Quantifying the relative importance of multiple stressors faced by polar bears

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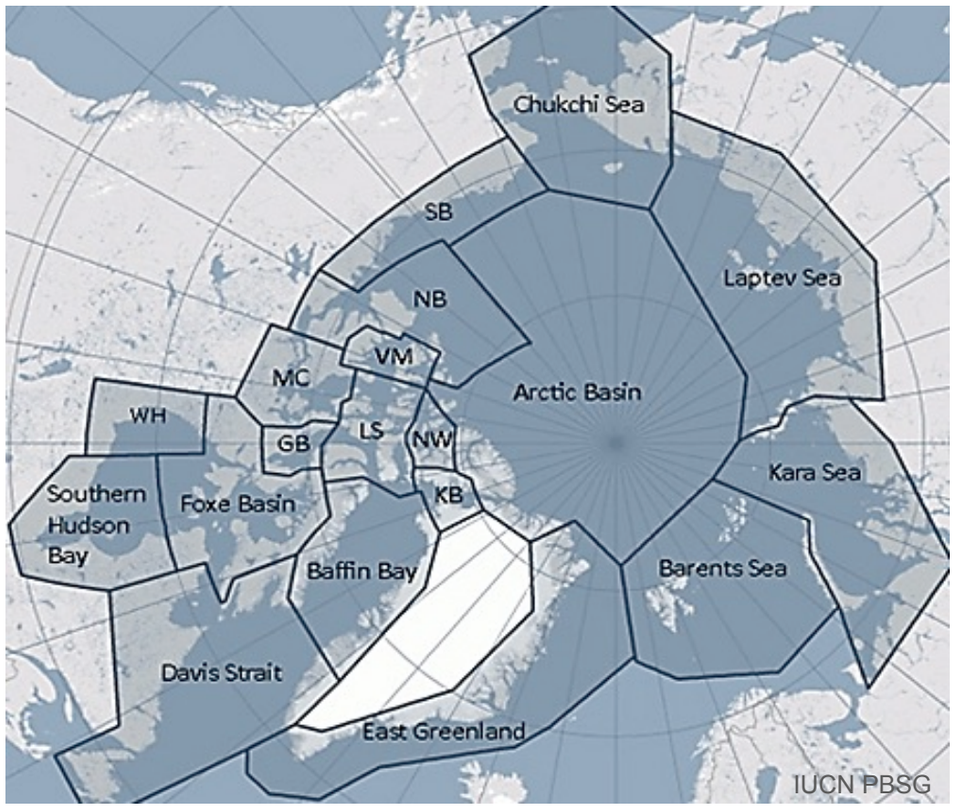
Introduction – *Ursus maritimus*

- Arctic top-predator
- 19 subpopulations recognized (IUCN PBSG)
- Conservation status: Vulnerable (IUCN Red List 2014.3)
- Main threats:
  - Climate change
  - Harvest
  - Persistent pollution
- Relative importance?



Assessment of threats

- Preferably
  - Subpopulation specific
  - Detailed data
    - Population
    - Threats
  - Little uncertainty

- But,
  - Time-consuming
  - A lot of data needed
  - Only specific conclusions

- Alternative
  - General, circumpolar assessment of threats

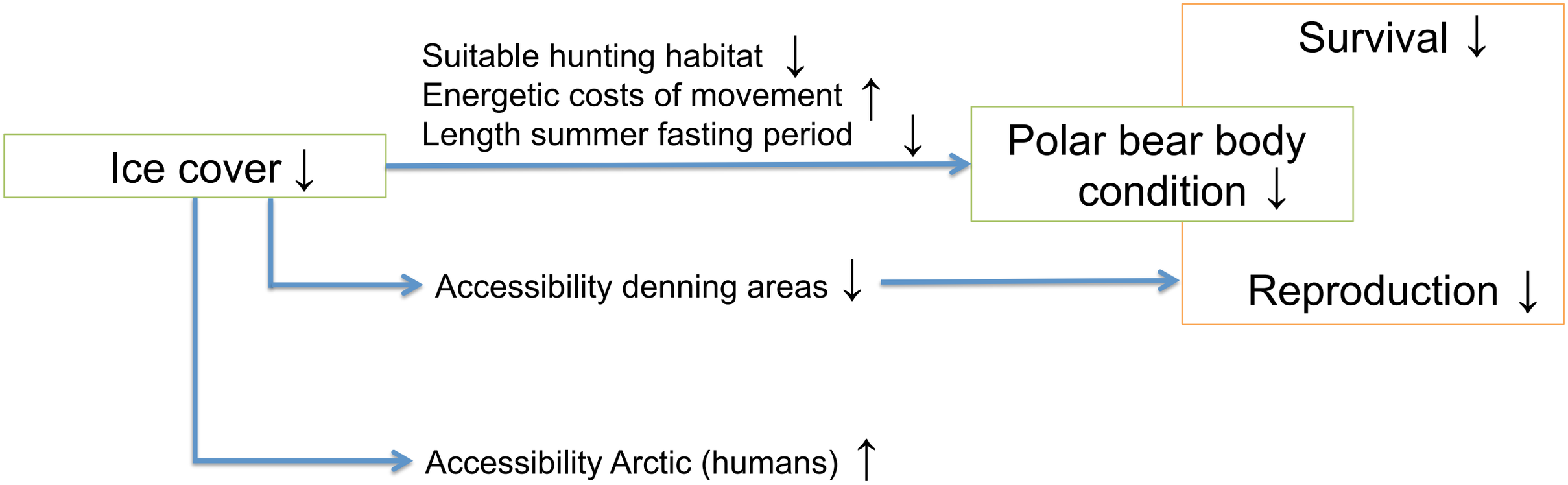
- Drawbacks
  - No population specific results
  - Uncertainty involved
  - No specific conclusions

- Advantages
  - Fast
  - Less detailed data needed
  - General conclusions that can play a supporting role in decision making

Introduction – Climate change

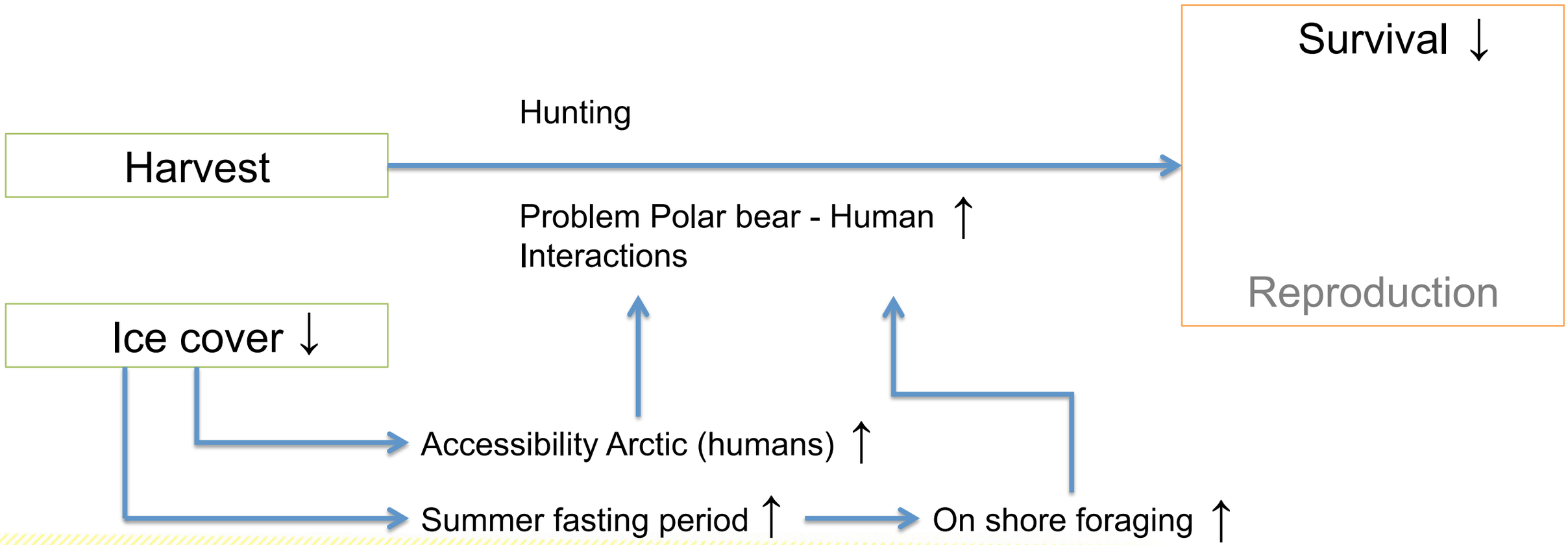
- Very pronounced effects in the Arctic
- Important variable for polar bears: Ice cover
- Ice-dependency:

- Global warming



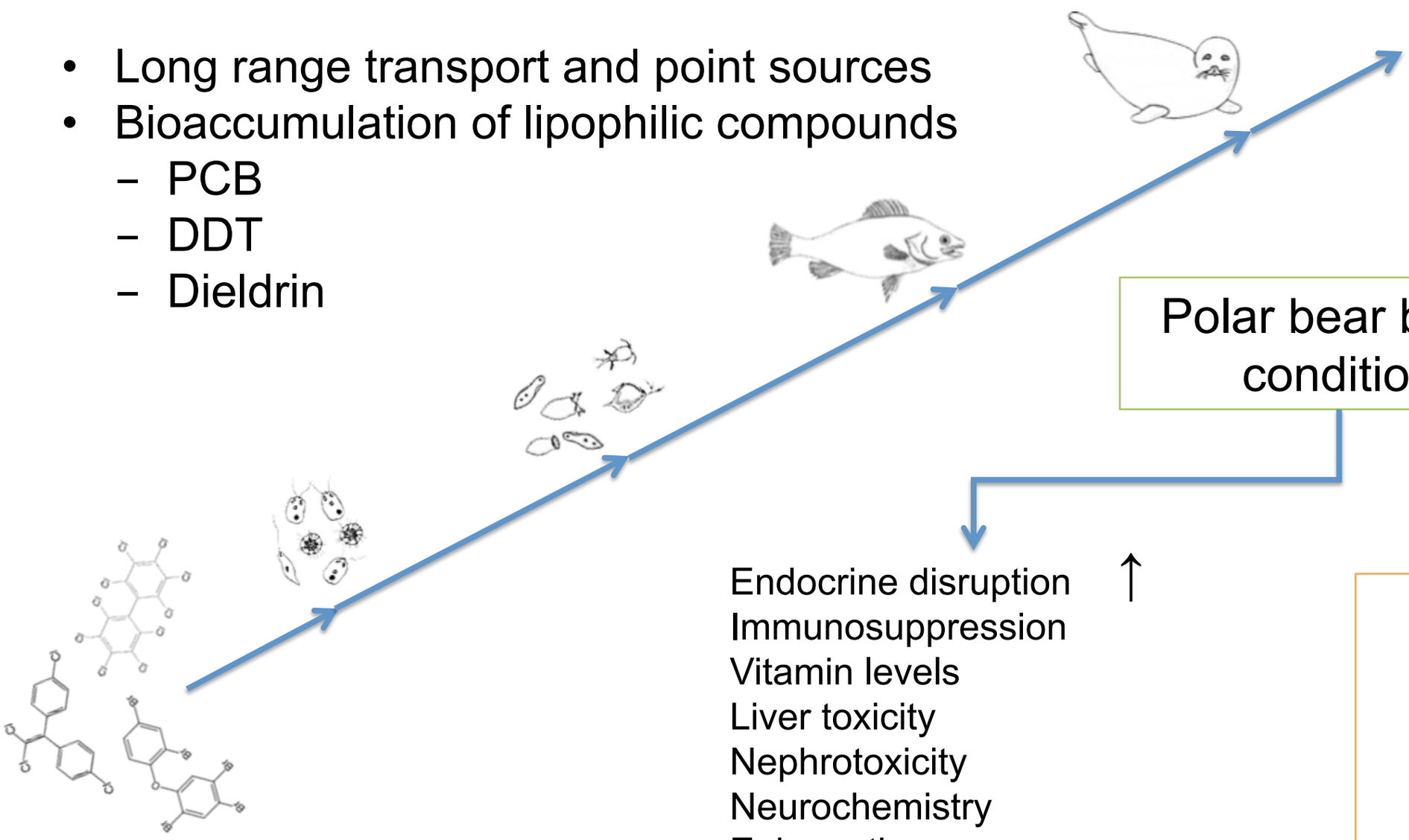
Introduction – Harvest

- Legislation:
  - Russia: no hunting since 1957
  - Norway: no hunting since 1973
  - Canada and US: hunting quota
  - Greenland: hunting quota



Introduction – Pollution

- Long range transport and point sources
- Bioaccumulation of lipophilic compounds
  - PCB
  - DDT
  - Dieldrin



Pollution

Endocrine disruption
Immunosuppression
Vitamin levels
Liver toxicity
Nephrotoxicity
Neurochemistry
Epigenetics

Polar bear body condition ↓

Survival ↓

Reproduction ↓

Ice cover

- Average summer ice
- Average days <50%

Human population

- Density

Harvest

- 5yr average

Survival

Population density

Reproduction

Pollution

- Dieldrin
- DDT
- PCB

Relative importance of threats?

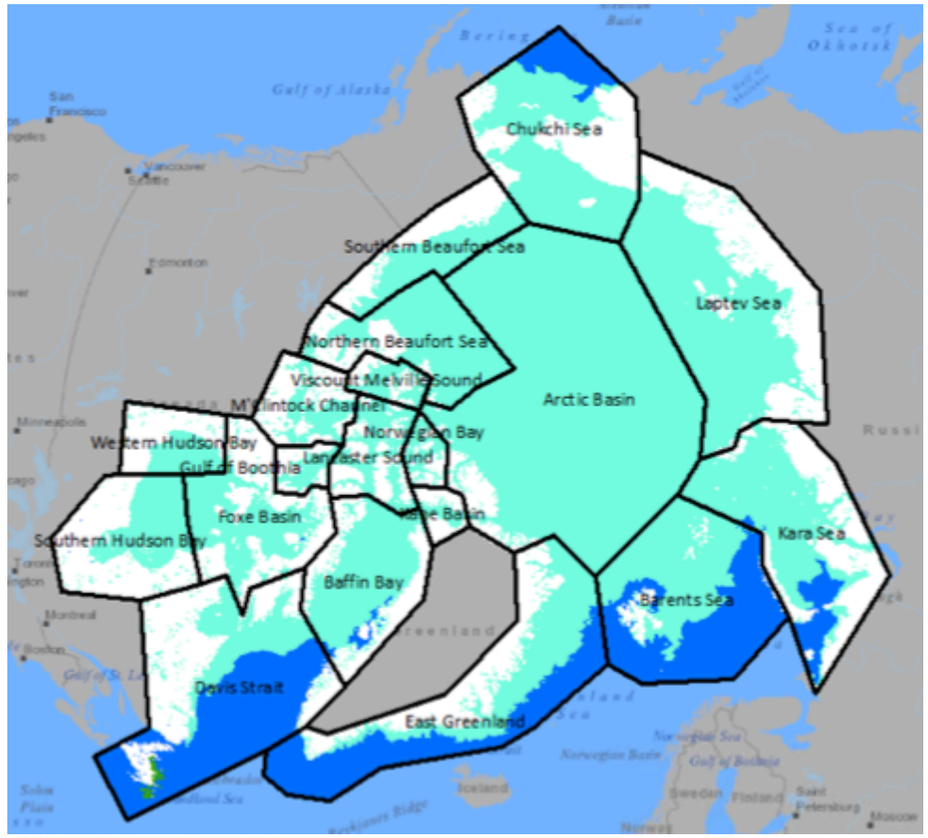
Methods – Data collection

- Ice-cover
  - National Snow and Ice Data Centre (NSIDC) Boulder, US
  - Years: 1999-2013

- Human Population Density
  - Center for International Earth Science Information Network (CIESIN)
  - Year: 2000

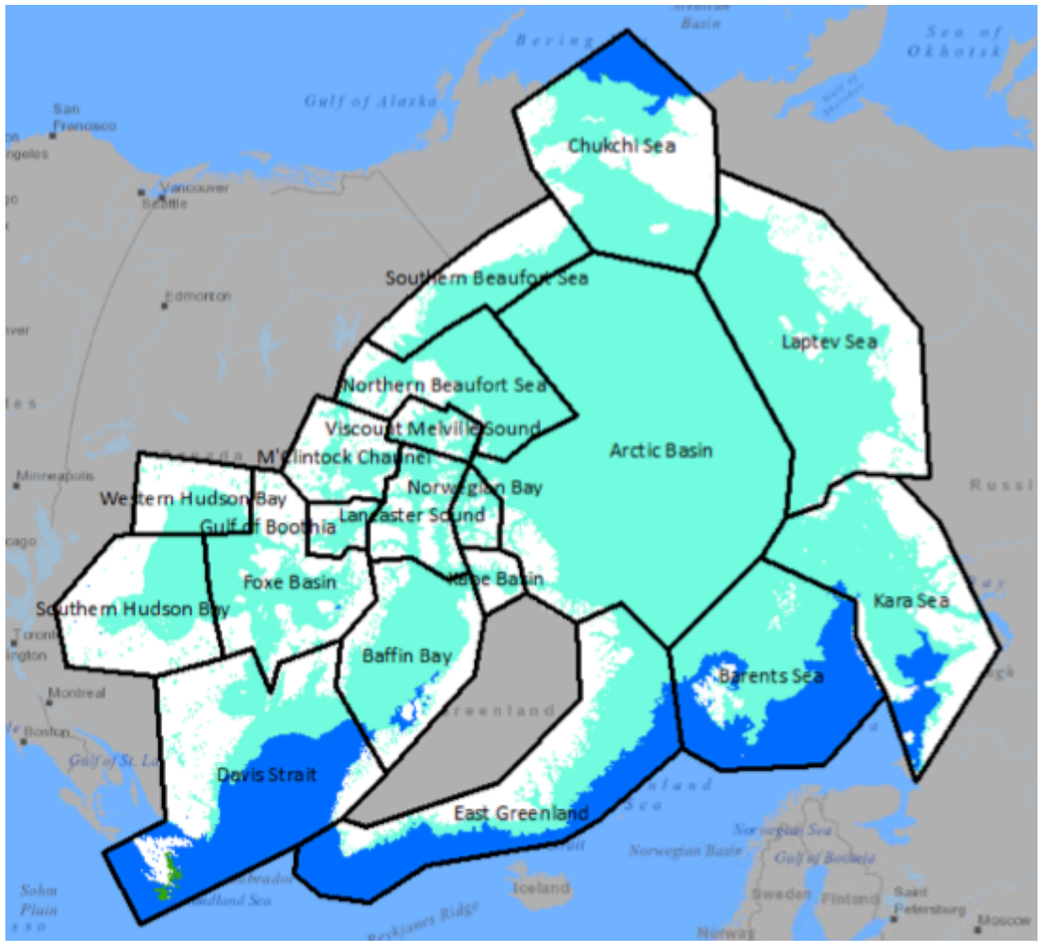
- Harvest
  - Polar Bear Specialist Group (PBSG) IUCN
  - Current 5yr average

- Pollution
  - Literature search
  - Concentration in (adult) polar bear adipose tissue (ng/g lipid weight)



Methods – Data collection

- Ice-cover
  - National Snow and Ice Data Centre (NSIDC) Boulder, US
  - Temporal resolution: daily, 1999-2013
  - Spatial resolution: 24x24 km / 4x4 km
  - Clipped by polar bear subpopulation map
  - % ice coverage per day



- Human population Density
  - Center for International Earth Science Information Network (CIESIN)
  - “Gridded population of the World”
  - Temporal resolution: 2000
  - Spatial resolution: ~5x5 km
  - Humans / km2

Methods – Data collection

- Harvest
  - Polar bear Specialist Group IUCN (www.pbsg.npolar.no)
  - 5yr average
    - Human polar bear interactions not included
- Pollution
  - Literature search
  - Dieldrin, sumDDT, sumPCB
  - Average concentration in polar bear adipose tissue (ng/g per lipid weight)
- Human population Density
  - Center for International Earth Science Information Network (CIESIN)
  - Clipped by polar bear subpopulation map
  - Humans / km2

Methods – Analysis

- 14 sub-populations in final multiple regression model

Response variable	**Predictor variables**
Polar bear population density (/1000 km2)	% Summer ice (1999-2013)
	Days ice <50% (1999-2013)
	Human population density (/km2)
	5 year harvest average (/yr)
	Dieldrin concentration (ng/g lw)
	PCB concentration (ng/g lw)
	DDT concentration (ng/g lw)

ln transformed

Standardized

Which predictor variables explain the variation in polar bear population density best?

Methods – Analysis

- 14 sub-populations

Response variable	**Predictor variables**
Polar bear population density (/1000 km2)	Summer ice (1999-2013)
→ ln transformed	Days ice <50% (1999-2013)
	Human population density (/km2)
	5 year harvest average (/yr)
	Dieldrin concentration (ng/g lw)
	PCB concentration (ng/g lw)
	DDT concentration (ng/g lw)

Standardized

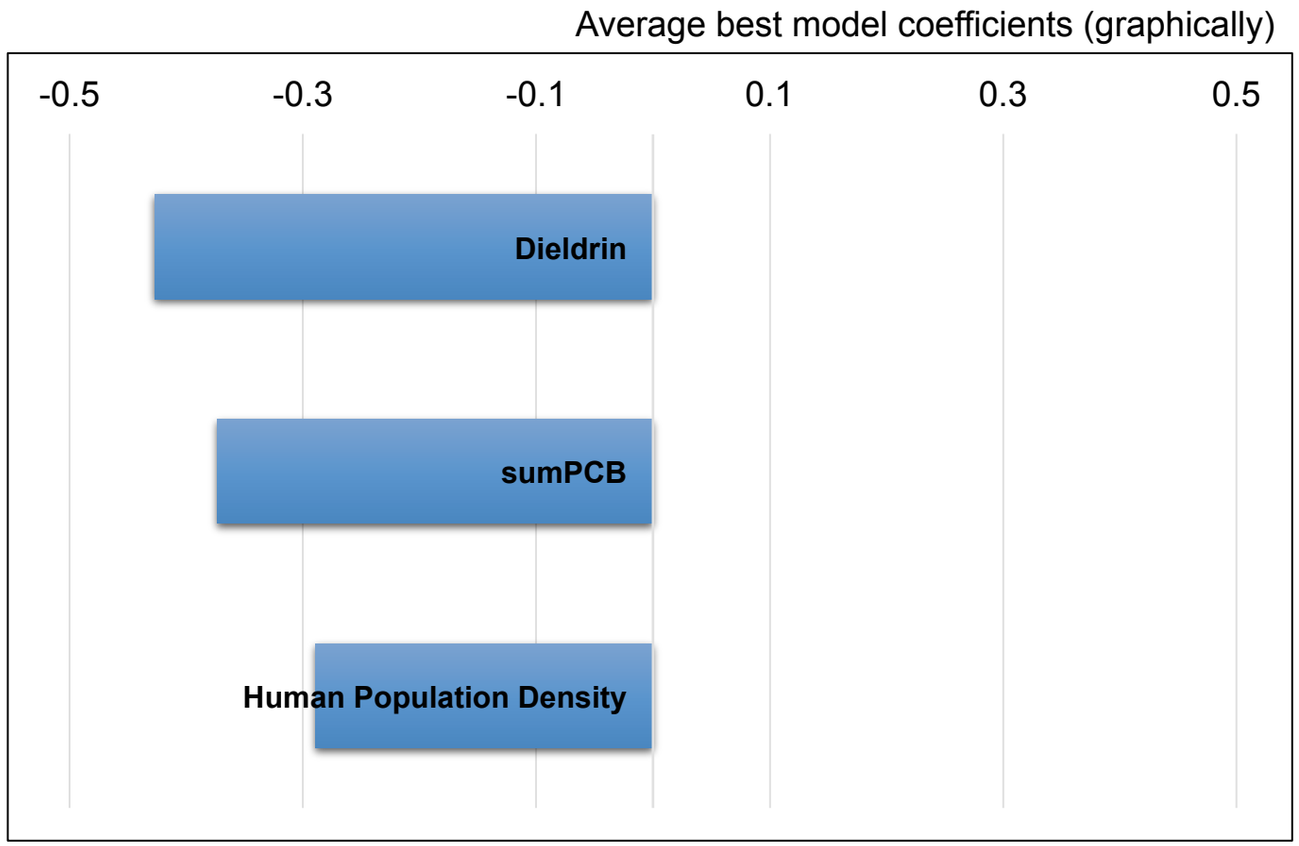
- General Linear regression Model - Rstudio
- Ranking of models based on corrected Akaike Information Criterion (AICc)
  - Maximum of 2 predictors (excl intercept) per model
- Average best model selection: ΔAICc < 2

Results

- Model ranking based model performance score (AICc)
  - The lower the score the better the model

- No distinction between models within AICc of 2

- Average best model coefficients:
  - Dieldrin -0.4271
  - sumPCB -0.3730
  - Human Population -0.2889

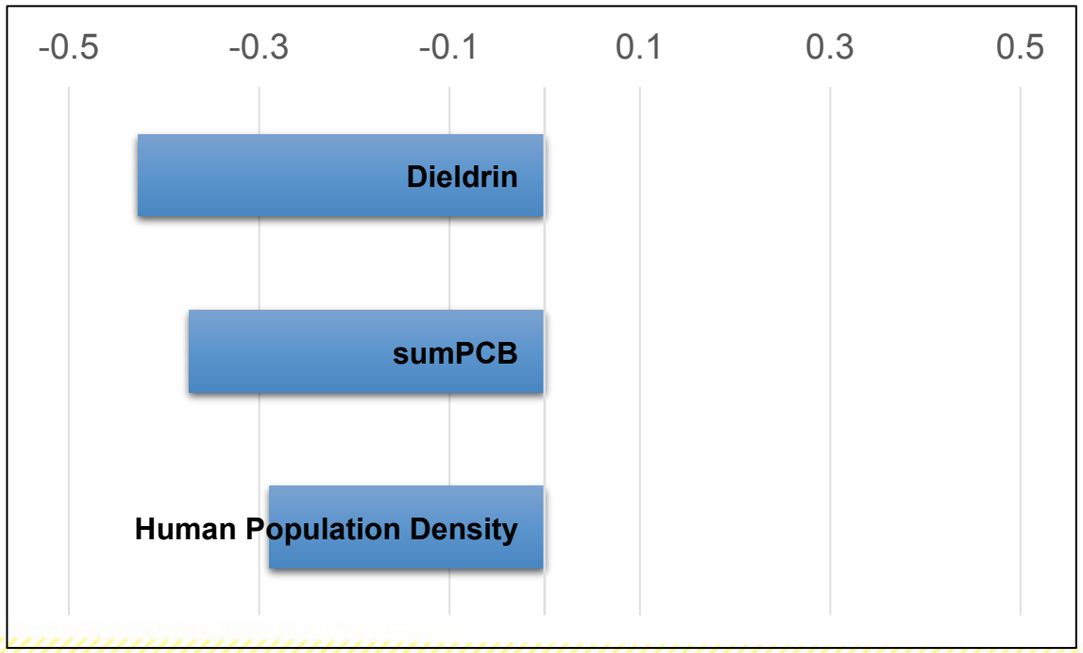


Results

- Model ranking based on AICc

(Intercept	Ice_50_av	Sept_15_a	**Dieldrin**	Harvest	**HumanPo**	sumDDT	**sumPCB**	df	logLik	AICc	delta	weight
0.669035	NA	NA	NA	NA	NA	NA	NA	2	-18.5602	42.21123	0	0.149696
0.669035	NA	NA	**-0.42492**	NA	NA	NA	NA	3	-16.9805	42.36094	0.149705	0.1389
0.669035	NA	NA	NA	NA	NA	NA	**-0.36984**	3	-17.3974	43.1949	0.983662	0.09154
0.669035	NA	NA	**-0.43063**	NA	NA	NA	**-0.37638**	4	-15.4309	43.30624	1.095002	0.086583
0.669035	NA	NA	NA	NA	**-0.28888**	NA	NA	3	-17.874	44.14802	1.936781	0.056838
0.669035	NA	NA	NA	NA	-0.37311	NA	-0.44109	4	-16.0322	44.50876	2.29753	0.047458
0.669035	NA	NA	-0.42696	NA	-0.29186	NA	NA	4	-16.0902	44.62478	2.41355	0.044783

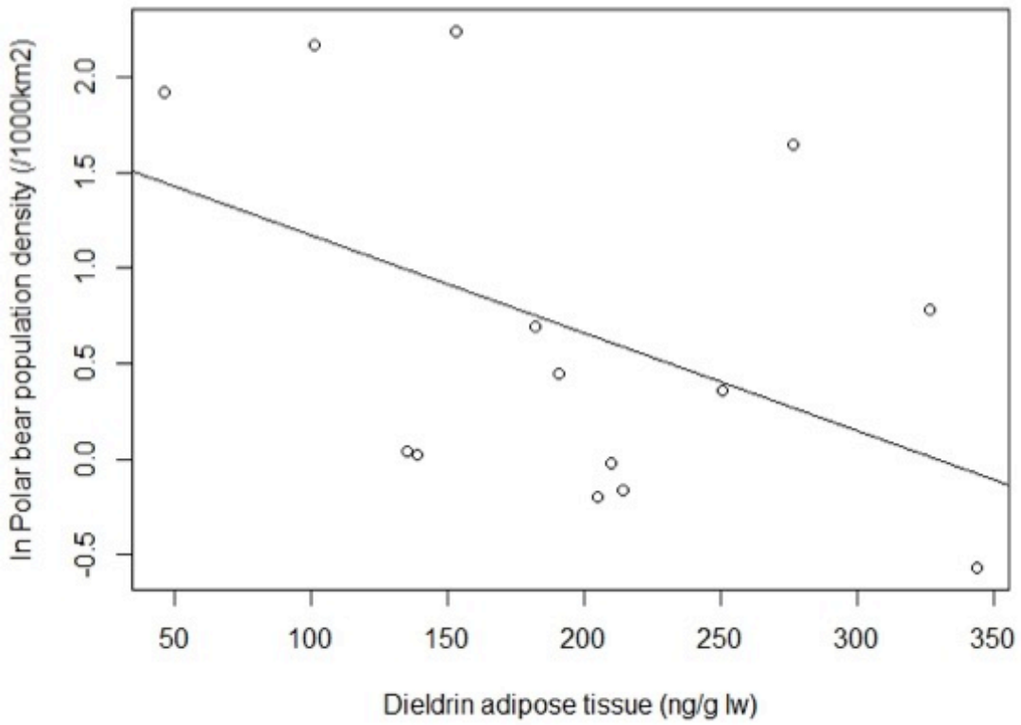
- Average best model selection (ΔAICc < 2)
- Average parameter values:
  - Dieldrin -0.4271
  - sumPCB -0.3730
  - Human Population -0.2889

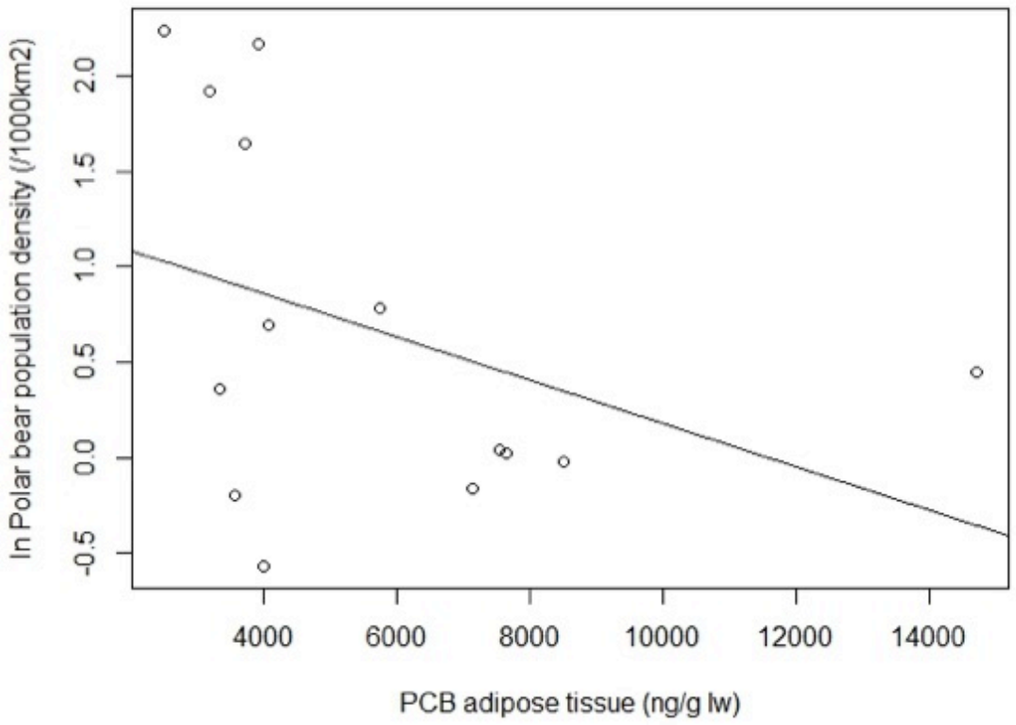


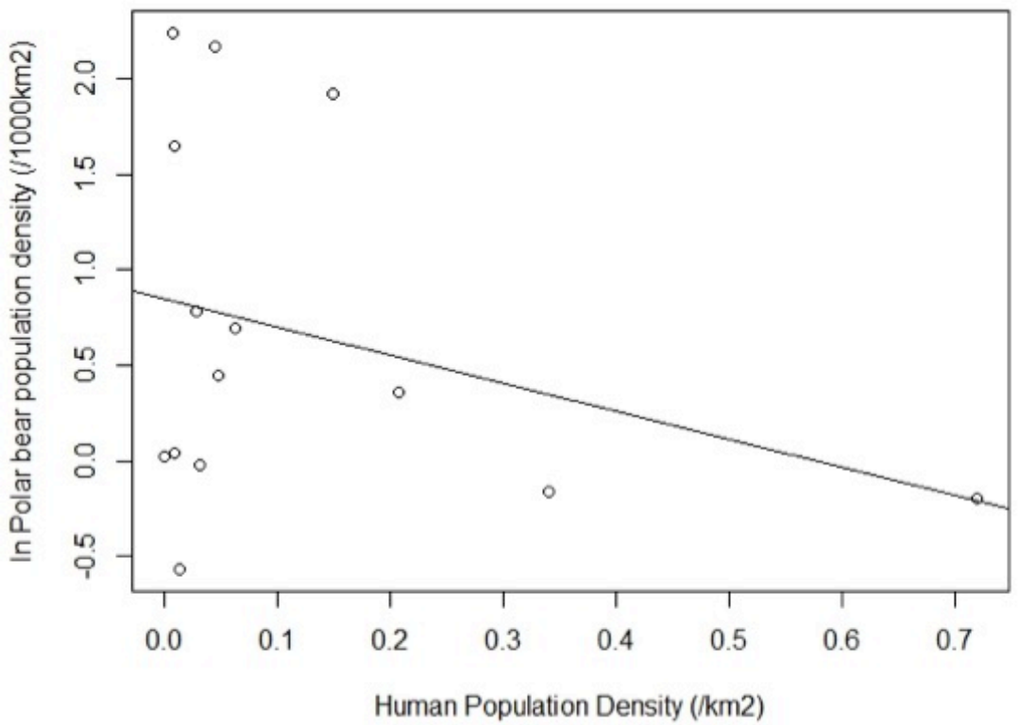
Results

- Average best model coefficients:
  - Dieldrin -0.4271
  - sumPCB -0.3730
  - Human Population -0.2889

<u>max 22% of variation explained</u>



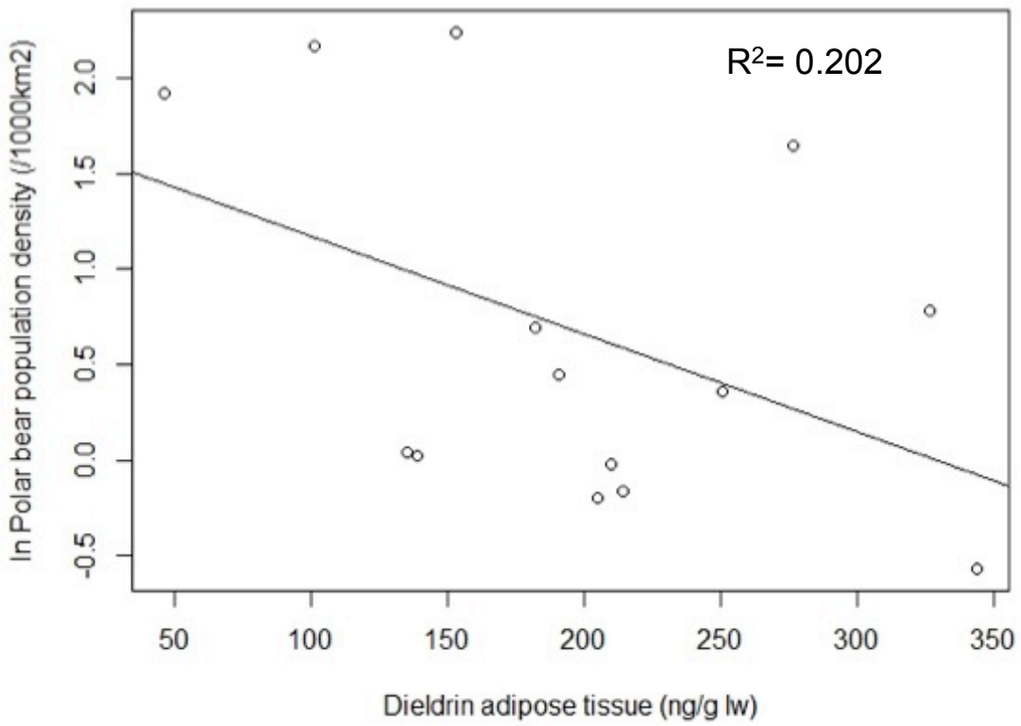


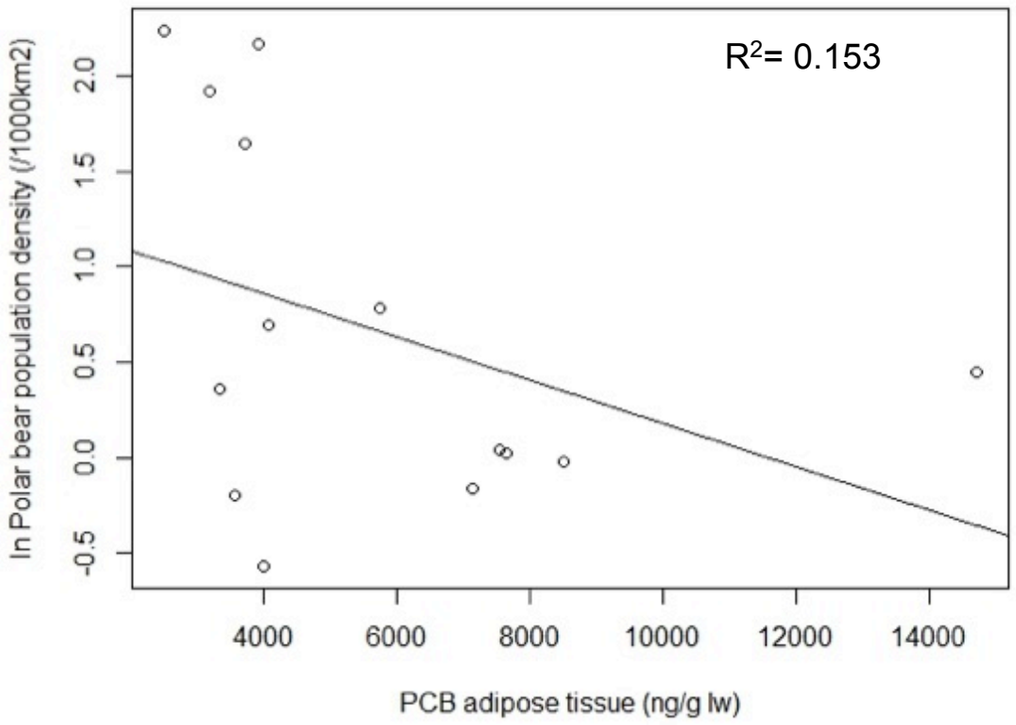


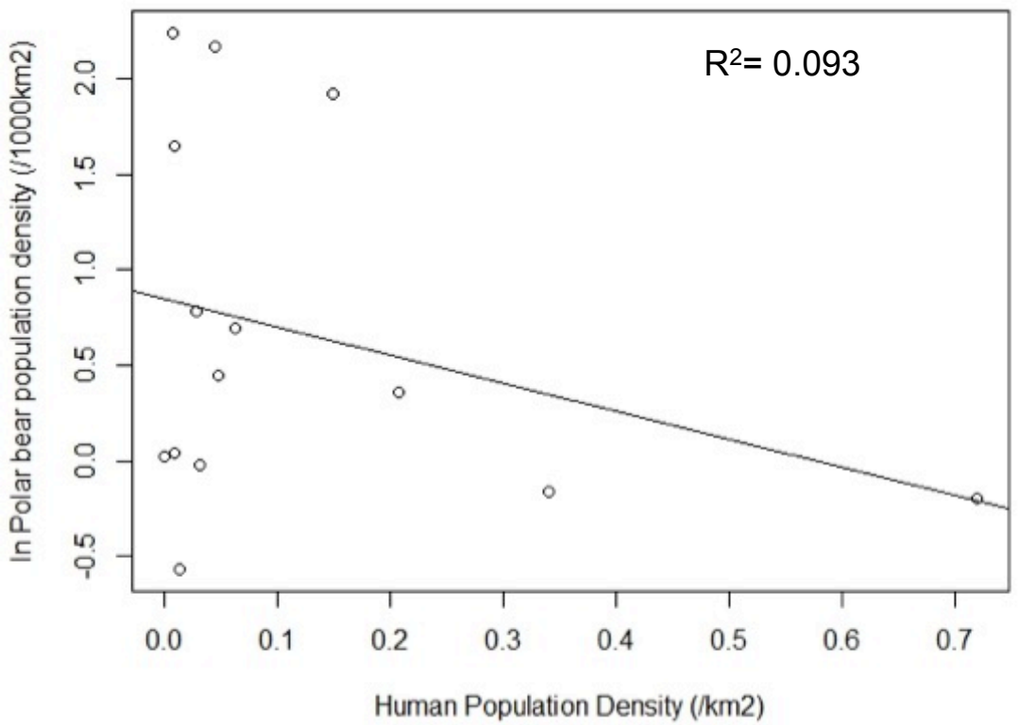
Results

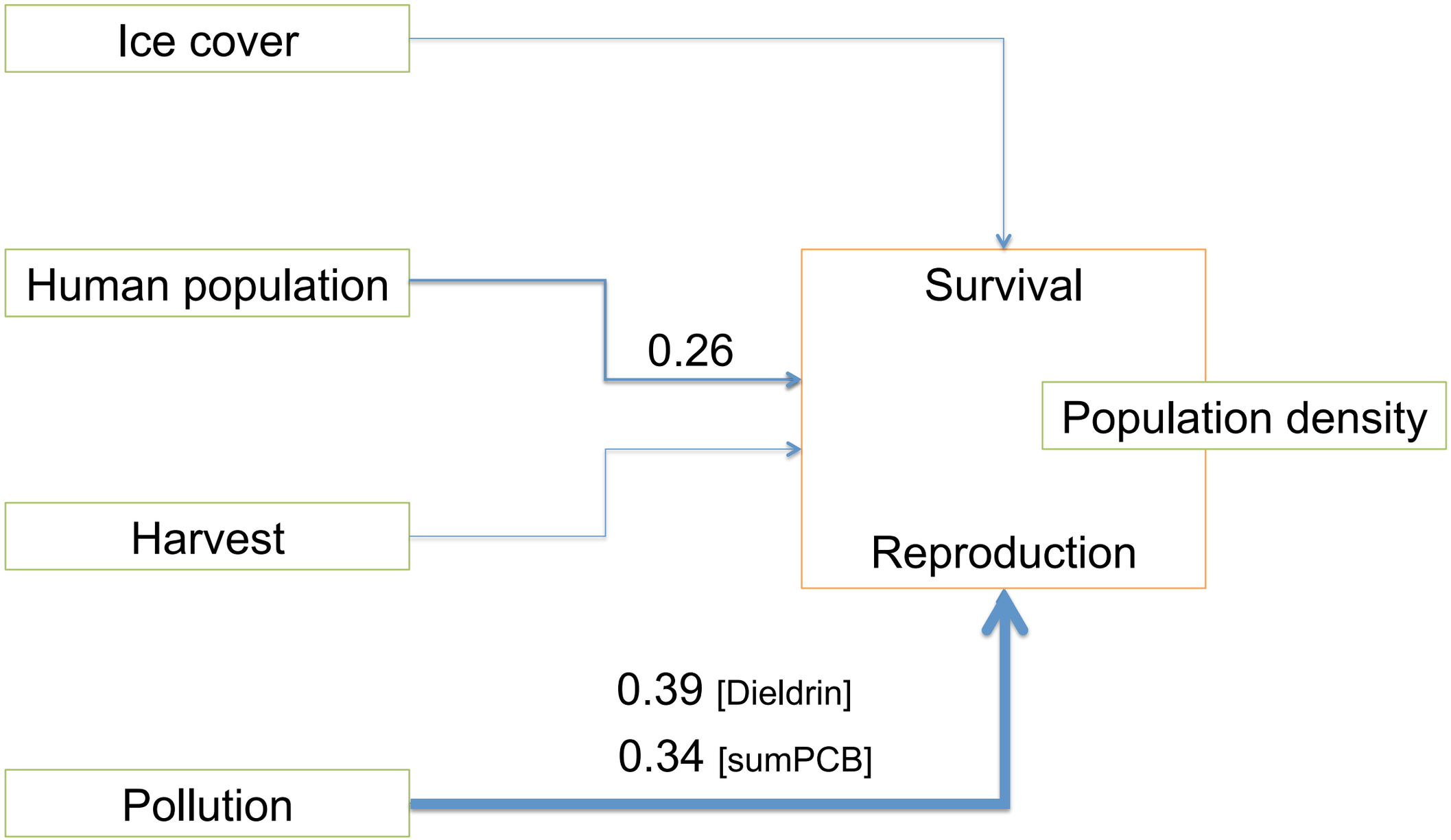
- Average best model coefficients:
  - Dieldrin -0.4271
  - sumPCB -0.3730
  - Human Population -0.2889

- R^2 average best model = 0.15

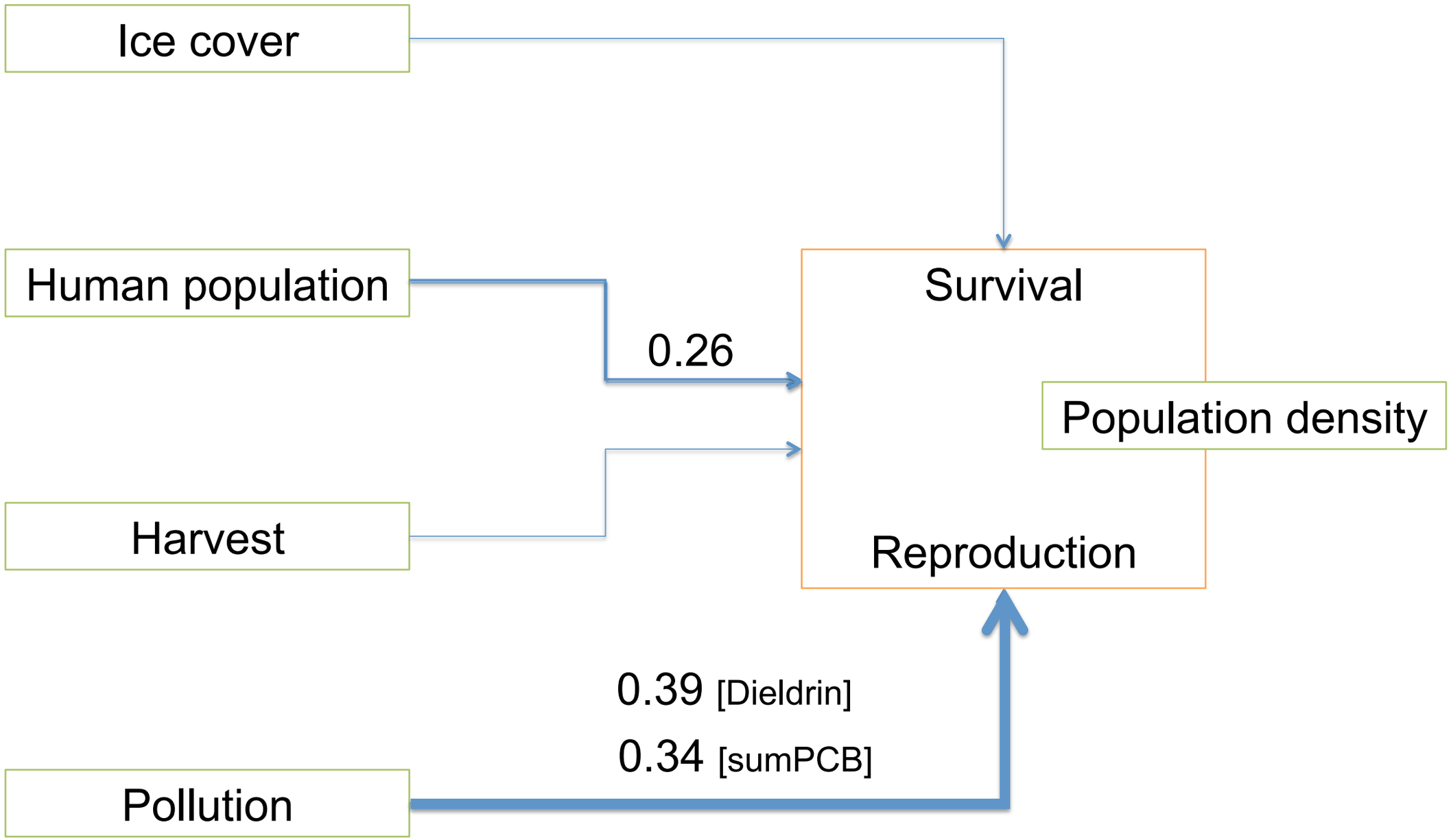






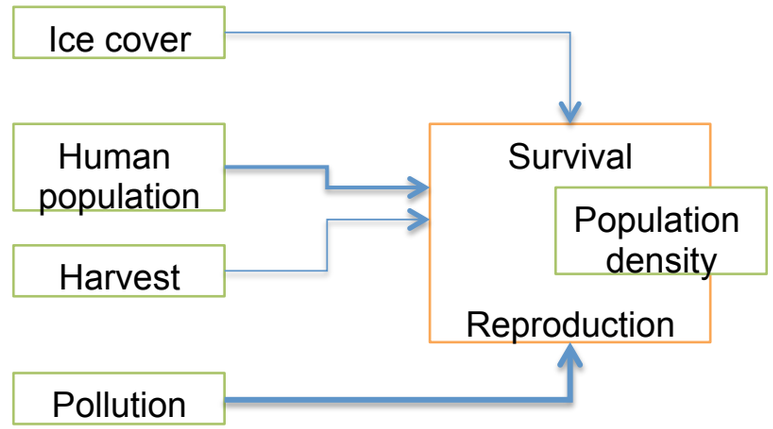


Relative importance of threats?



~~Relative importance of threats?~~

Discussion

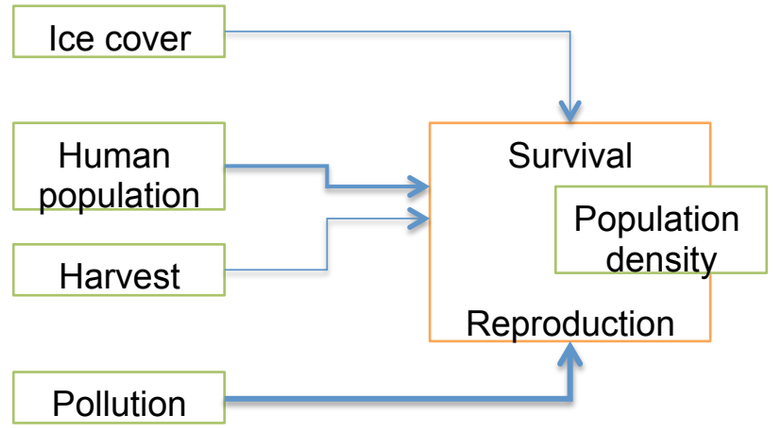


- No ice cover variable in best model

We cannot conclude from these results that climate change isn't affecting polar bear populations,

we can only conclude that the differences in ice cover between the subpopulations do not explain the variation in polar bear densities.

Discussion

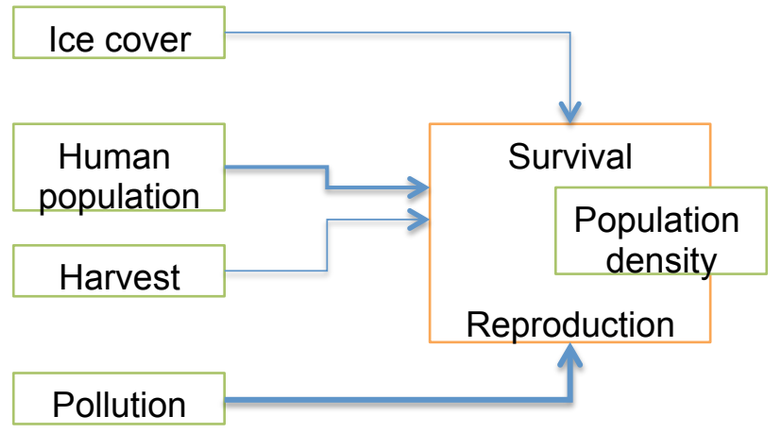


- No ice cover variable in best model
  → No climate change only spatial differences in ice cover

  - 15 years (1999-2013) not long enough for climatic variable
  - Variable ‘Days <50% ice cover’ maybe not suitable for all subpopulations?

- No harvest
  - 5 year average
  - No data on Polar bear human interactions

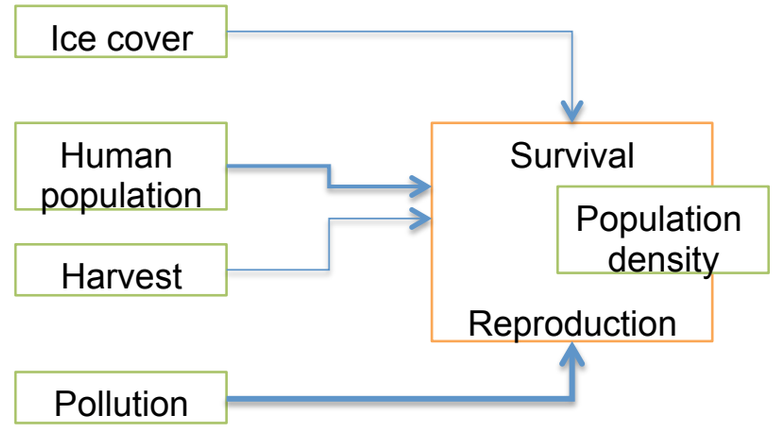
Discussion



- Harvest
  - Data from Polar Bear Specialist Group website
  - No data on Polar bear human interactions (maybe in the future?)

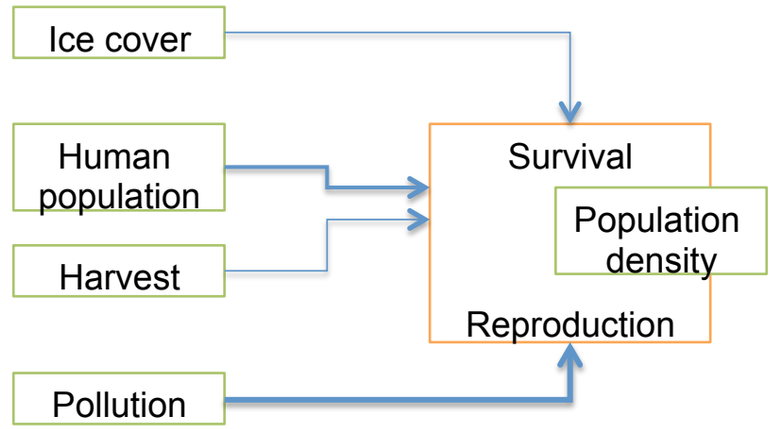
We cannot conclude from these results that harvest doesn't affect polar bear populations,
we can only conclude that the data available on harvest does not explain the variation in population density between subpopulations.

Discussion



- Improvements approach
  - Different response variable(s)
    - Reproduction / Survival
  - Rates instead of states as predictor variables
    - Change in ice cover
    - Change in harvest rates
  - Validation with subpopulation specific regression model(s)

Discussion



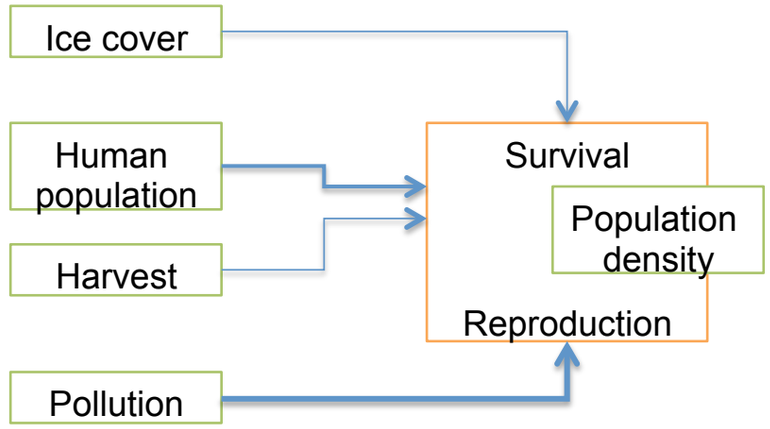
- Human Population Density
  - Direct influence
  - Influence via increasing activities (industry, research, tourism, etc.)

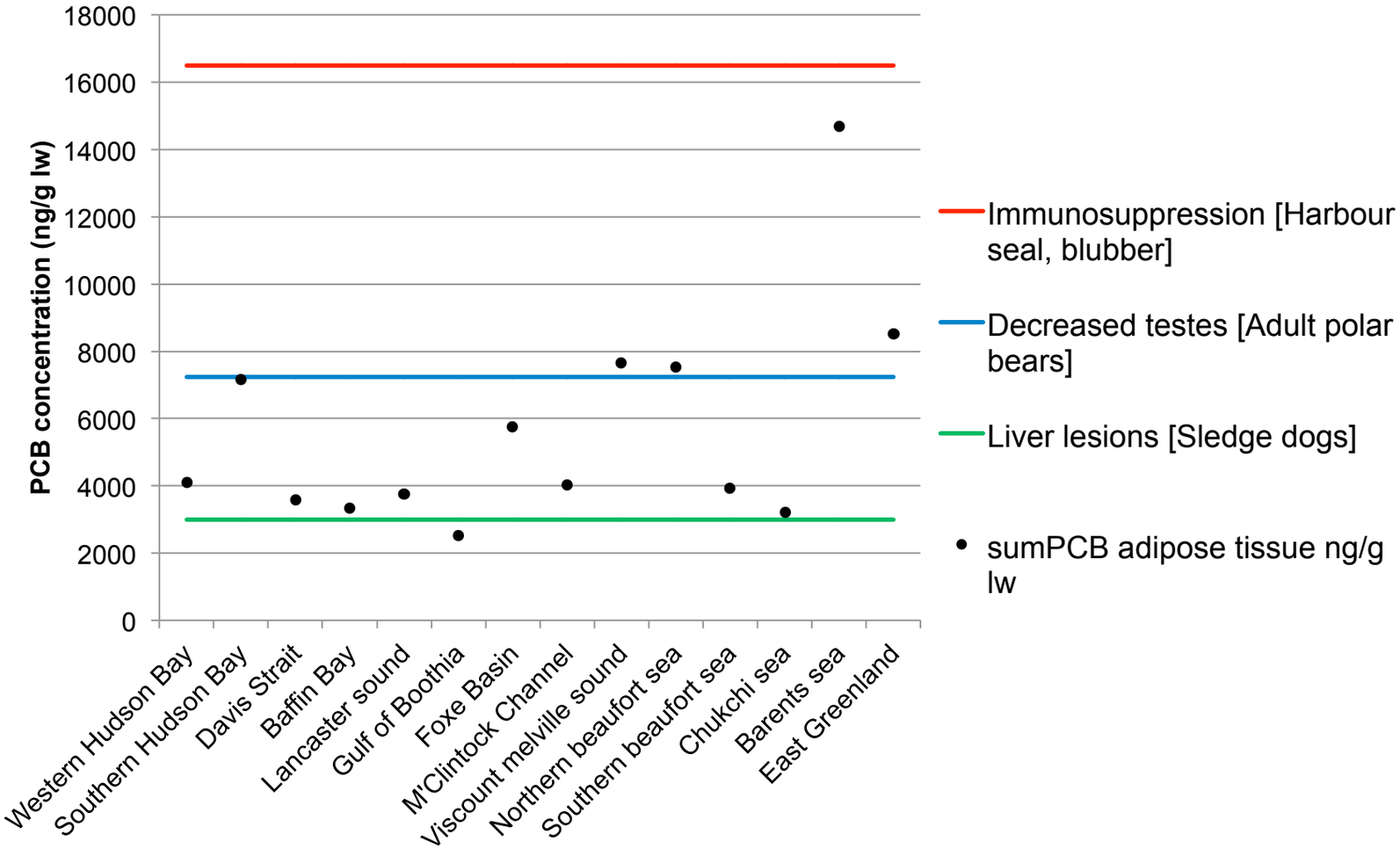
- Pollutants
  - No differentiation between ages (only adults included)
  - No differentiation between sexes
  - No differentiation between seasons

  - Influence via health effects

Discussion

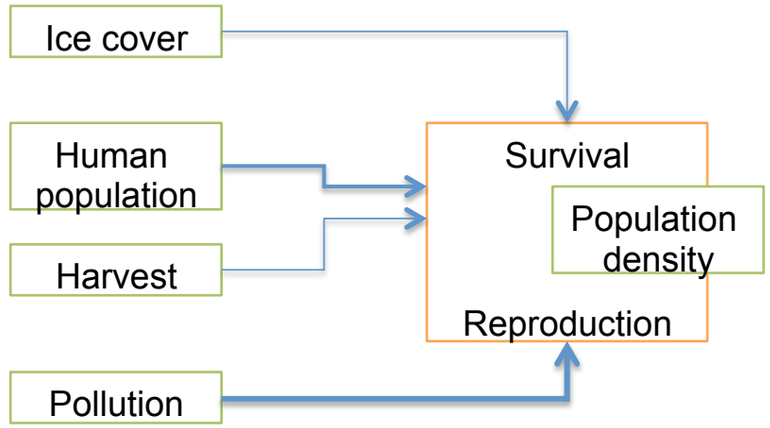
- PCB concentrations polar bear populations in perspective

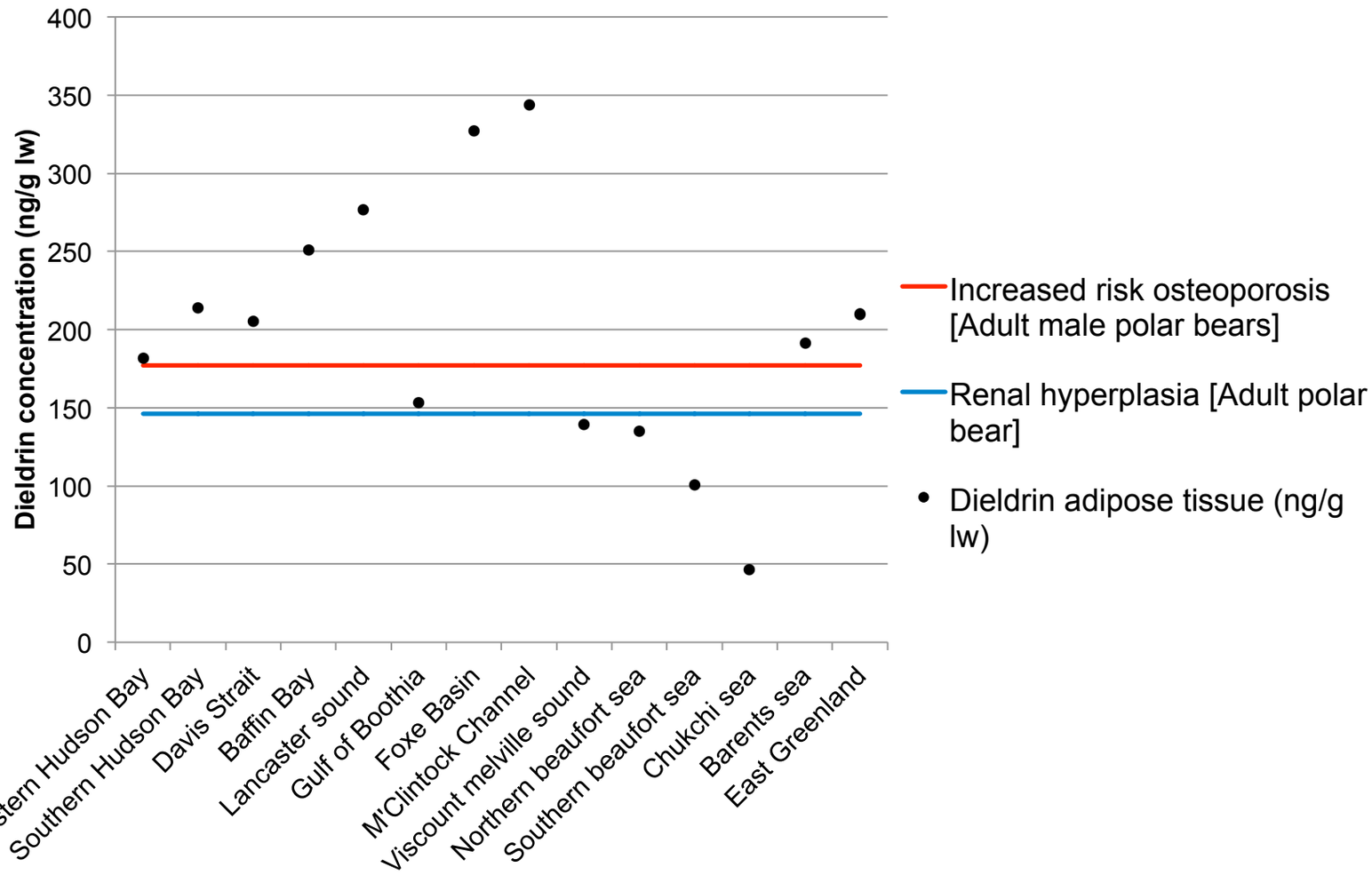




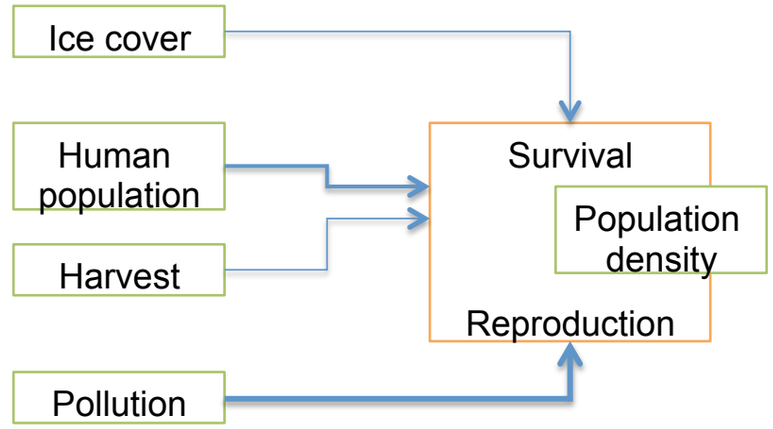
Discussion

- Dieldrin concentrations polar bear populations in perspective





Outlook



- Clear indication pollution can influence populations
- Next steps:

Bioaccumulation model (OMEGA)	**Population viability analysis (PVA)**
- Simulate bioaccumulation of persistent pollutants such as Dieldrin and PCB in the Arctic food chain - Validate model with existing data - Extrapolate model to emerging pollutants	- Include effects of pollution in Population Viability Analysis for polar bears - Derive stressor-response relationships for pollutants - Population endpoints like survival and reproduction
↳ Combine bioaccumulation model with population viability analysis ↲	

Supervision:

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Collaborators on the project:

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Prof. Bjorn M Jenssen	NTNU
Dr. Bjorn E Grosvik	IMR
Prof. Dik vd Meent	RU


Polar bears international

Thank you for your attention!


Polar bears international

Questions? Suggestions?

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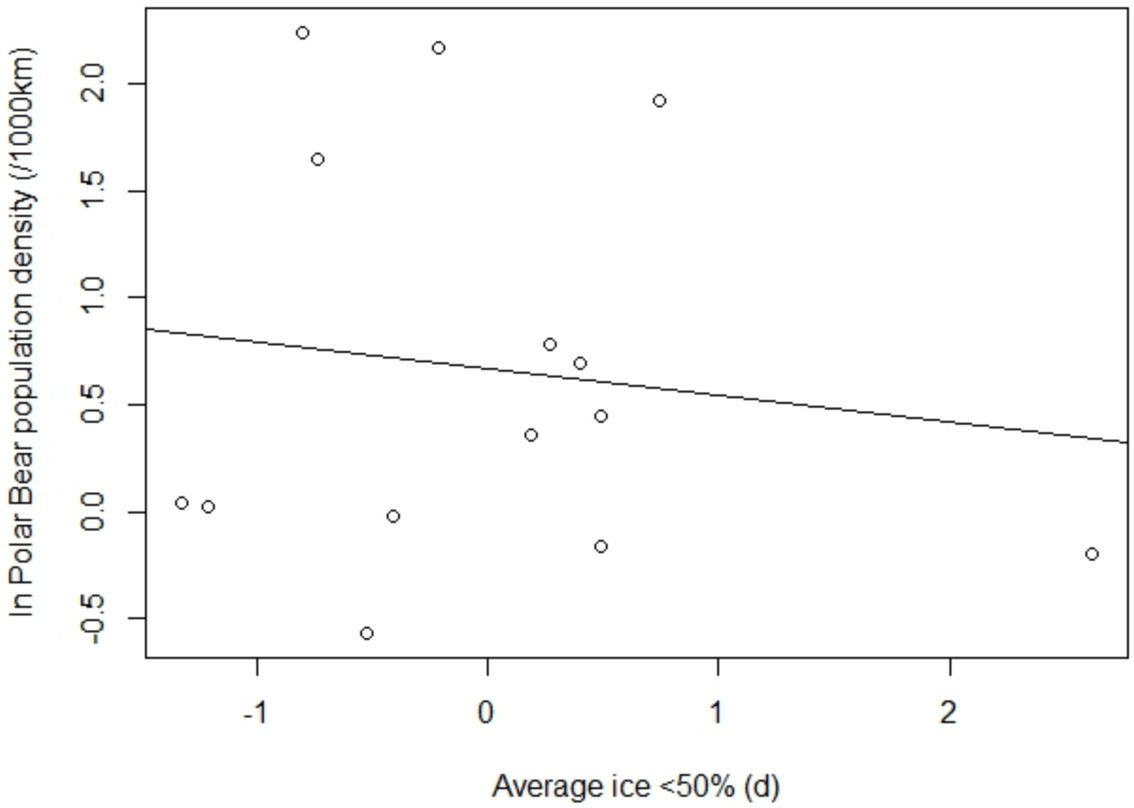
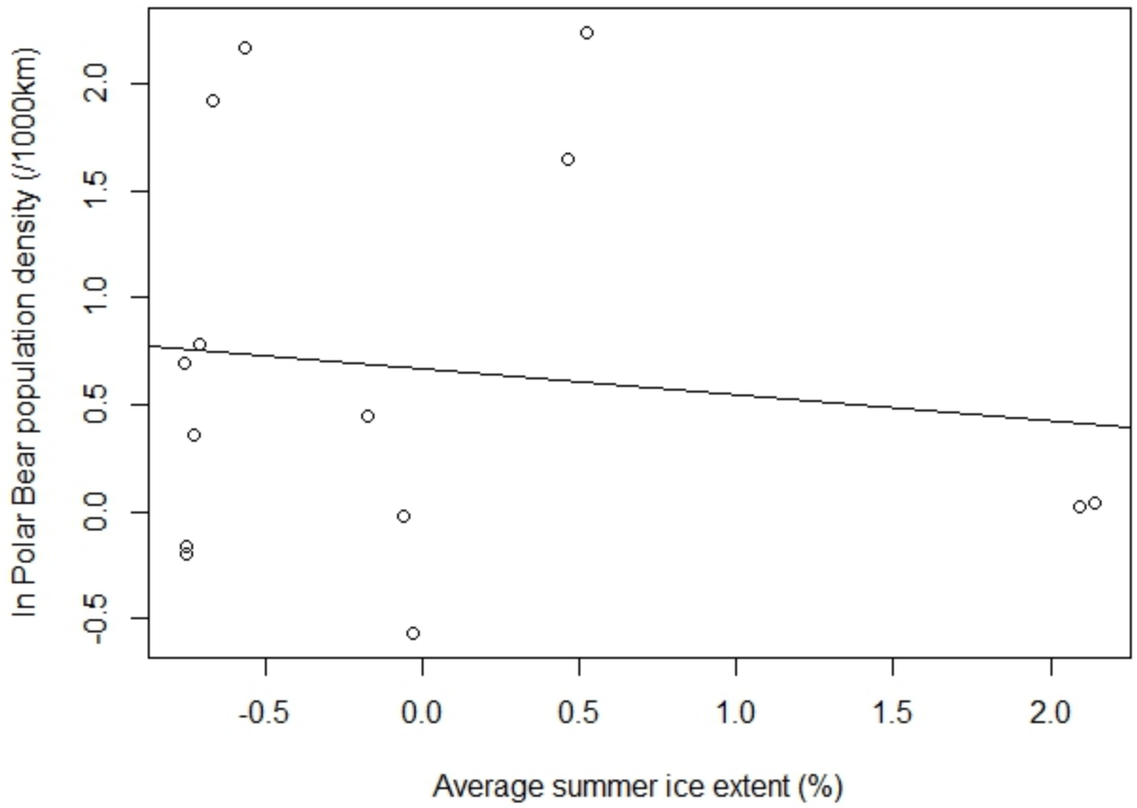
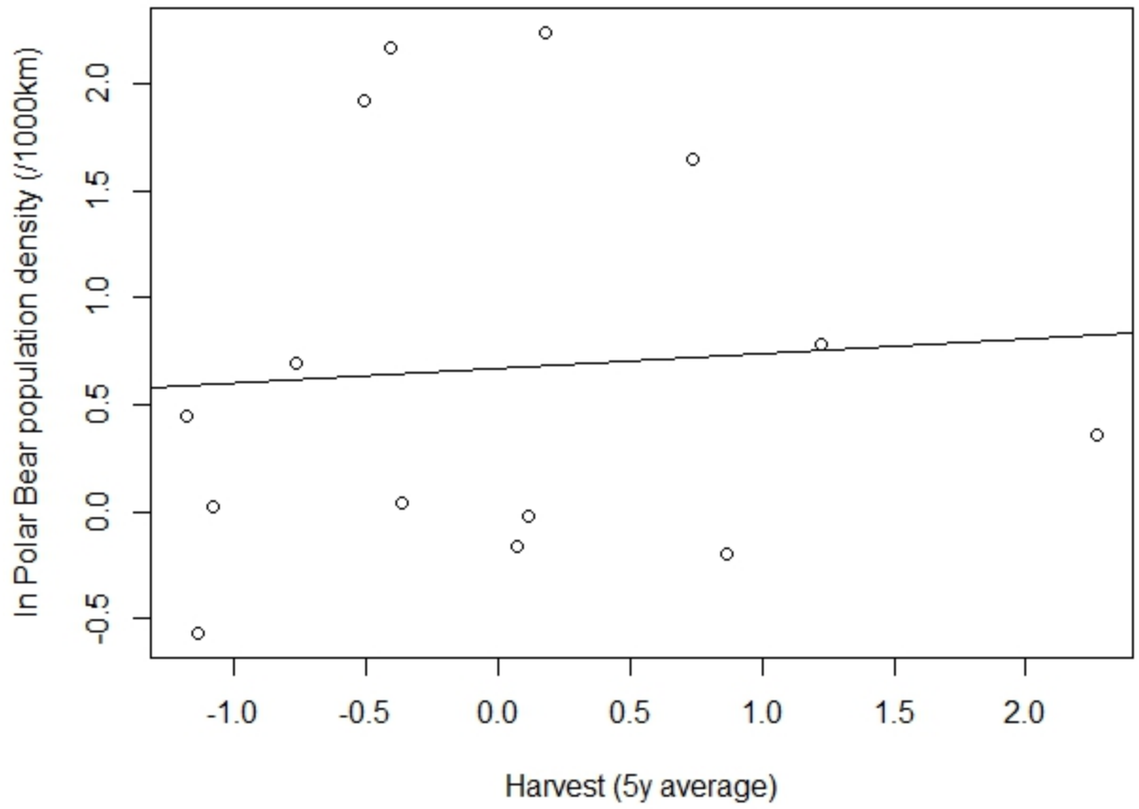
Ice variables

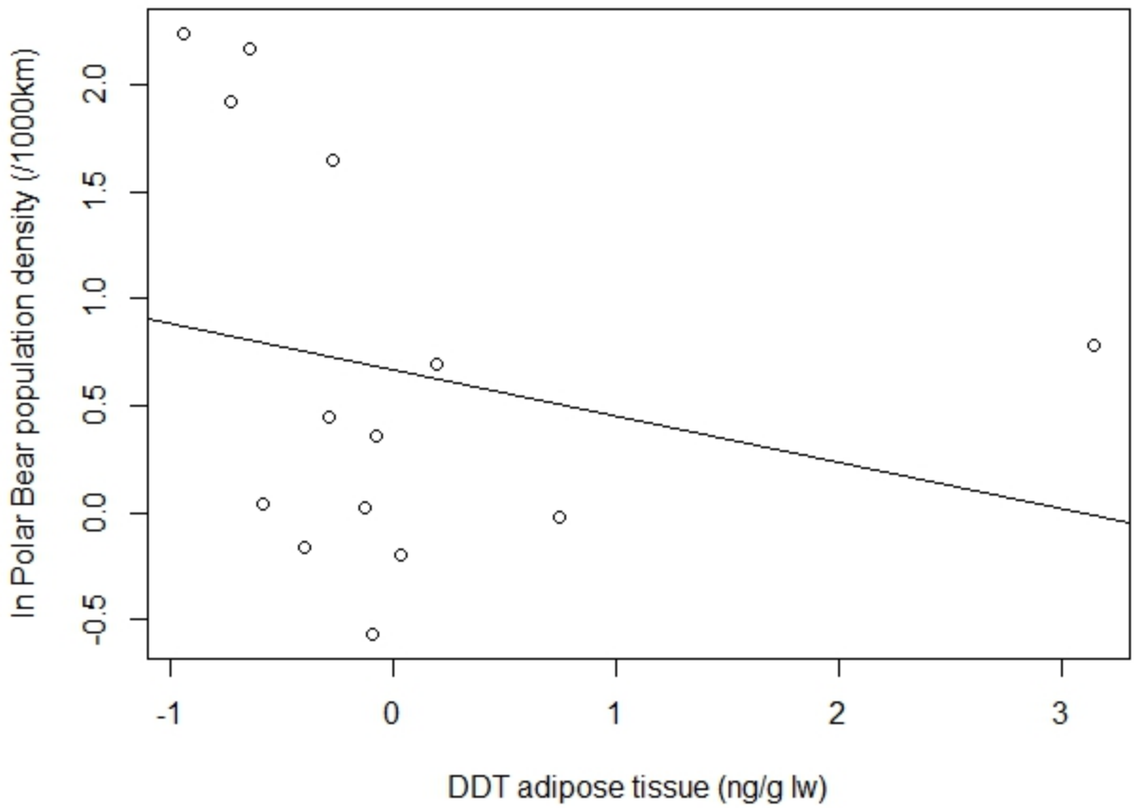




Harvest


ln Polar Bear population density (/1000km)
-0.5
0.0
0.5
1.0
1.5
2.0
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Harvest (5y average)

DDT


ln Polar Bear population density (/1000km)
-0.5
0.0
0.5
1.0
1.5
2.0
-1
0
1
2
3
DDT adipose tissue (ng/g lw)