Landscape-scale indicators of protected area quality and effectiveness

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The role of parks

<u>Human-focussed</u>:

- recreation
- ecosystem services
- etc.

(from whistlerblackcomb.com)

<u>Nature-focussed</u>:

- representation (species/ecosystems, biodiversity, natural processes)
- persistence of these features

(from bcadventure.com)

The performance of parks to support nature (“quality and effectiveness”)

Depends on such factors as:

- Where they are (what they contain)
- Disturbances (internal and external)
- Landscape ecology: “park design”
    - size
    - shape
    - configuration
    - context
    - connectivity

Park design has important effects

Conditions that favor/harm:

- edge species
- interior species
- invaders

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Buffering from the effects of disturbances

Support for dispersal and migration

Others...

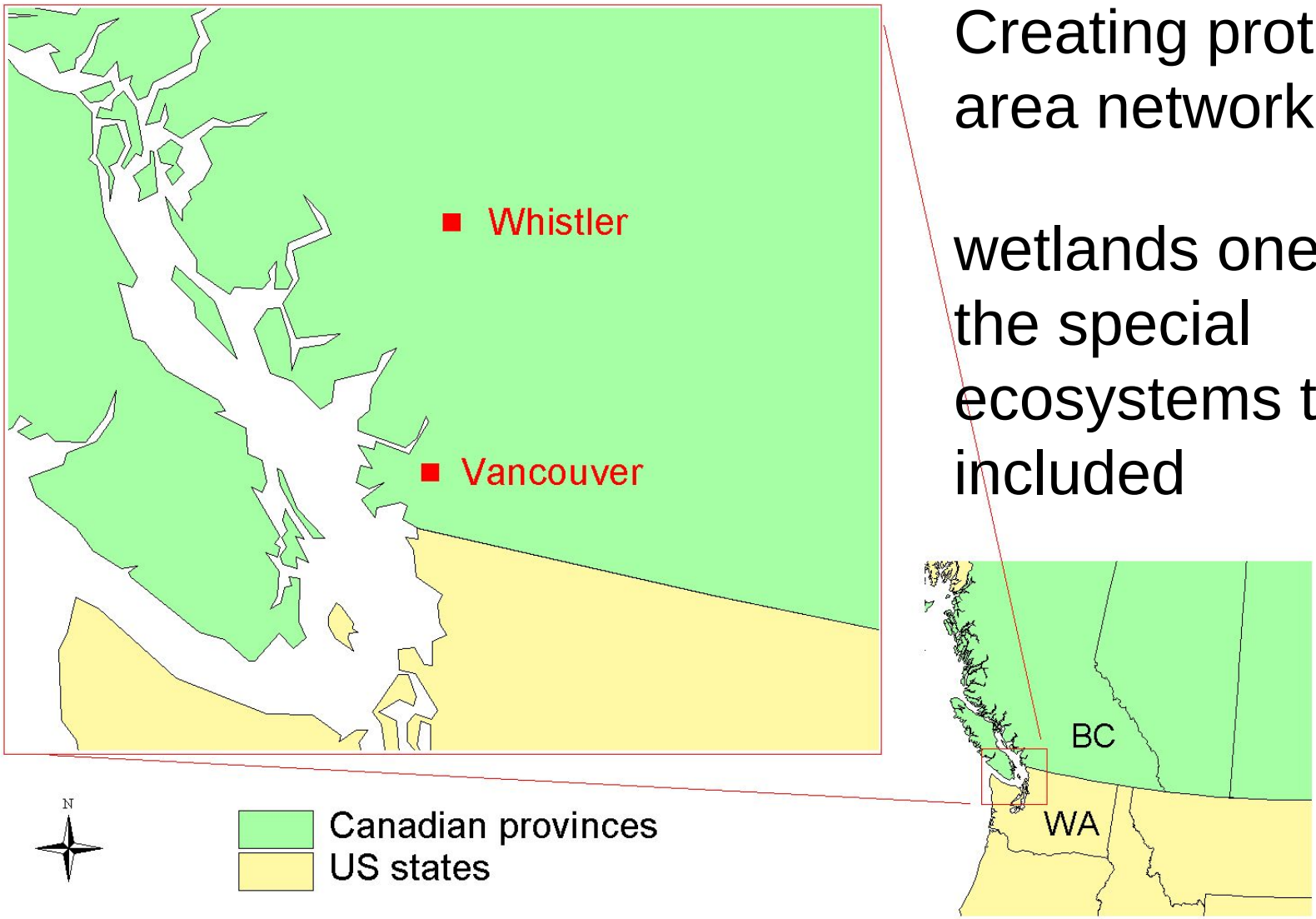
Park design challenges

- How can we "measure design" (are there landscape-scale indicators that can help us predict if parks will be effective?)

- Quality of design depends on species in question

- Land use/cover changes inside AND outside influence the effectiveness and quality of parks

Case study: wetlands in Whistler, BC



Creating protected area network

wetlands one of the special ecosystems to be included

Importance of design for wetlands

Size:

- larger wetlands support larger populations

Shape:

- rounder wetlands have more interior, less susceptible to disturbance

(from harwoods-lane.org.uk)

Connectivity:

- used as corridors by a variety of organisms
- dispersal of wetland organisms

Challenges for wetland Whistler PA designers

1. Major changes since the 1940's...

- how does what used to be there compare with what's there now?

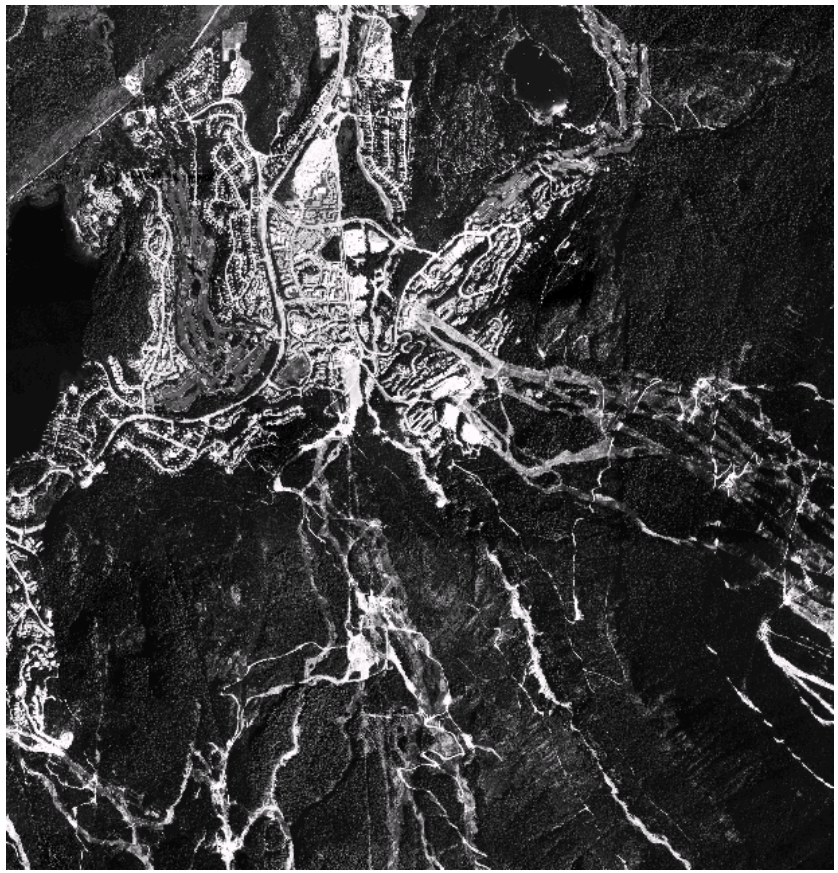
2. Major changes to the wetlands themselves AND changes to the matrix

- what has been the role of changes in wetland extent vs. changes in matrix conditions?

3. Many metrics

How will our assessment of effectiveness/quality change depending on the metrics we use?

The remotely-sensed data



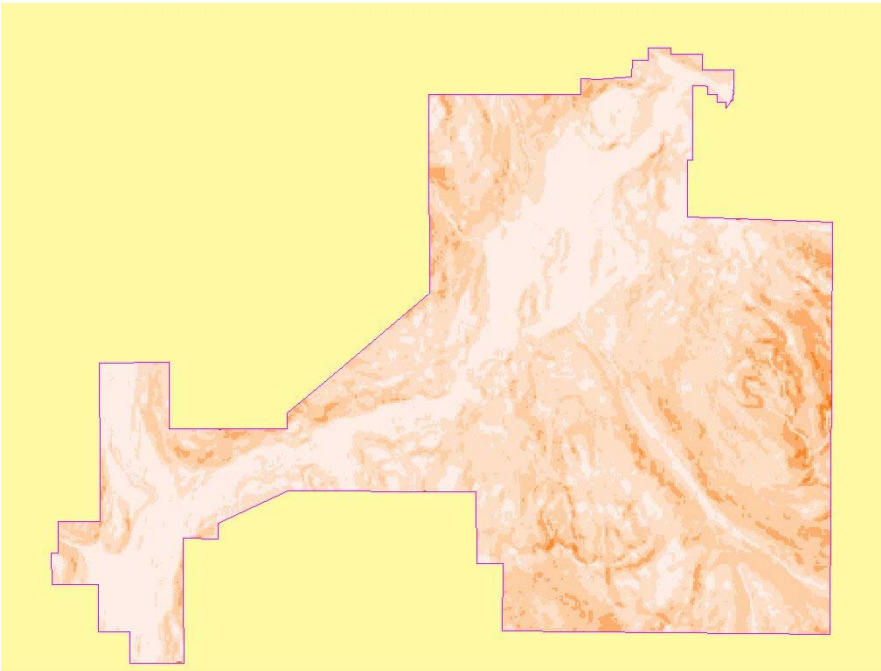
Provincial aerial photo archive

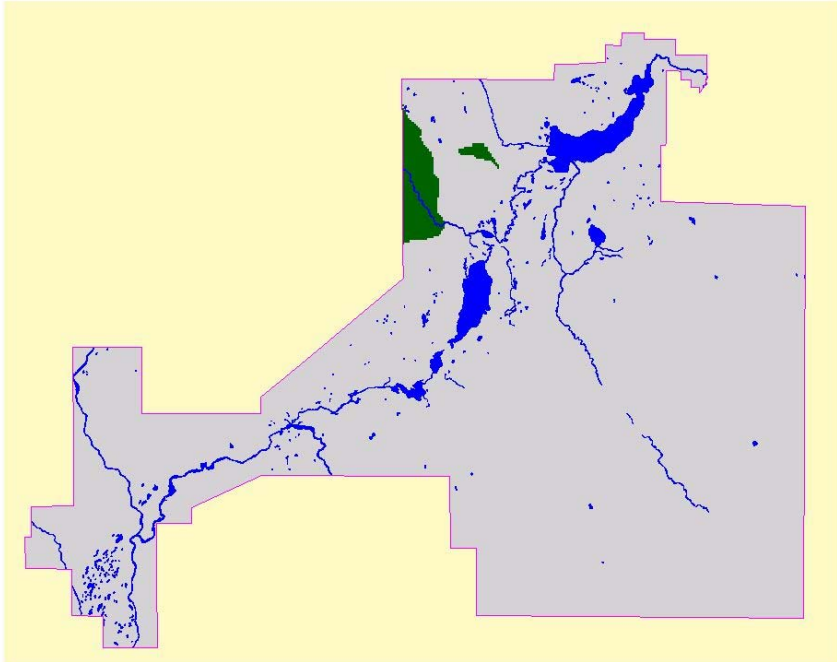
Obtained fours sets of photos:

Date	Reason chosen:
1946	earliest available, post-railway but pre-highway
1969	post-highway, Whistler Mt. (skiing) Open
1982	post-Whistler Village, Blackcomb Mt. (skiing) open
2003	post-1990's development explosion

Additional data

Raster: slope layer





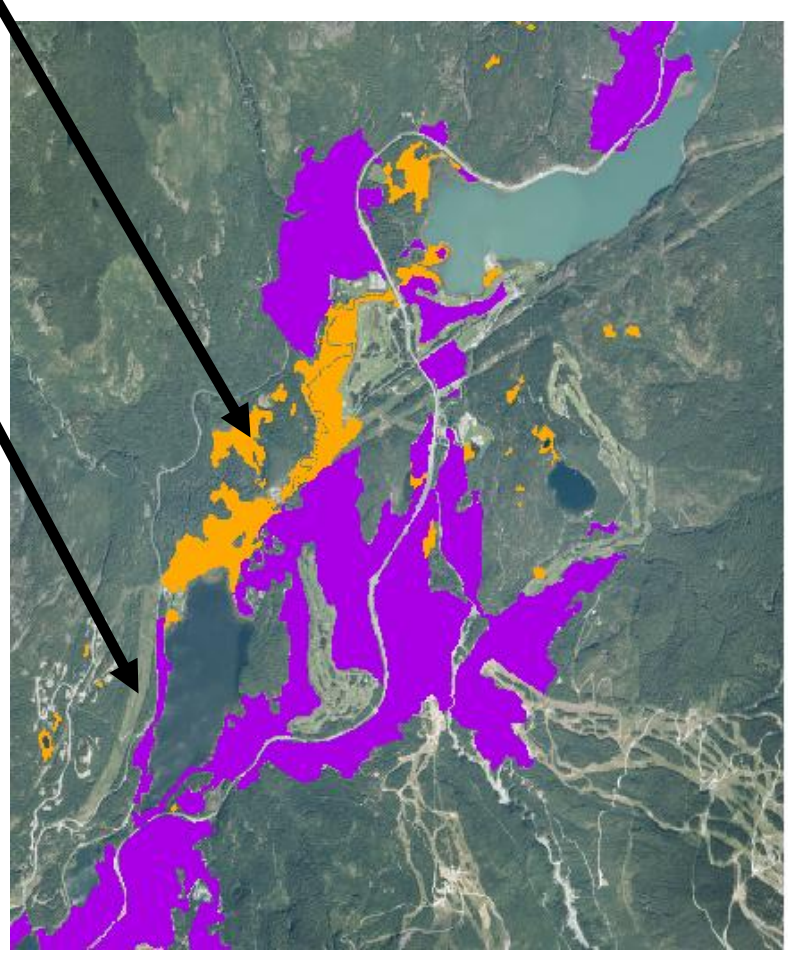
Vector: major water bodies and streams

Step 1: photointerpretation

Digitize boundaries of wetland in each photo

Digitize development footprint in each photo

Result: 4 sets of polygons (1946, 1969, 1982, 2003)



Step 2: “standard” measures of landscape pattern (Fragstats)

1. total area
2. mean patch size
3. total edge
4. mean shape index
5. mean patch fractal dimension
6. total core area
7. mean core area

Result: how have individual wetlands changed over time according to these metrics?

Step 2: “standard” measures of landscape pattern

Risks of relying on standard measures:

1. reliability of connectivity metrics? (mean patch size?)

2. Wetlands are evaluated individually as opposed to members of a network (e.g., are there key stepping stones?)

3. Non-functional: ignores effect of the matrix

Step 3: graph-model based measure of connectivity

An alternative conceptual model for representing space:

habitat patches are represented by “nodes”

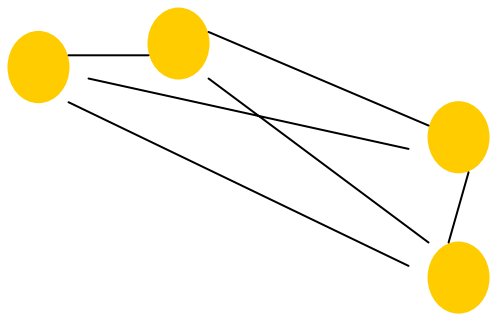
“edges”: paths between patches

straight-line distance

least cost path (e.g., consider roads, golf courses, etc.)

“cluster”: group of nodes for which

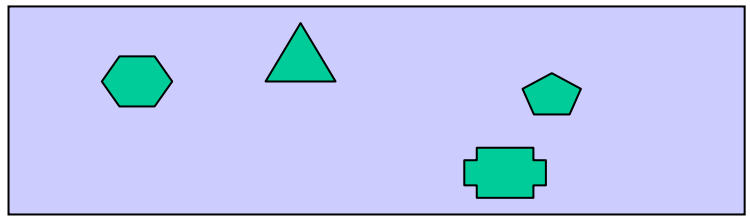
all edges <= dispersal distance *d*



Graph models to measure landscape connectivity

To measure connectivity of a landscape for an organism with maximum dispersal distance *d*:

1) replace the habitat patches with nodes



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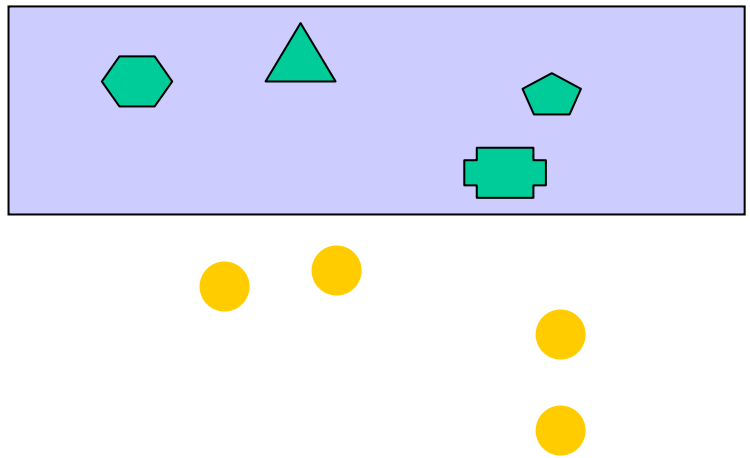

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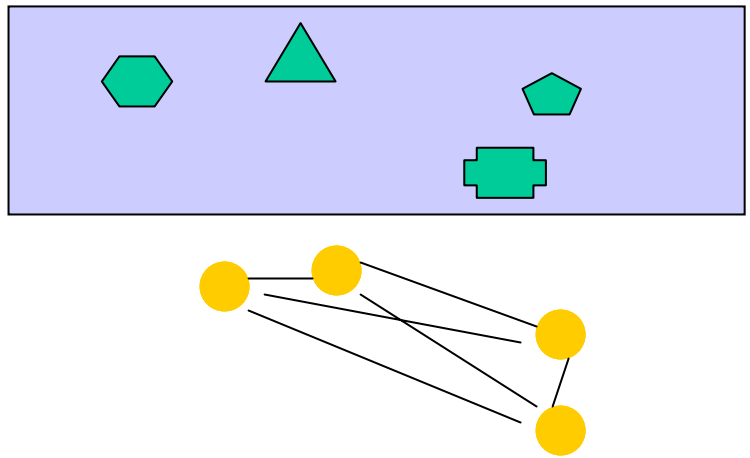

Graph models to measure landscape connectivity

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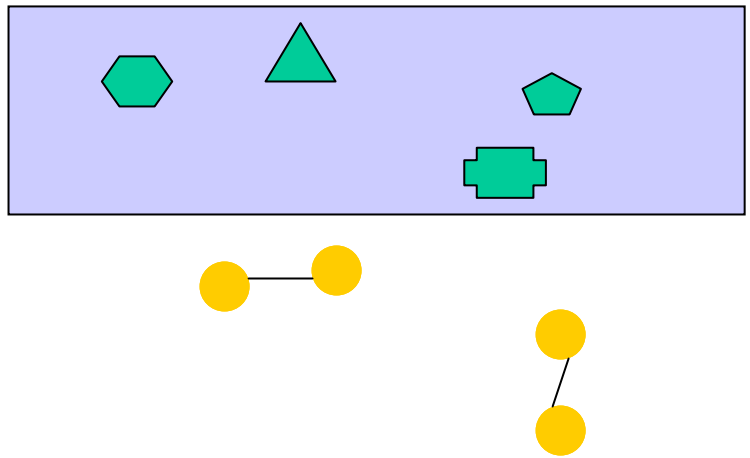
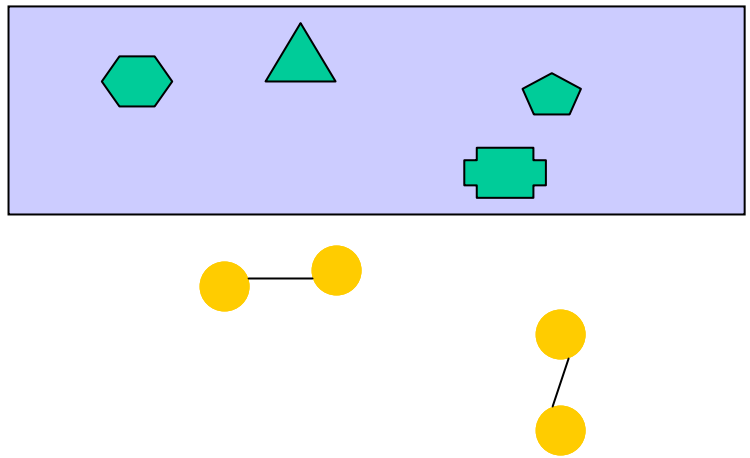


Graph models to measure landscape connectivity

To measure connectivity of a landscape for an organism with maximum dispersal distance *d*:

1) replace the habitat patches with nodes
2) calculate the edge distance between the patches
3) remove all edges > *d*
4) calculate the "size" of all the clusters in the landscape

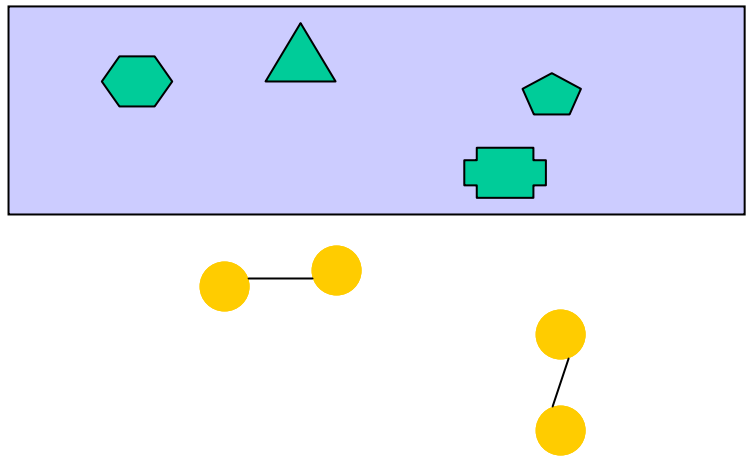


R"radius of gyration" (average distance to the center of the cluster):

$$R_i = \frac{1}{n_i} \sum_{j=1}^{n_i} \sqrt{\left(x_j - \bar{x}_i\right)^2 * \left(y_j - \bar{y}_i\right)^2}$$

Graph models to measure landscape connectivity

To measure connectivity of a landscape for an organism with maximum dispersal distance *d*:

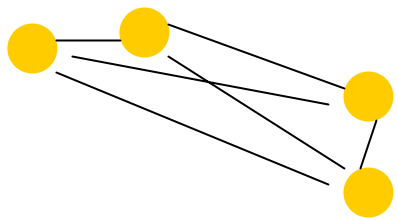


1) replace the habitat patches with nodes
2) calculate the edge distance between the patches
3) remove all edges > *d*
4) calculate the "size" of all the clusters in the landscape
5) calculate the correlation length, C_d, the average cluster size for the landscape

$$C_d = \frac{\sum_{i=1}^{m} n_i R_i}{\sum_{i=1}^{m} n_i}$$

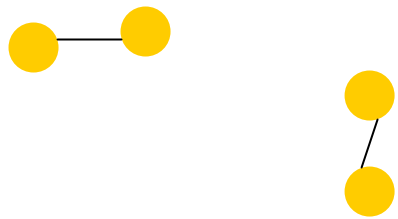
Graph models to measure landscape connectivity

For a “good” disperser
- high *d*



- high average cluster size
- high correlation length, C_d
- highly connected

For a “poor” disperser
- low *d*



- low average cluster size
- low correlation length, C_d
- poorly connected

Step 3: graph-based measure of connectivity

Our patch maps were the wetlands from the aerial photos

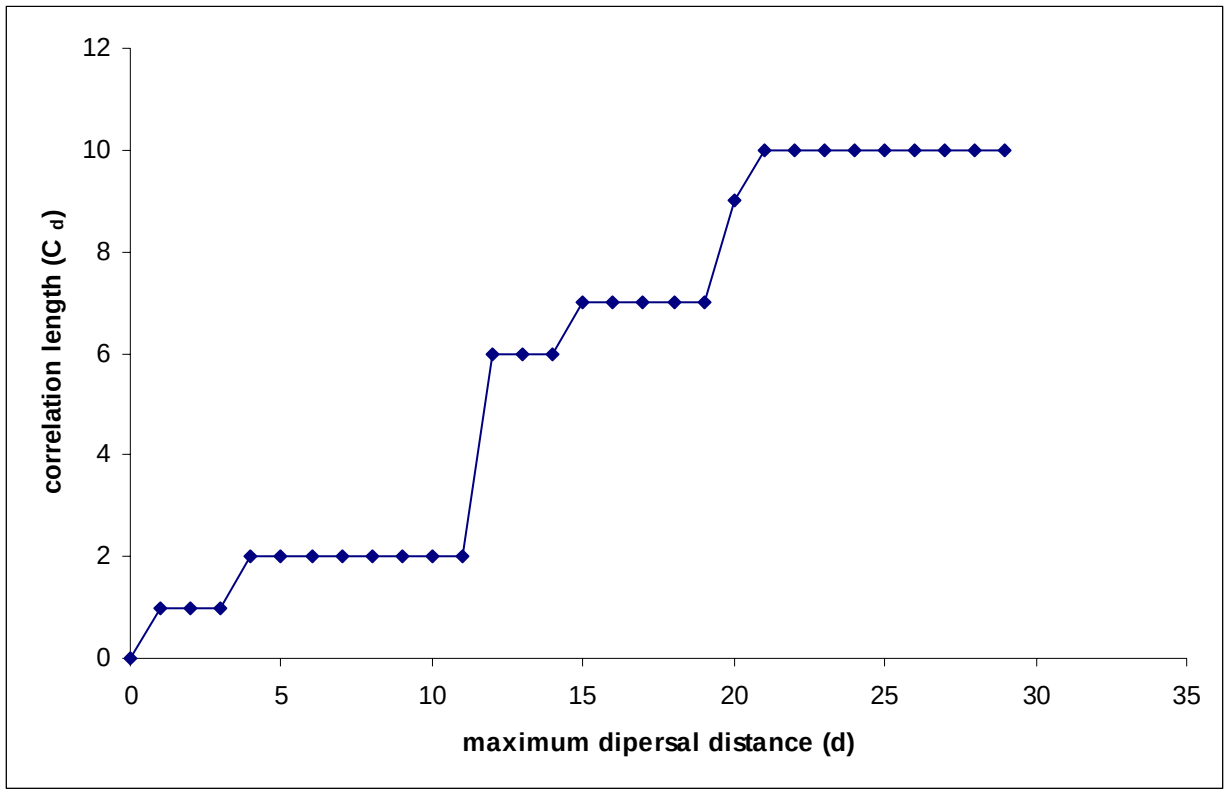
Step 3: graph-based measure of connectivity

Edge distance between patch nodes calculated from ancillary data and aerial photo

Resistance surface, 1982

Step 3: graph-based measure of connectivity

Quantify connectivity of each graph for each disperser



Step 3: graph-based measure of connectivity

Version 1:

wetland map	resistance surface
1946	1946
1969	1969
1982	1982
2003	2003

Result: how has connectivity changed for wetlands over time?

Step 3: graph-based measure of connectivity

Version 2:

	1946 Patch	1969 Patch	1982 Patch	2003 Patch
1946 Matrix	Original	Patch Effect		
1969 Matrix	Matrix Effect	Original	Patch Effect	
1982 Matrix		Matrix Effect	Original	Patch Effect
2003 Matrix			Matrix Effect	Original

- Effect of the Highway
- Effect of Ski Development
- Effect of Urban Development

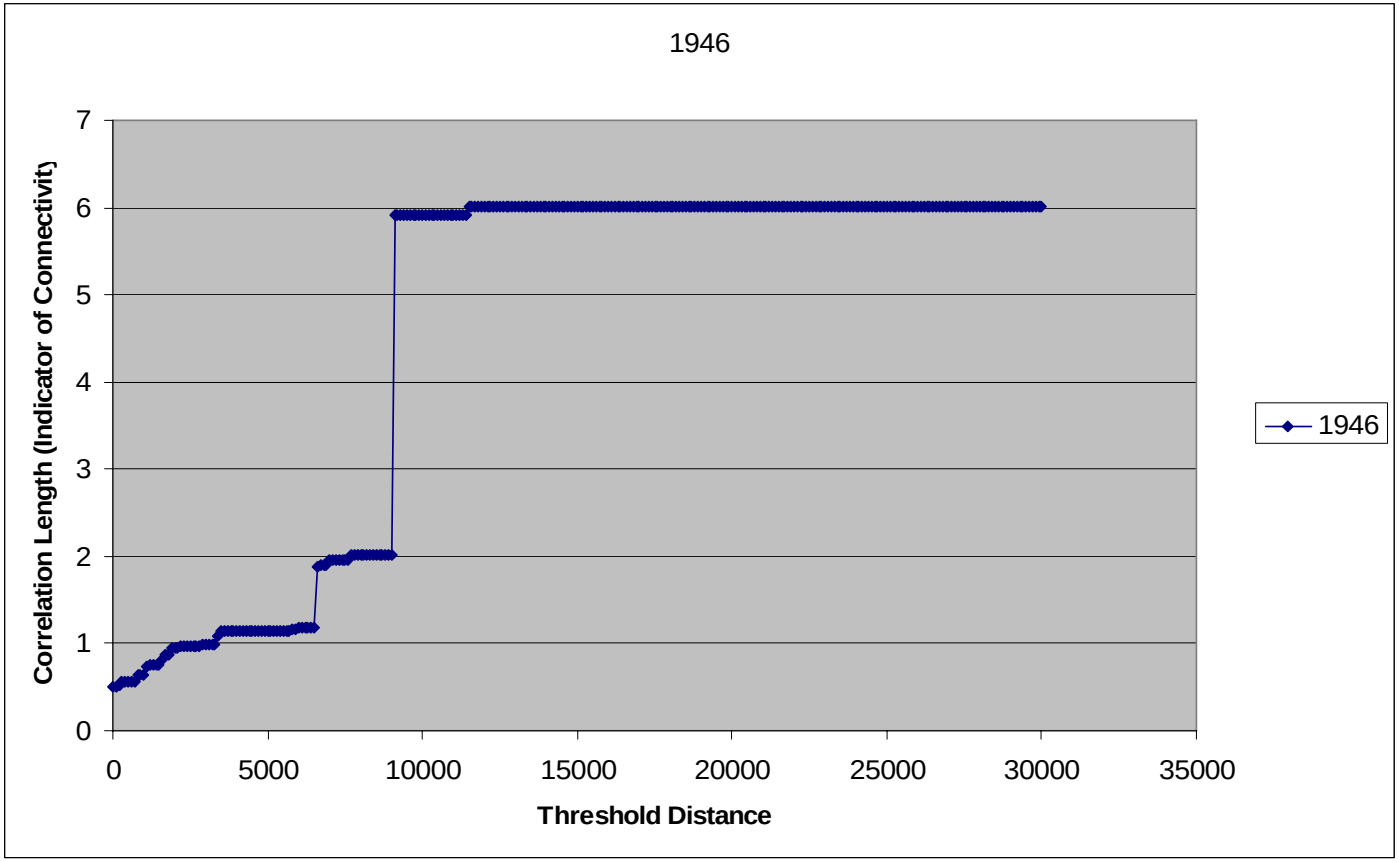
Results: standard measures of landscape pattern

	Number of Patches	Class Area	Mean Patch Size	Total Edge	Mean Shape Index	Mean Patch Fractal Dimension	Total Core Area	Mean Core Area
1946	80	604.44	7.56	114450	1.55	1.08	419.31	5.24
1969	67	505.88	7.55	90450	1.55	1.08	358.38	5.51
1982	66	426.44	6.46	82350	1.54	1.08	294.62	5.26
2003	67	169.94	2.54	60350	1.54	1.08	79.94	1.63

- loss in number
- loss in total area
- loss in mean area
- loss in interior habitat

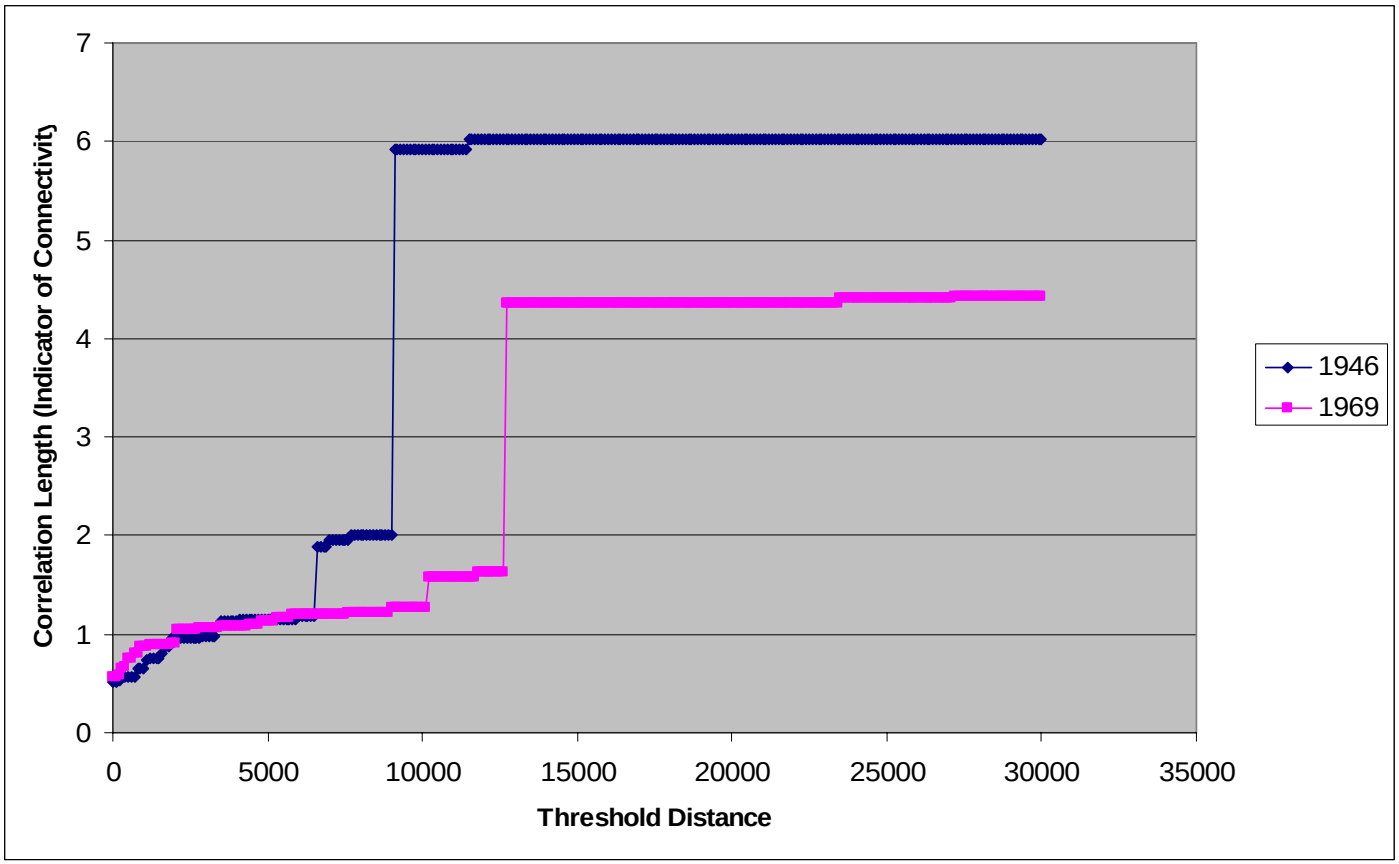
But what about connectivity???

Results: 1946



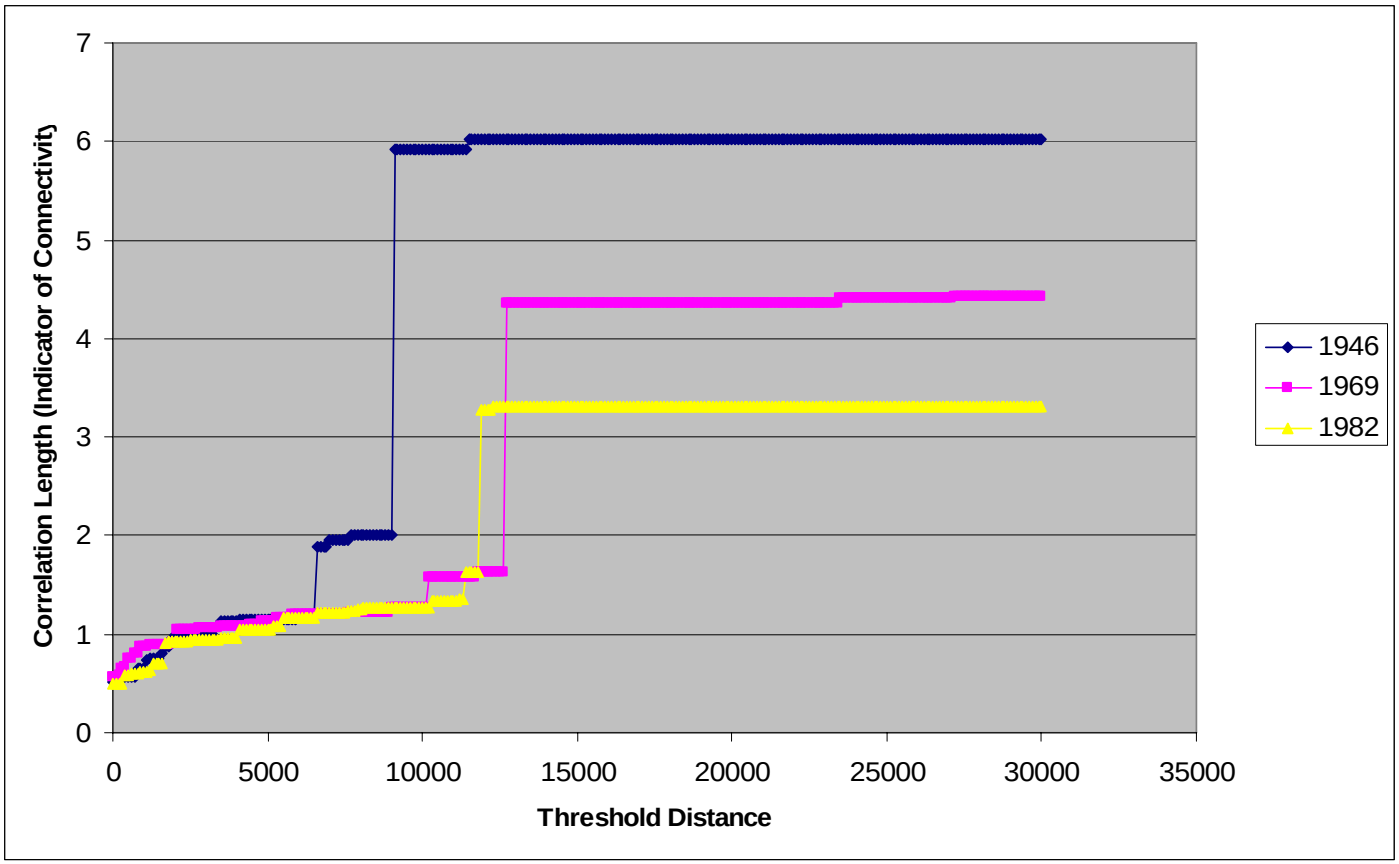
- wetlands form single cluster for most organisms
- several smaller clusters for poorer dispersers

Results: 1946, 1969



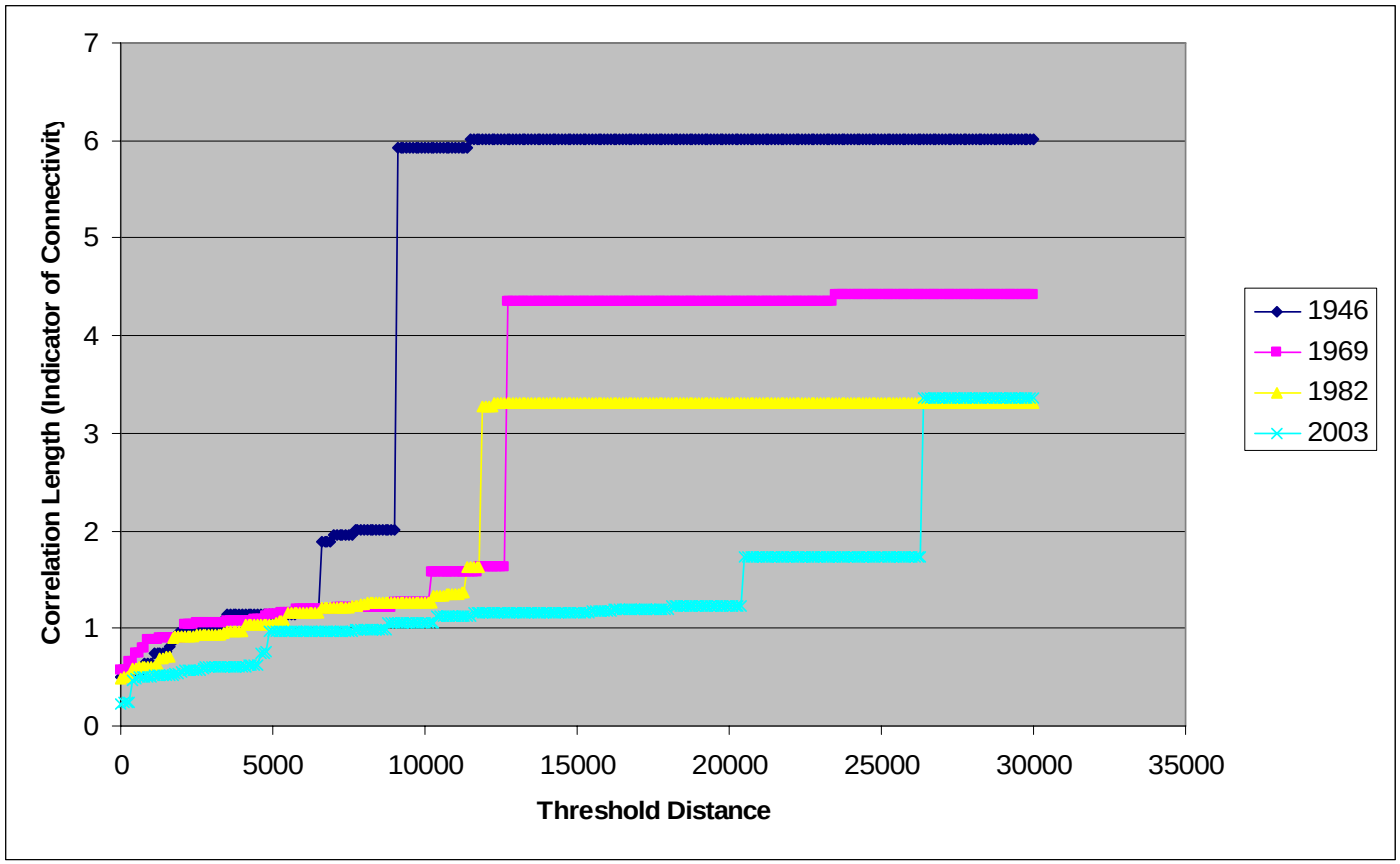
- loss in connectivity for nearly all organisms
- landscape becomes disconnected “sooner”

Results: 1946, 1969, 1982



- again, loss in connectivity for nearly all organisms
- recovery of connectivity for one group

Results: 1946, 1969, 1982, 2003



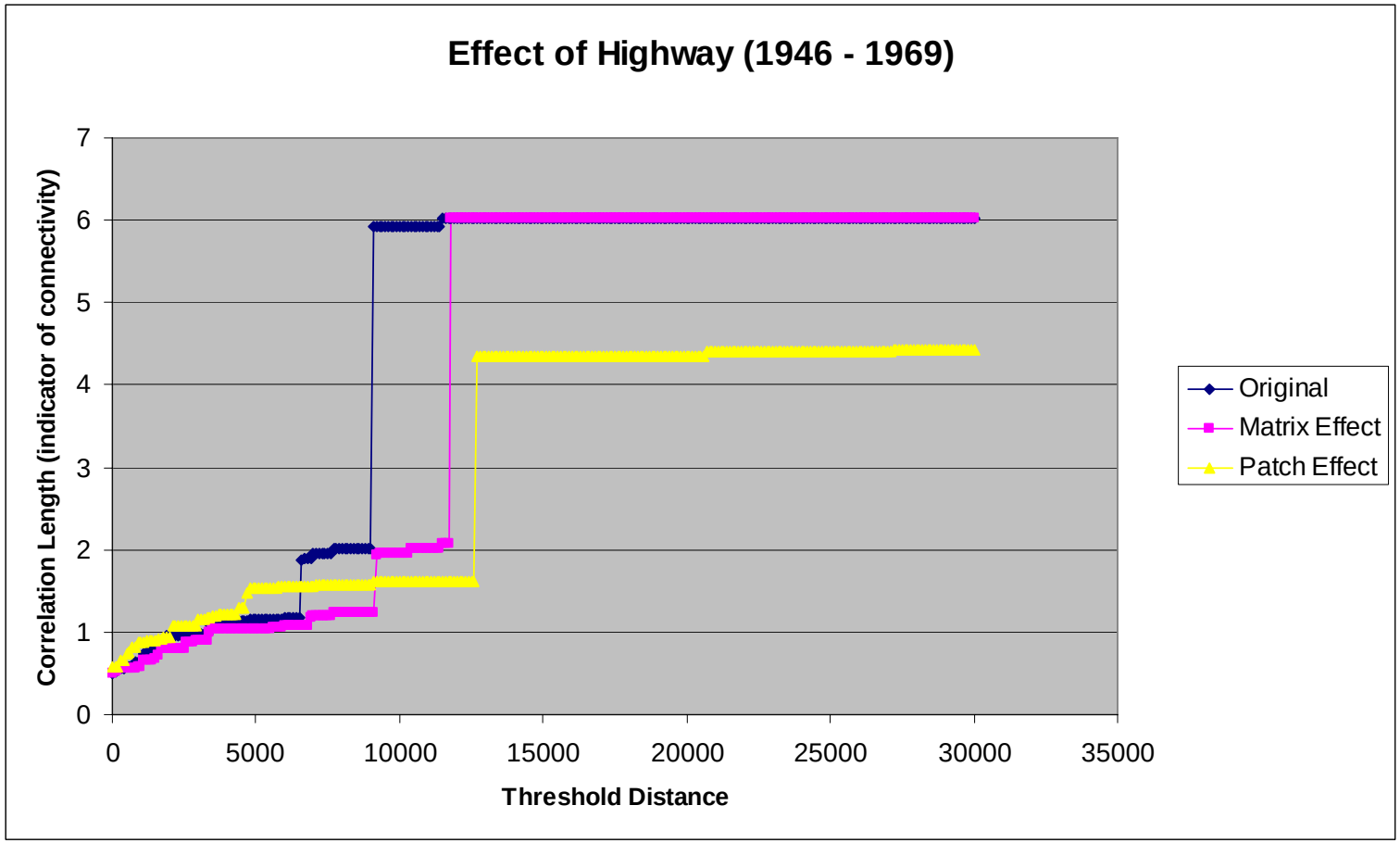
- no change for best dispersers
- intermediate dispersers have big loss again

Are losses in connectivity due to:

- wetland patches?
- changes to the matrix?

More questions that the graph-metrics can answer...

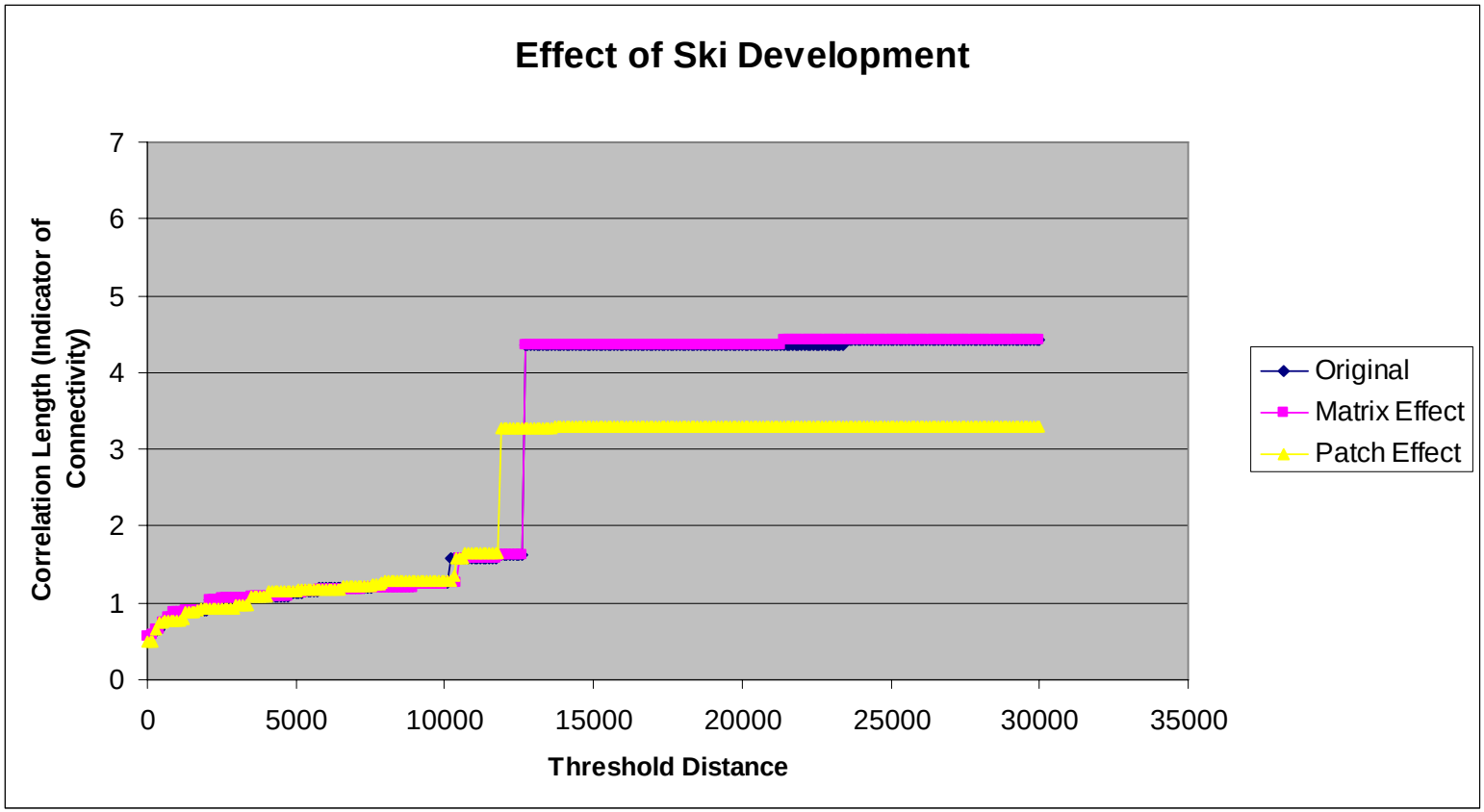
Effect of implementation of the highway + Whistler Mt.



- introduction of highway/skiing hurt intermediate dispersers

- changes to wetland patches hurt everybody

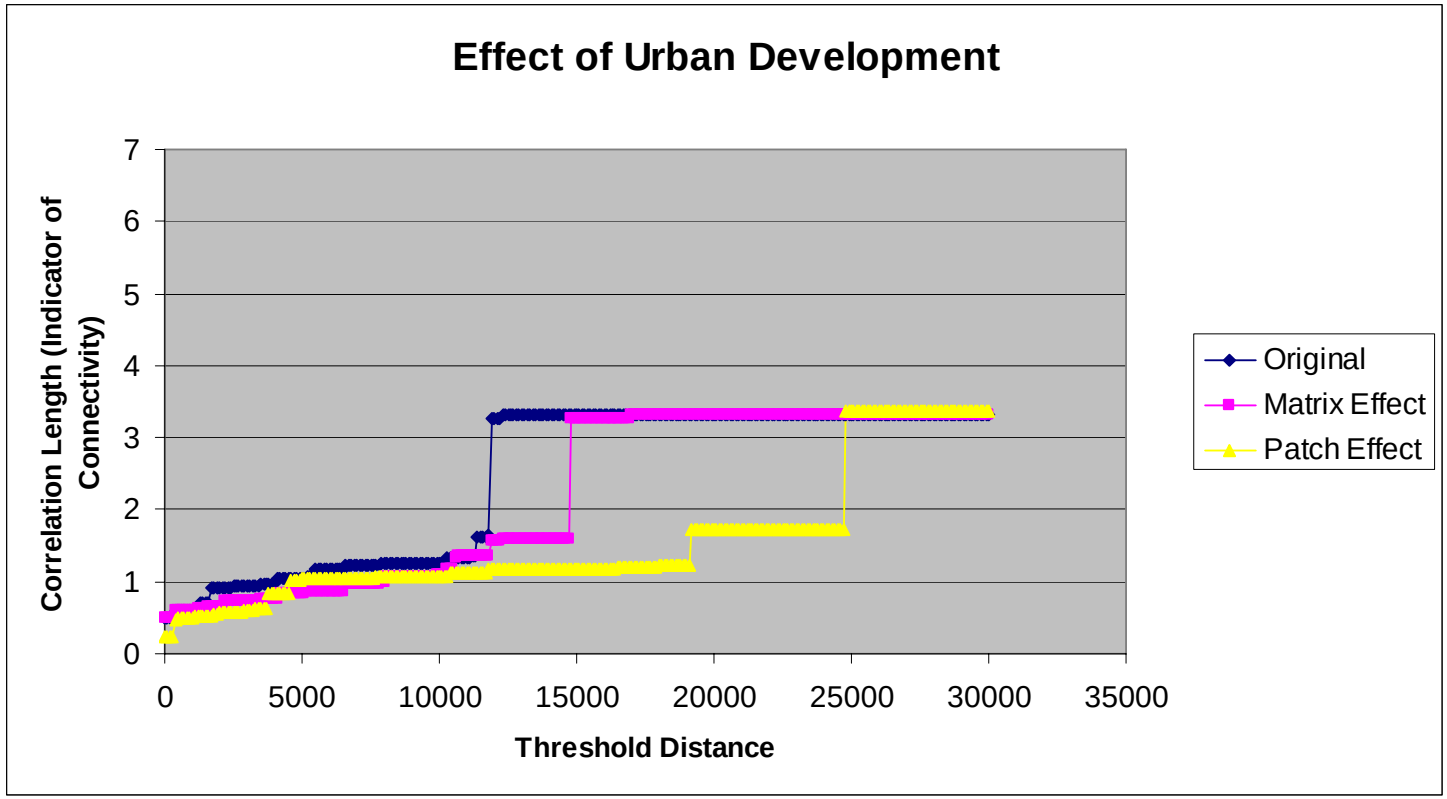
Effect of implementation of the village + Blackcomb Mt.



- introduction of village/skiing hurt most good dispersers

- changes to matrix had no effect (connectivity already compromised)

Effect of intense development (1982-2003)



- changes to wetlands by development hurt everyone

- changes to matrix hurt intermediate dispersers

Major conclusions for Whistler

Wetlands have changed substantially since 1940's

- total area, number of patches, etc.

Losses in connectivity, particularly for best dispersers

Losses result of changes to wetland patches AND changes to the matrix

Protected area designation should include guidelines for inclusion of wetlands AND development guidelines for sites outside the protected area

Applicability: major conclusions for parks

Consider design metrics that look at habitat and the matrix

Park quality/effectiveness can be substantially influenced by land use changes outside the boundaries

Graph-metrics of connectivity are easy to use (e.g., SELES) and require relatively little data (habitat map, resistance map) that can come from remote sensing