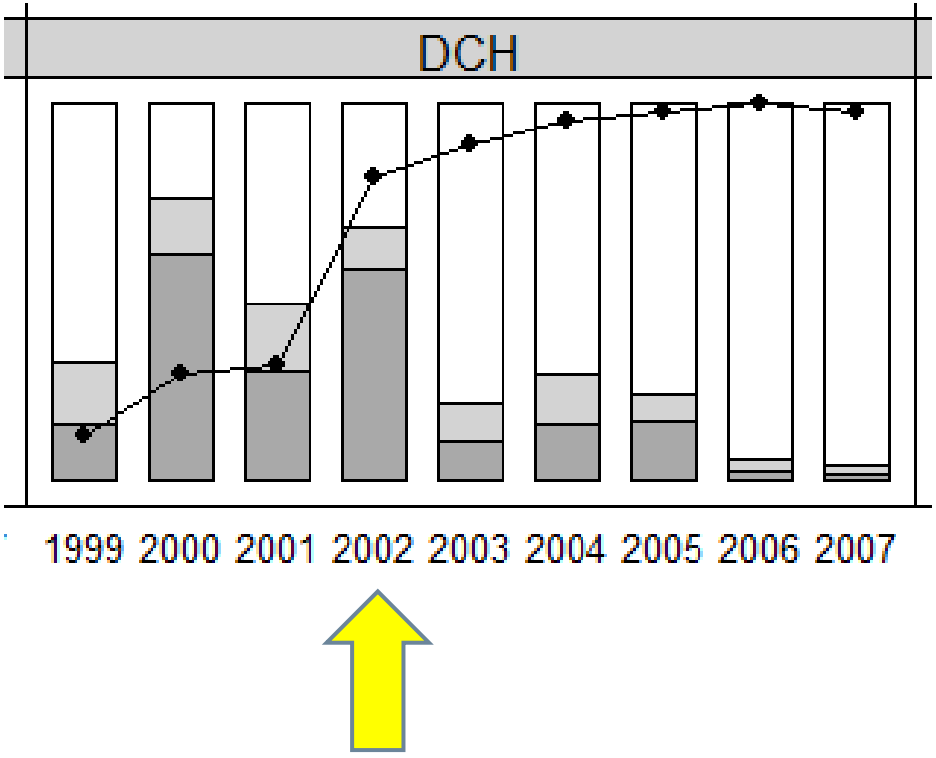

DVA
1999 2000 2001 2002 2003 2004 2005 2006 2007

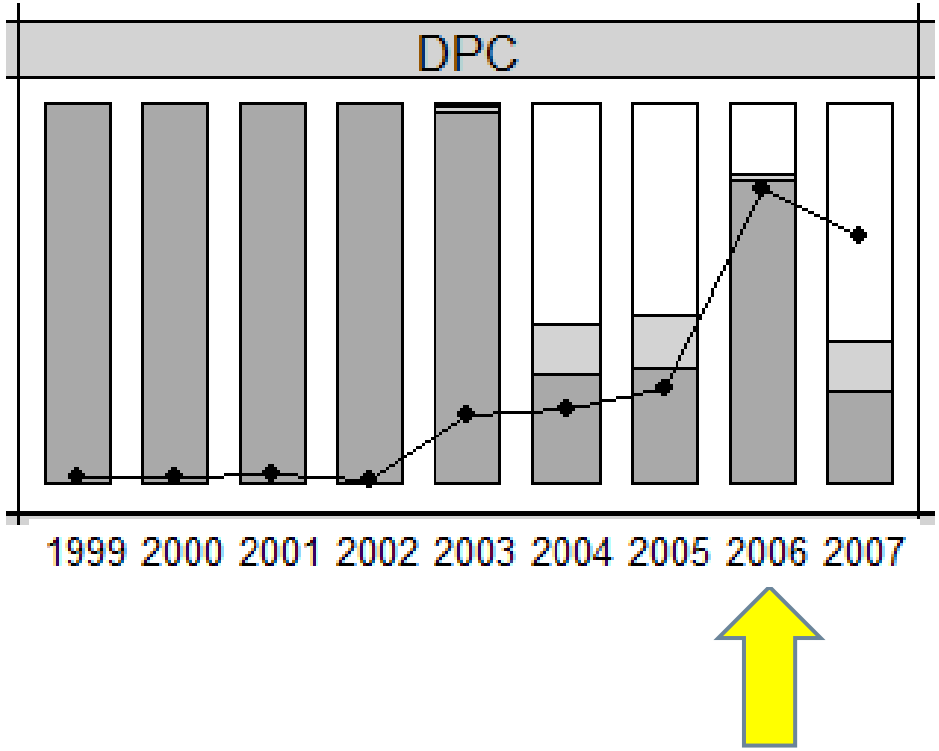

DQU
1999 2000 2001 2002 2003 2004 2005 2006 2007

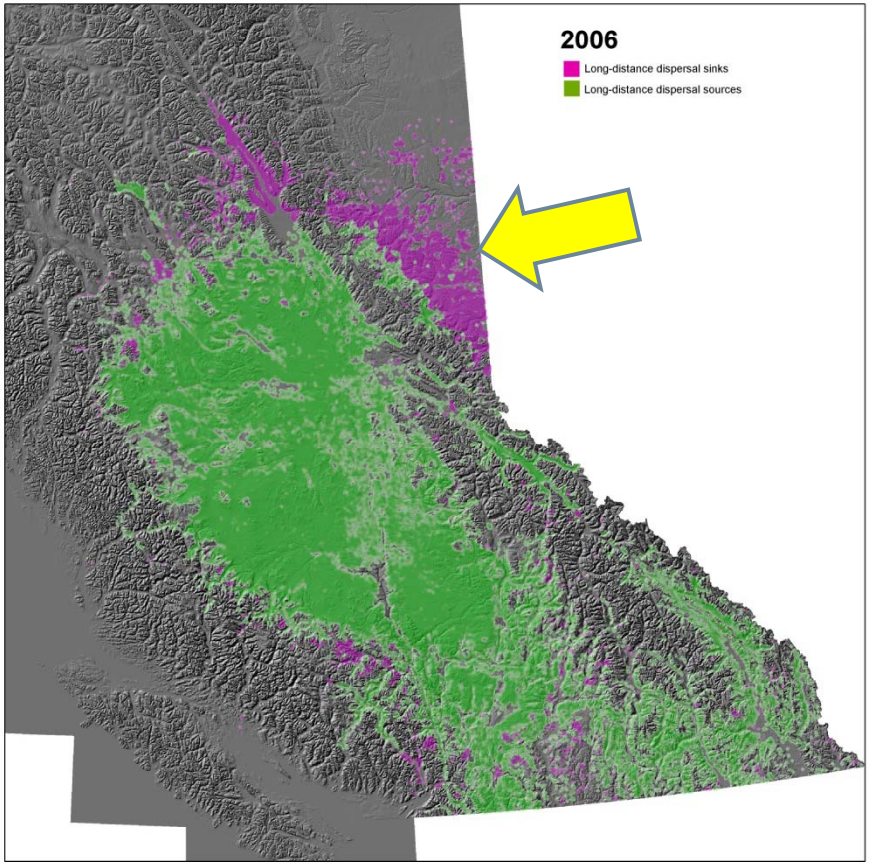

DND
1999 2000 2001 2002 2003 2004 2005 2006 2007


DCC
1999 2000 2001 2002 2003 2004 2005 2006 2007


2002
Long-distance dispersal sinks
Long-distance dispersal sources


DCH
1999 2000 2001 2002 2003 2004 2005 2006 2007

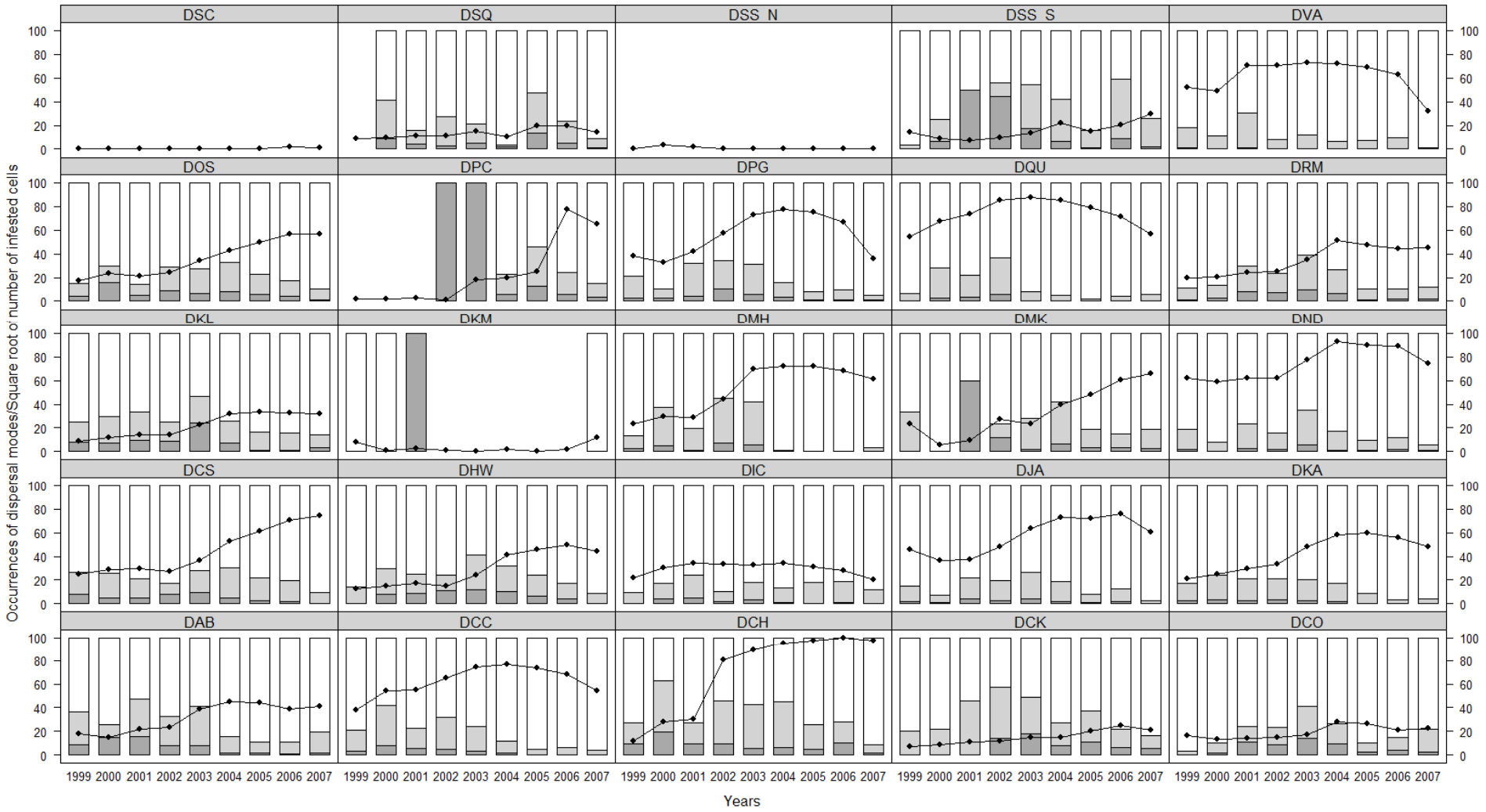

DPC
1999 2000 2001 2002 2003 2004 2005 2006 2007


2006
Long-distance dispersal sinks
Long-distance dispersal sources

# Results



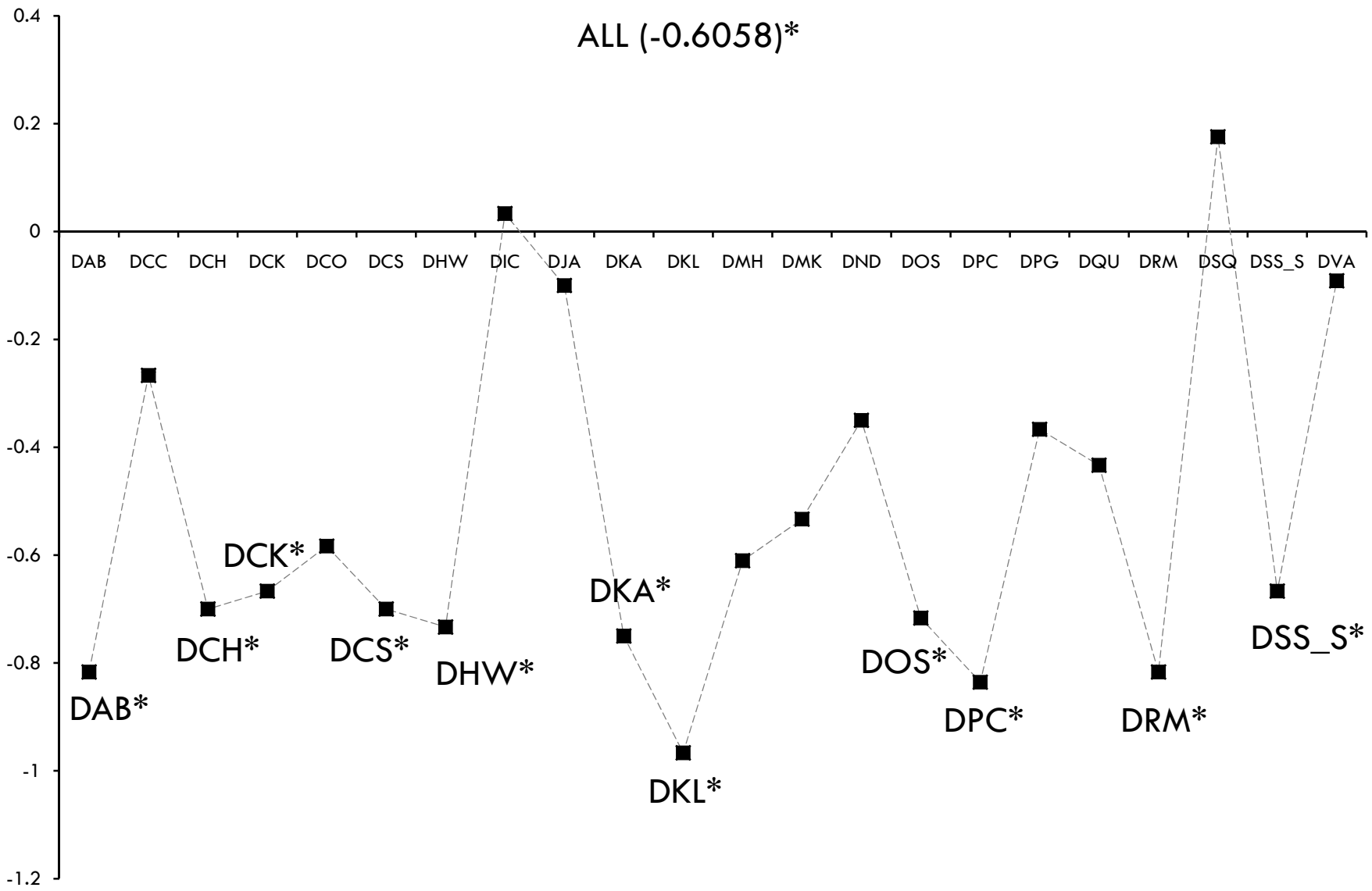
- Dispersal at the local (district) scale
  - The occurrences of three modes of mountain pine beetle dispersal to infested areas


DSC
DSQ
DSS_N
DSS_S
DVA
DOS
DPC
DPG
DQU
DRM
DKL
DKM
DMH
DMK
DND
DCS
DHW
DIC
DJA
DKA
DAB
DCC
DCH
DCK
DCO
Occurrences of dispersal modes/Square root o' number of infested cells
0
20
40
60
80
100
1999 2000 2001 2002 2003 2004 2005 2006 2007
Years

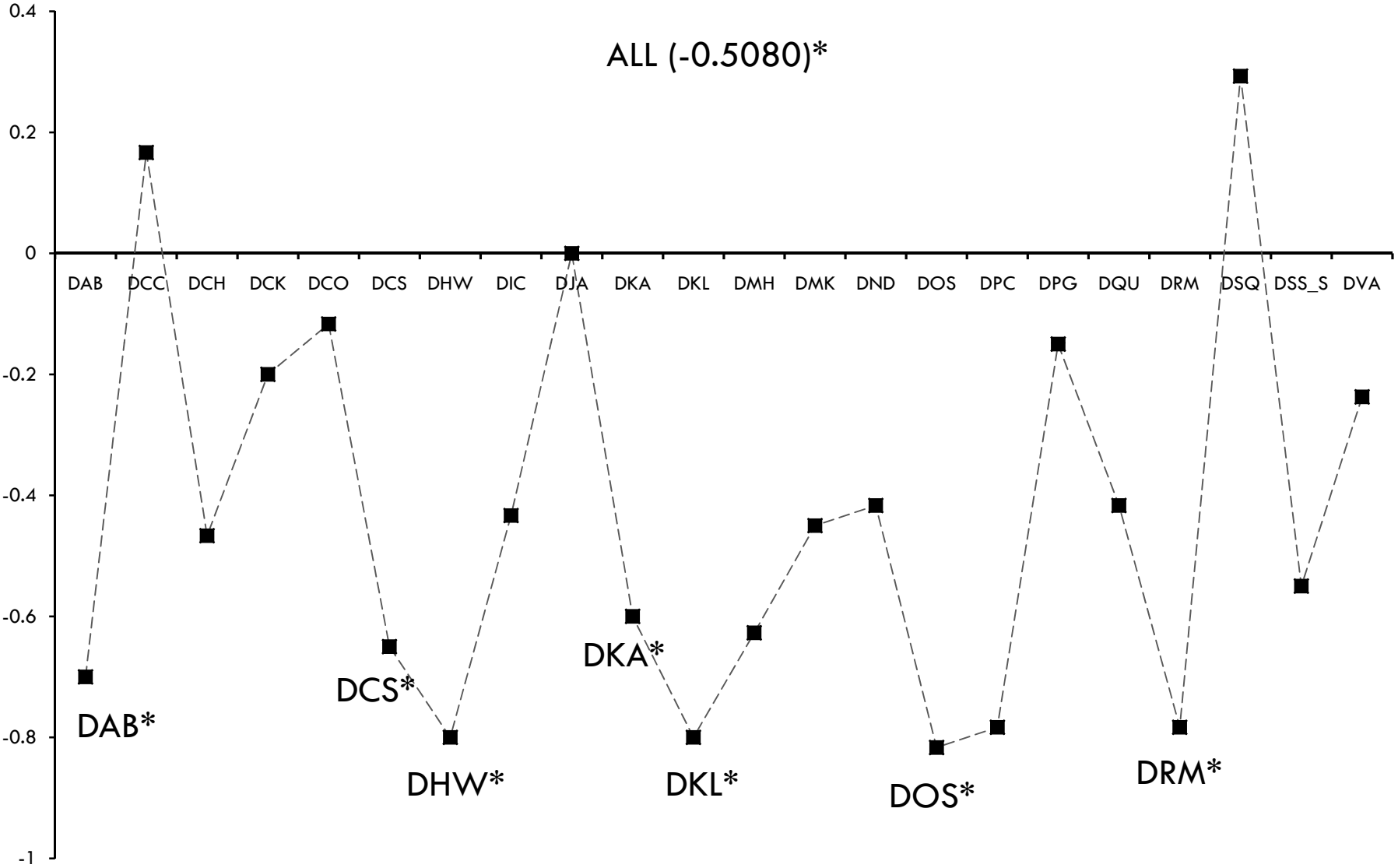
# Results



- Dispersal at the local (district) scale
  - Spearman rank coefficients of occurrences of long-distance dispersal (LDD) with total number of infested grid cells and landscape aggregation indices (AI) of the infestations
    - LDD to non-infested areas have stronger negative rank correlations between its occurrences and total number of infested grid cells, and aggregation indices of the infestations than LDD to infested areas for all districts and for most individual districts


Infested cell number
ALL (-0.6058)*
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
DAB
DCC
DCH
DCK
DCO
DCS
DHW
DIC
DJA
DKA
DKL
DMH
DMK
DND
DOS
DPC
DPG
DQU
DRM
DSQ
DSS_S
DVA
DAB*
DCH*
DCK*
DCS*
DHW*
DKA*
DKL*
DOS*
DPC*
DRM*
DSS_S*

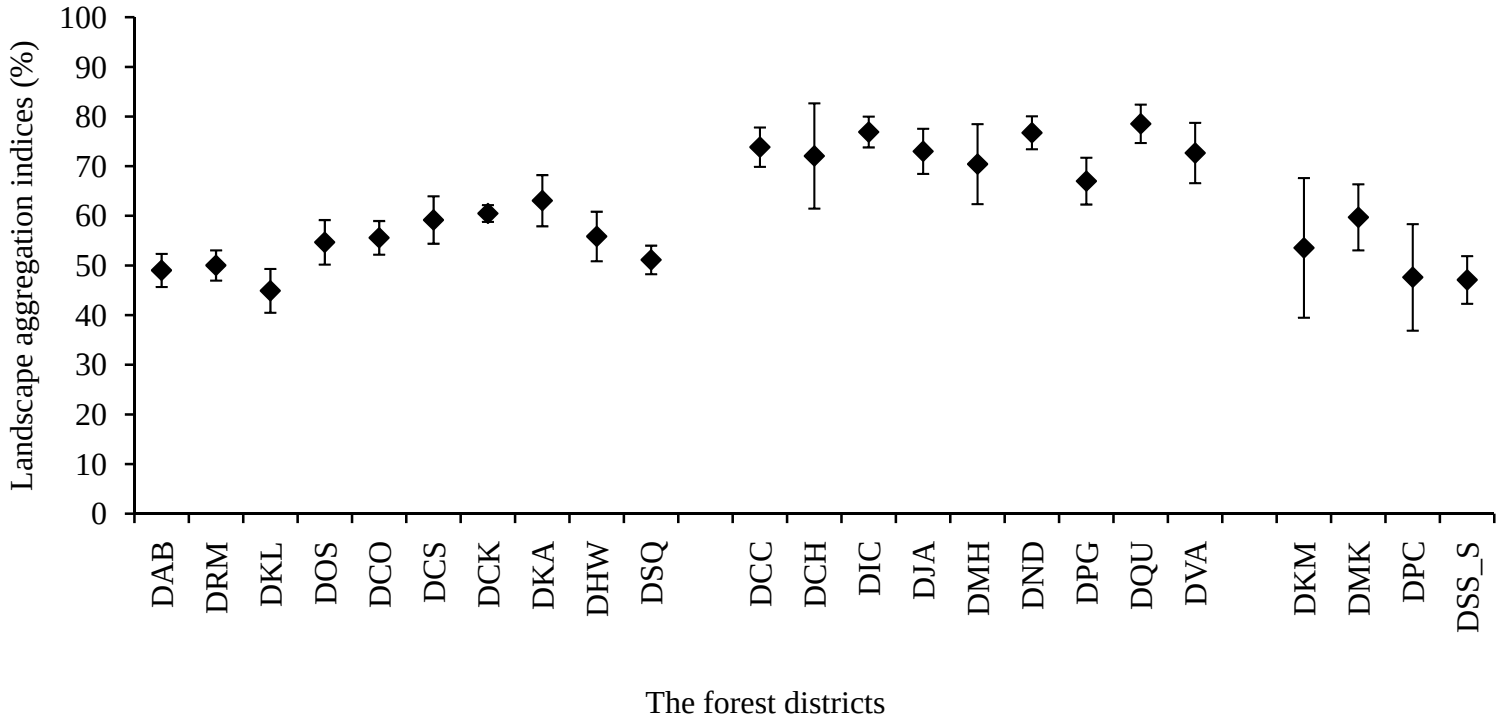
## Landscape AI



# Results



- Dispersal at the local (district) scale
  - Means of landscape aggregation indices of the infestation patches



# Discussion



- LDD plays a more important role in the early stage of infestations
  - As the infestations intensify and expand (assumed populations reaching epidemic levels), rapid depletion of the host resources may largely decrease the possibility of successful colonization for the pioneer beetles from LDD because LDD may be more costly in energy and the pioneer beetles from LDD may have a higher expectation and requirement in terms of quantity and quality of the hosts

# Conclusions

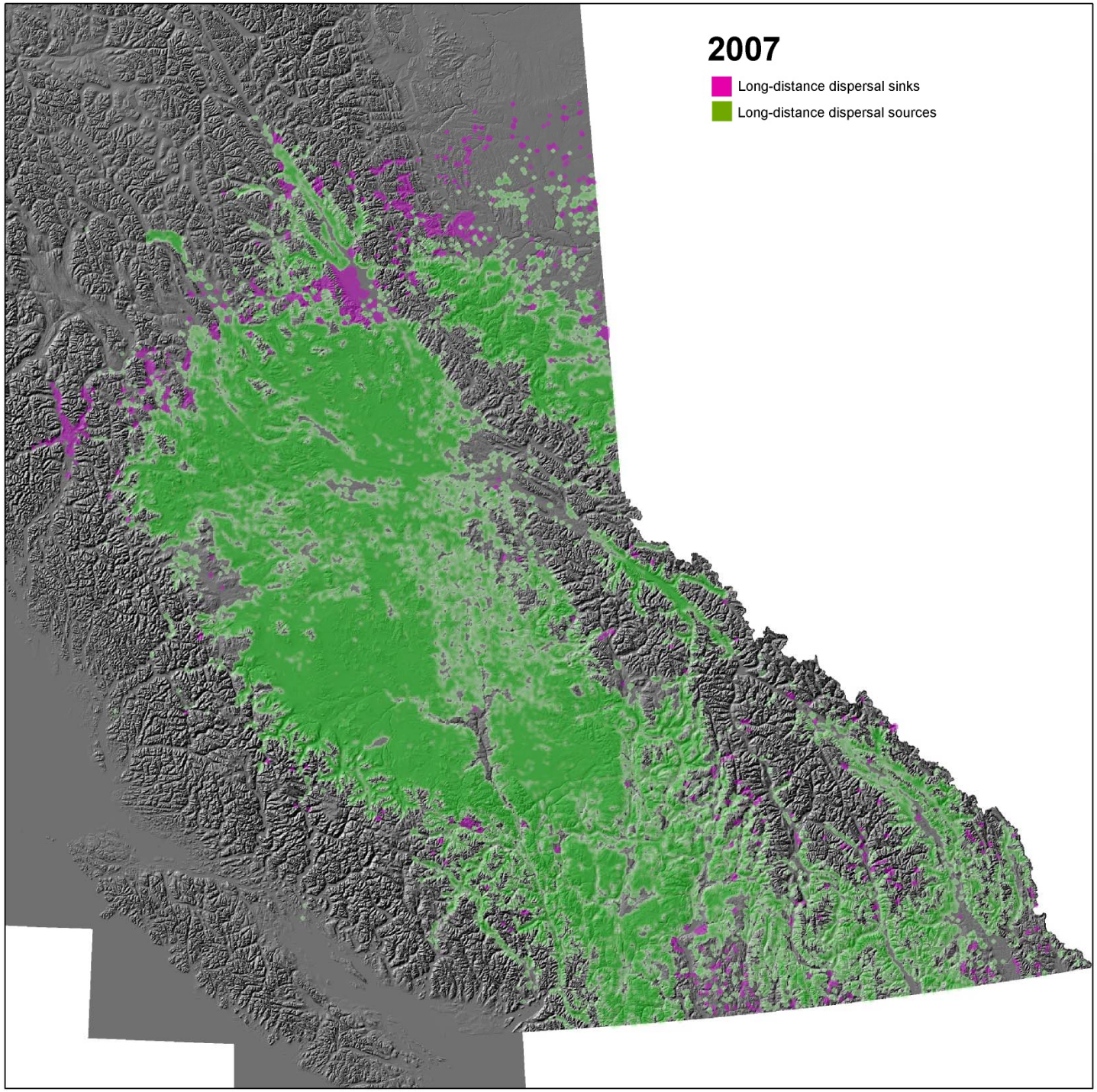


- The conceptual framework of mountain pine beetle infestations proposed in this study provides a practical and analytical approach to quantify dispersal and detect its spatiotemporal patterns at the landscape scale. This approach can be applied to other bark beetle species with long-term and sufficient monitoring data.
- The conceptual framework of MPB could be used to determine stages of infestation dynamics

# Conclusions



- LDD is a key factor in the initiation and early stage of the infestations in new remote areas and may play a critical role in expansion of the outbreak through facilitating the shifts of the beetle populations from incipient-epidemic levels to epidemic levels.


2007
Long-distance dispersal sinks
Long-distance dispersal sources

# Conclusions



- The spatiotemporal patterns of LDD can be used to detect and map potential conduits of LDD at the landscape scale, assisting to identify and prioritize the mitigation areas in strategic and tactical planning.
  - Implications to MPB management
    - LDD patterns should be considered in MPB provincial management zonations
    - LDD patterns should be considered in making suppression strategies for the BMUs
    - LDD should be considered in MPB risk rating or susceptibility systems

# Conclusions



- Future research
  - Mechanisms driving LDD
    - Link topographic modeling and meso-scale meteorological modeling together
    - Explore how topographic features interact with meso-scale meteorological events, affecting spatial patterns of LDD at the landscape scale

# Question??