POP2012-02

MS4 Correlative assessment (Presentation 3) Assessment results

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Scope of presentations

1. Intro & hypothetical model relating datasets
2. Presentation of datasets
3. **Correlative assessment**

Purpose of correlative assessment

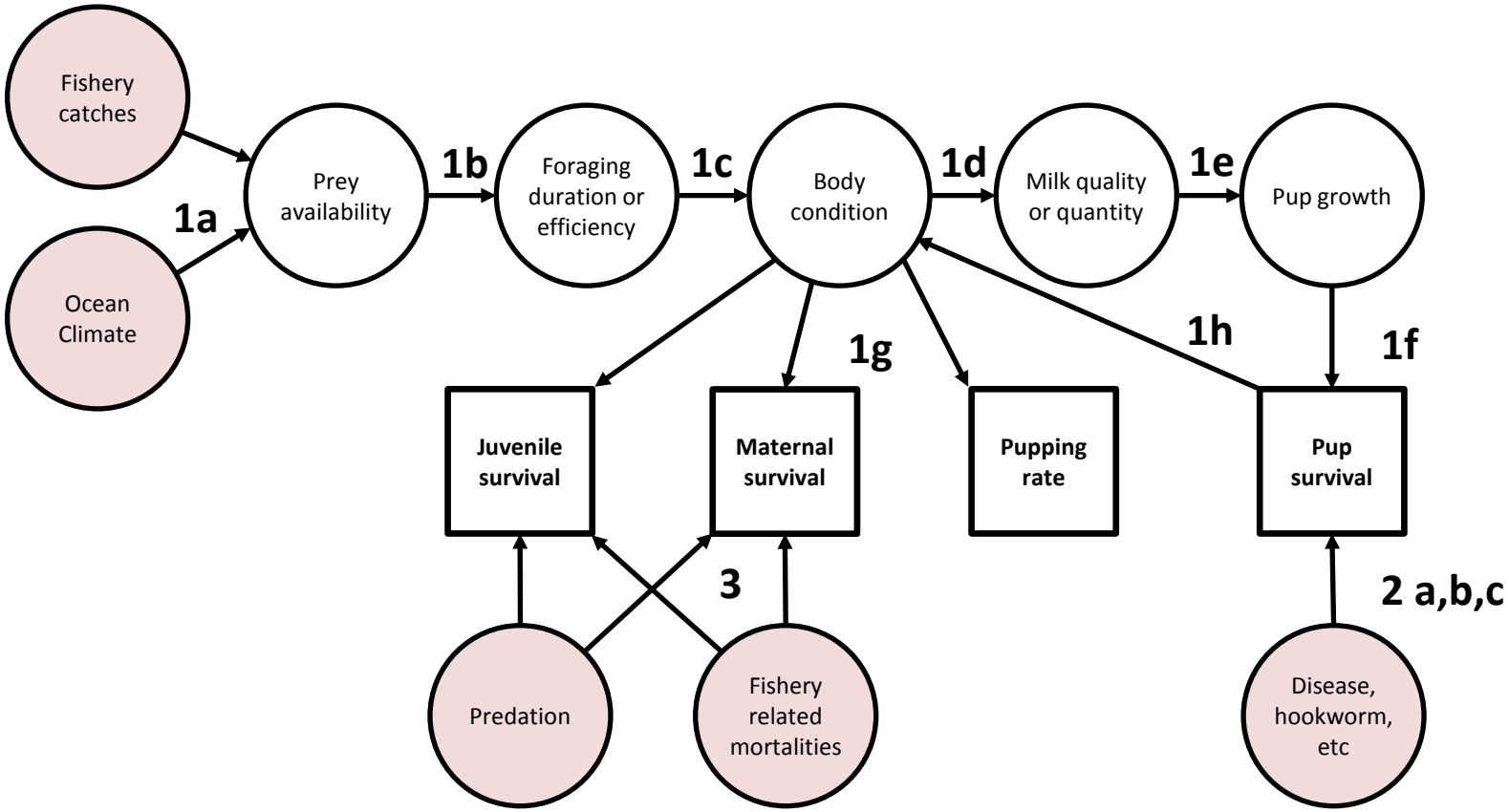
POP2012-02 Objectives to "*identify potential demographic mechanisms through which both direct and indirect effects of fishing can impact on sea lion population size at the Auckland Islands, or increase susceptibility of the population to such effects.*"

- Does correlative assessment support the hypothetical model for each candidate driver of population change?
- Do we see evidence for fisheries impacting directly or indirectly on the Auckland Islands sub-population?
- Can we identify probable demographic mechanisms that may render the population susceptible to the direct/indirect effects of fishing?

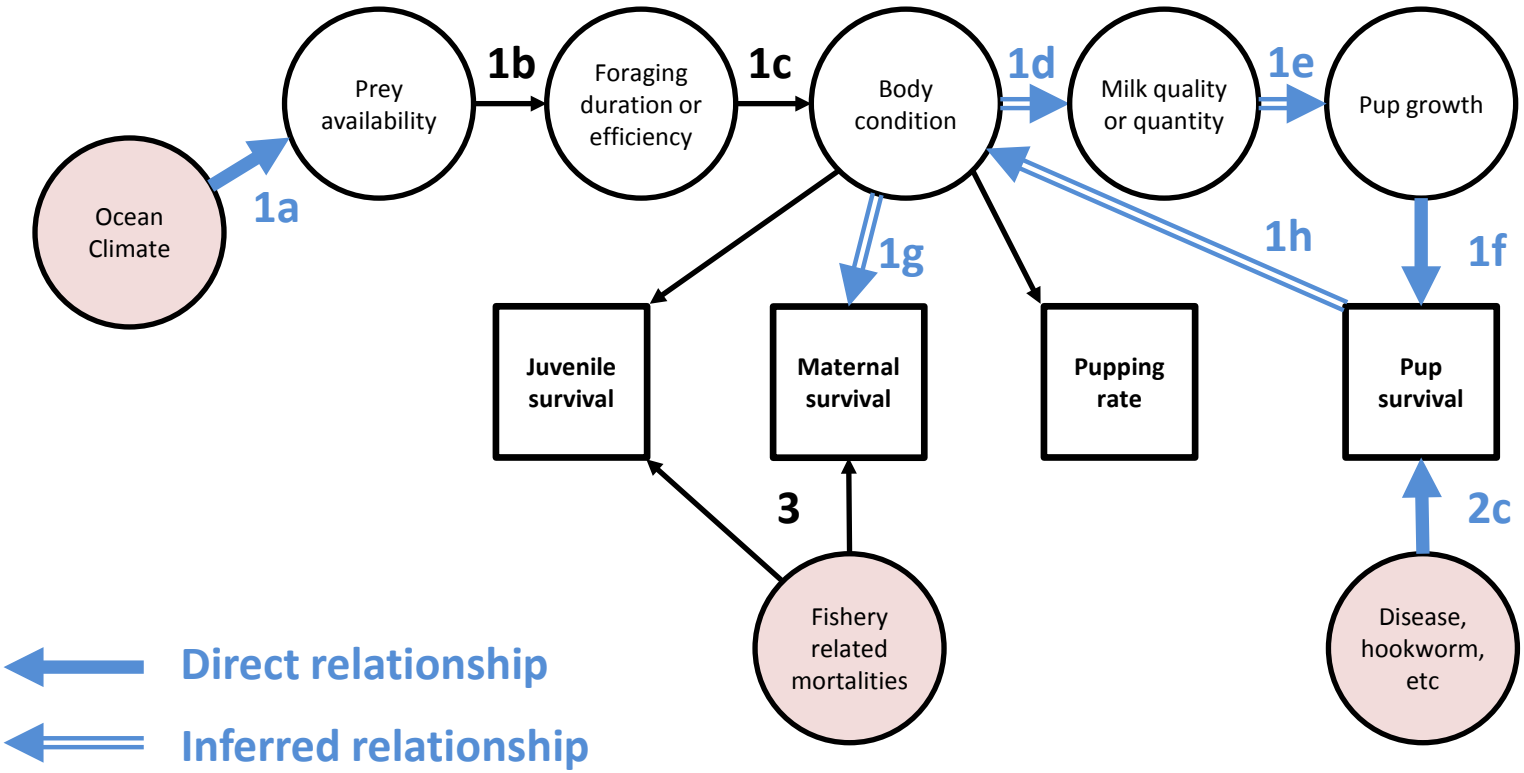
Hypothetical models – detailed relationships assessed

Candidate driver of population change	ID	Relationships assessed
Nutritional stress	1a	Climate and prey abundance/diet
	1b	Prey abundance and diet
	1c	Diet and maternal condition
	1d	Diet and milk quality
	1e	Maternal condition/milk quality/breeder age and pup mass
	1f	Pup mass and pup/yearling survival
	1g	Maternal condition and maternal survival/pupping rate
	1h	Pup/yearling survival and demographic response in yr+1
Disease-related pup mortality	2a	Pup mortality at 3 and 7 weeks and pup/yearling survival
	2b	Pup mortality by cause and pup/yearling survival
	2c	Bacterial disease related mortality and pup/yearling survival
Direct fishery-related mortality	3	Estimated fishery interactions/captures and juvenile/adult survival

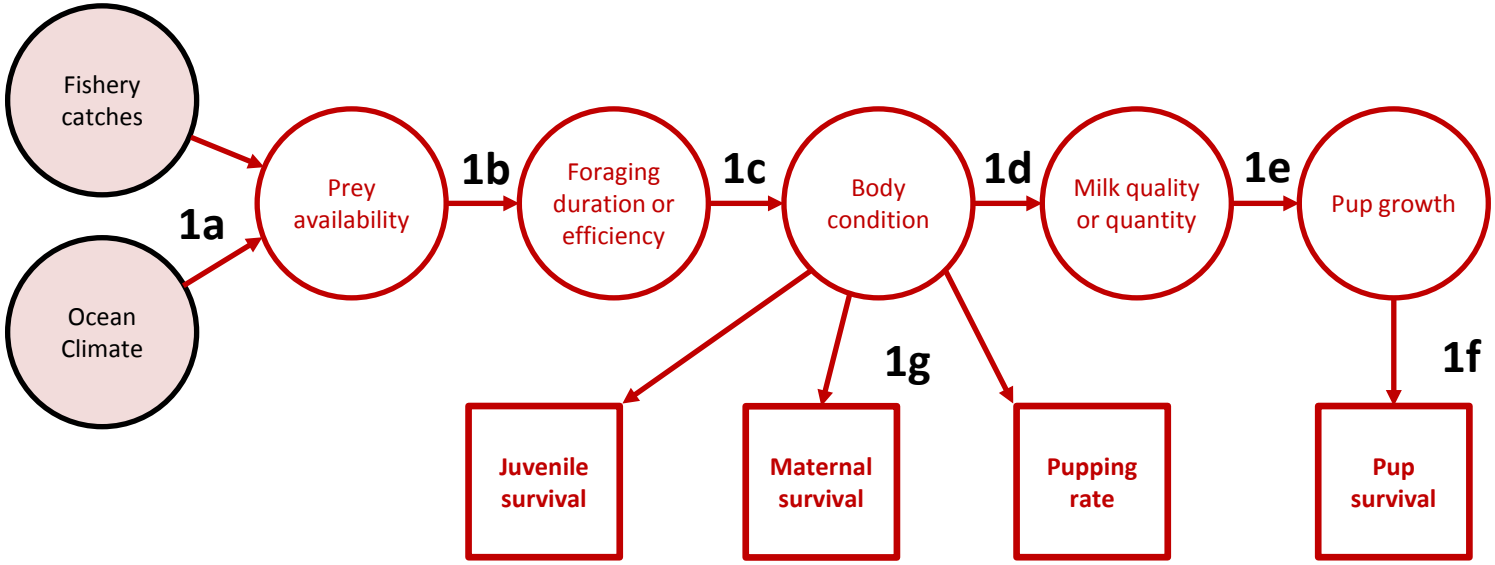
Hypothetical model
relating environment, biology & demographic rates



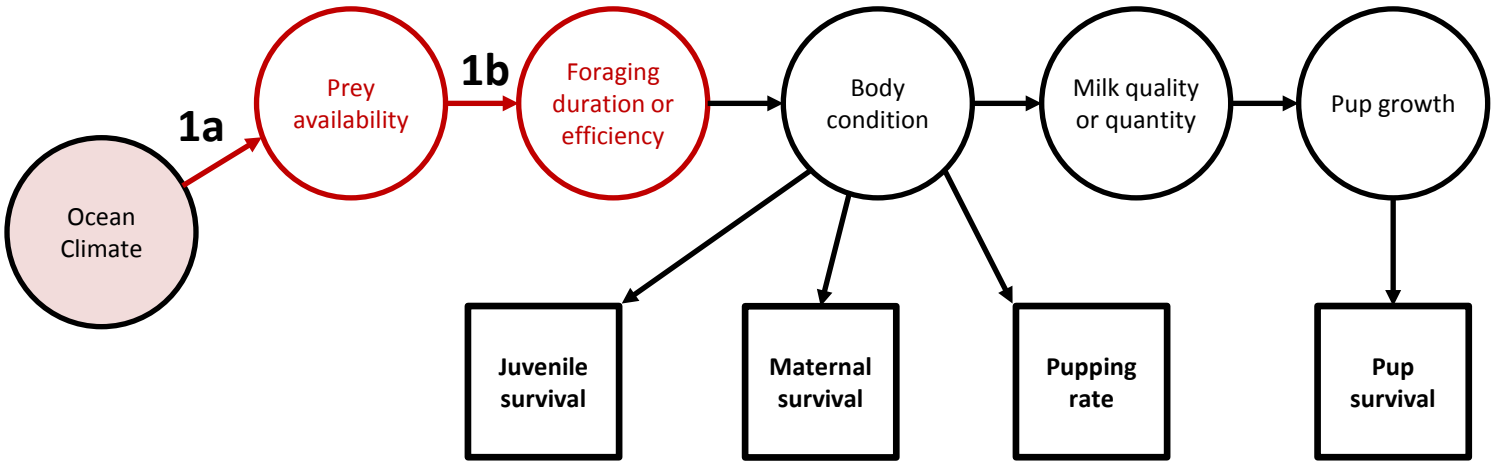
Hypothetical model
Which relationships supported by assessment?



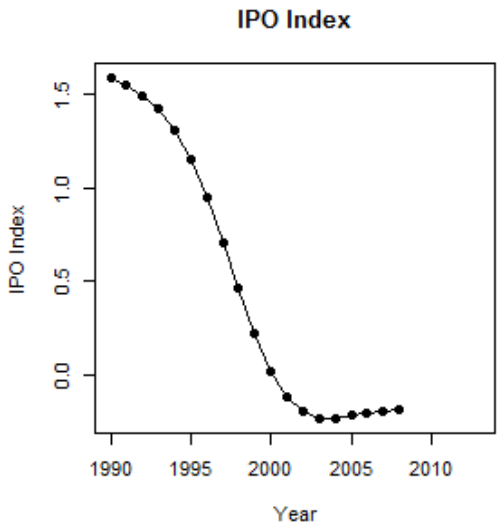
1. Responses to variation in prey availability

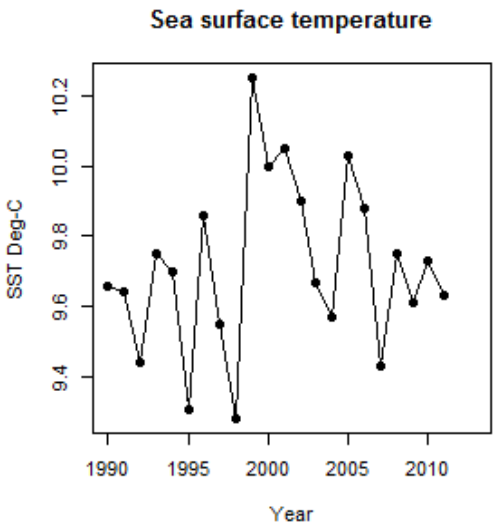


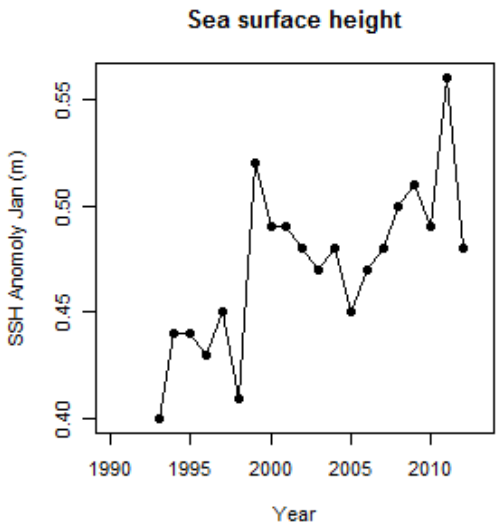
1a. Climate & **prey abundance/diet**

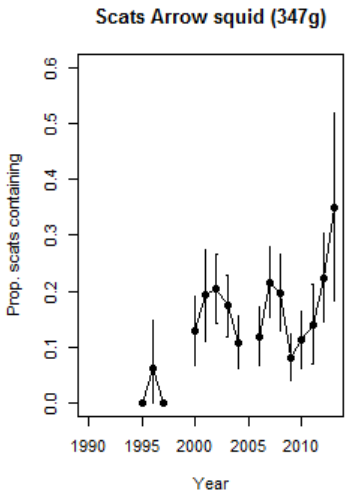


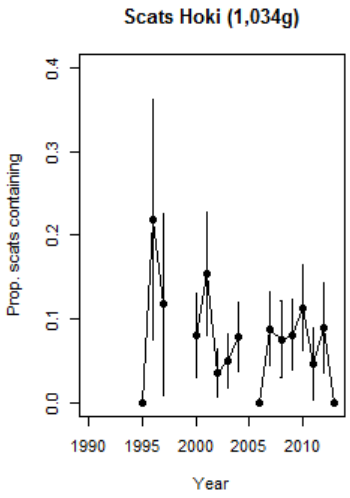
1a (ii) Climate & **diet**

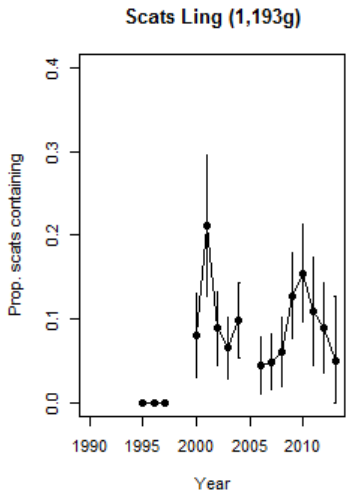


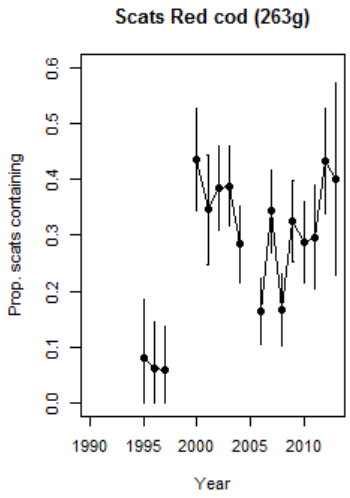


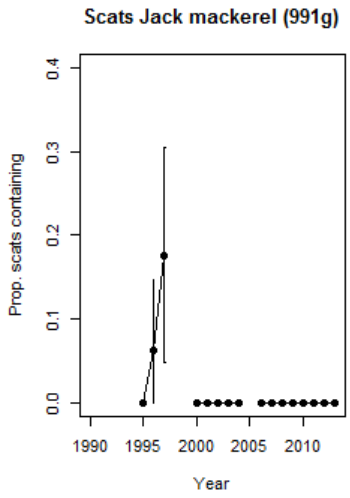




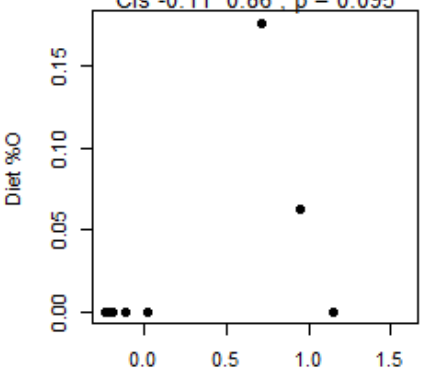


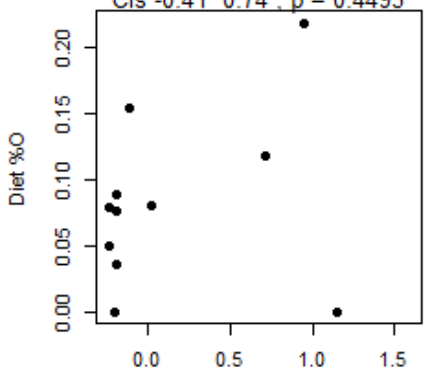


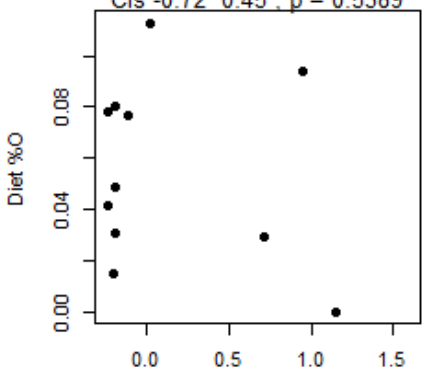


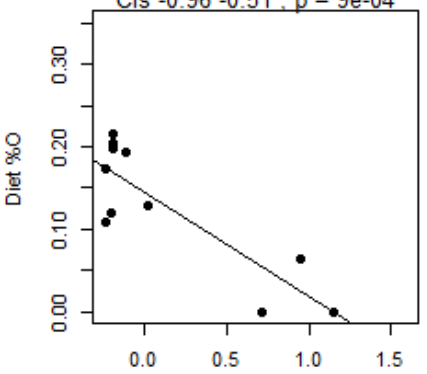


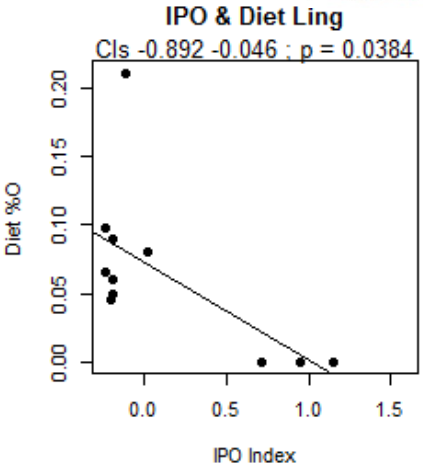
1a (ii) Climate & **diet** – Inter-decadal Pacific Oscillation

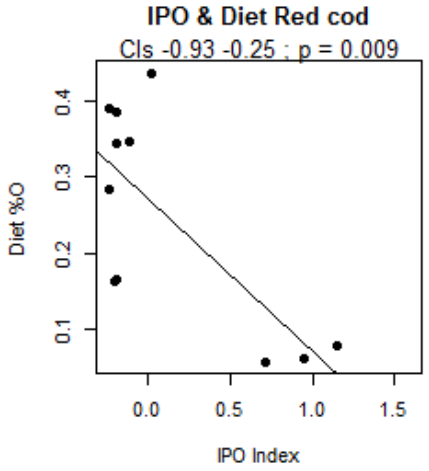


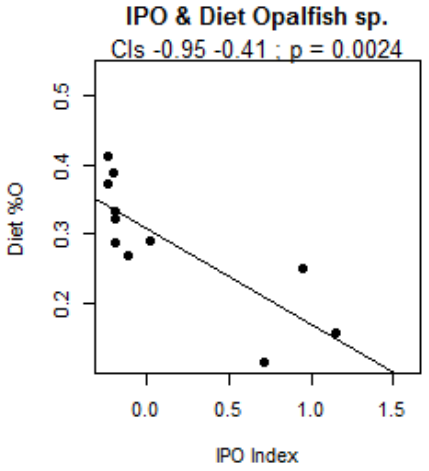


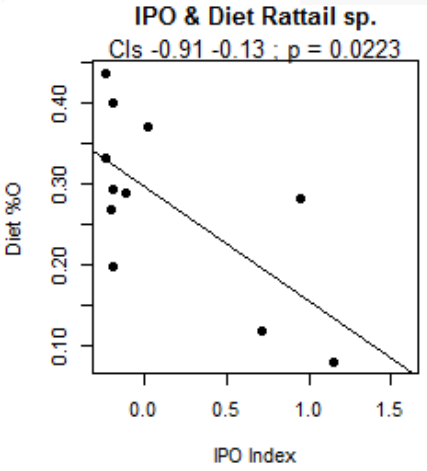




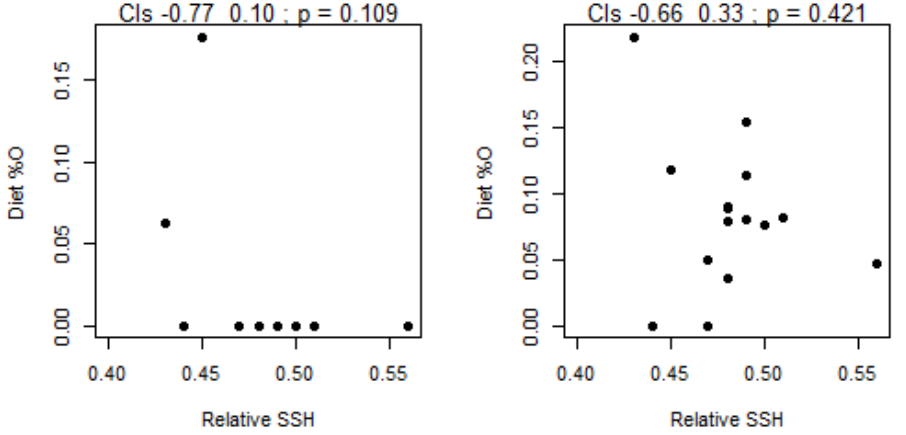


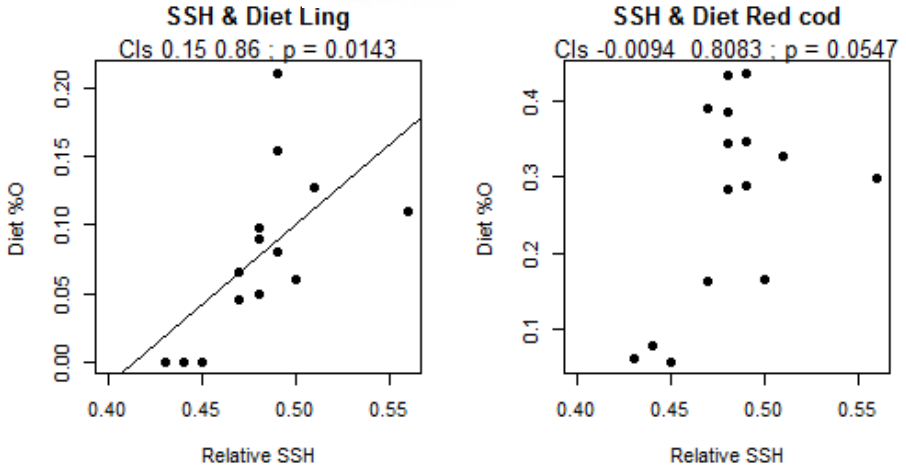




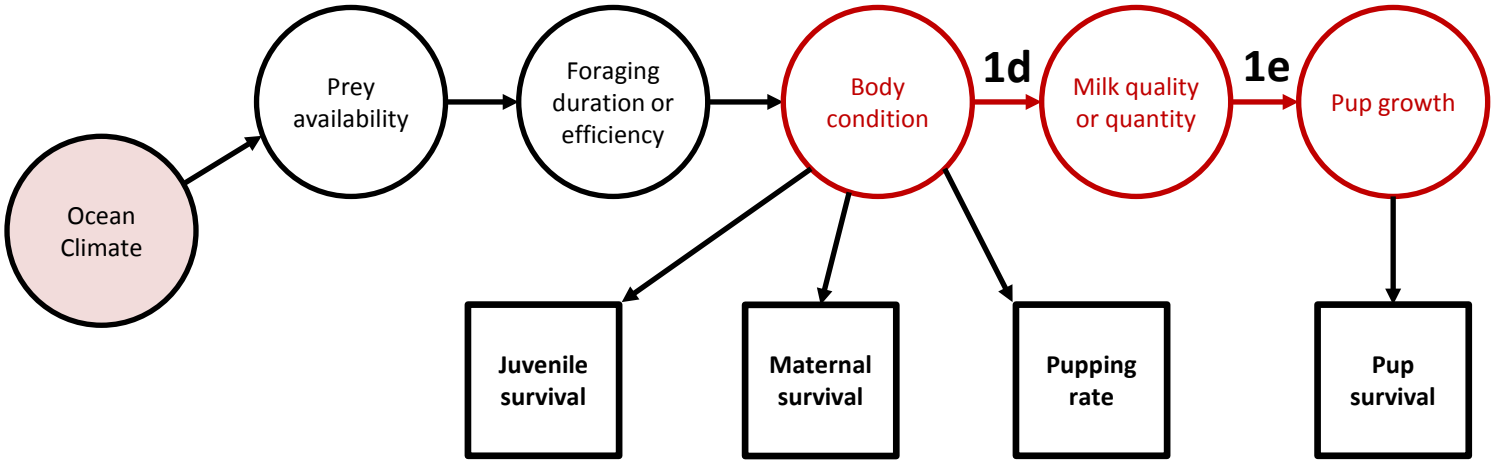


1a (ii) Climate & **diet** – Sea Surface Height





1e. Maternal condition/milk quality & **pup mass**



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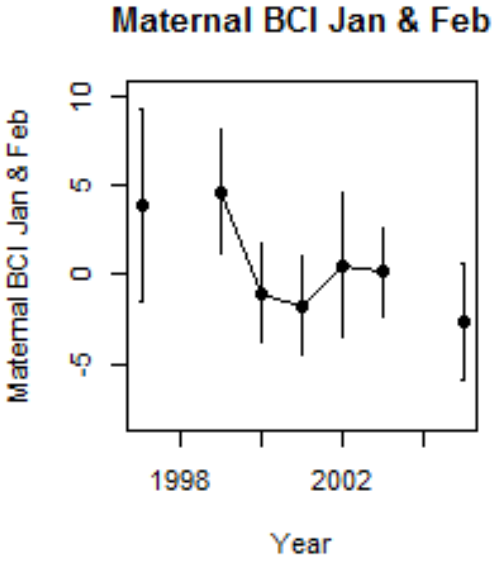

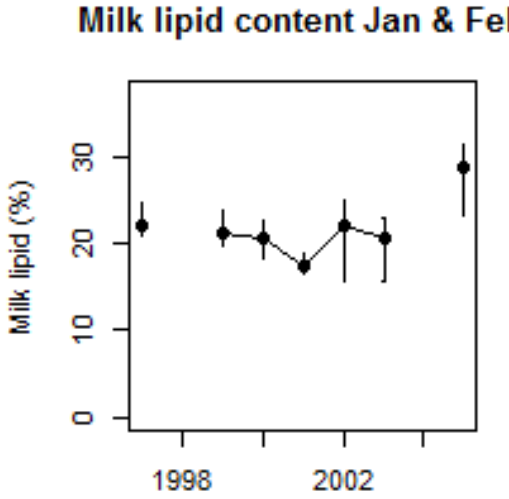

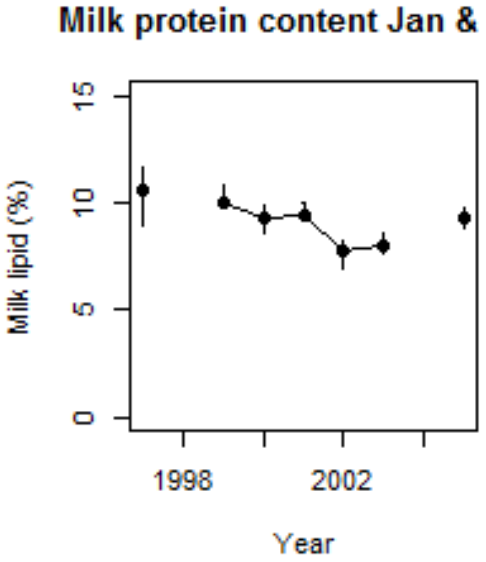

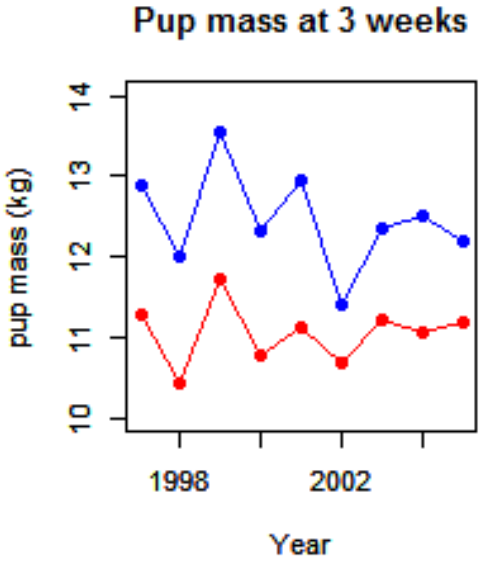

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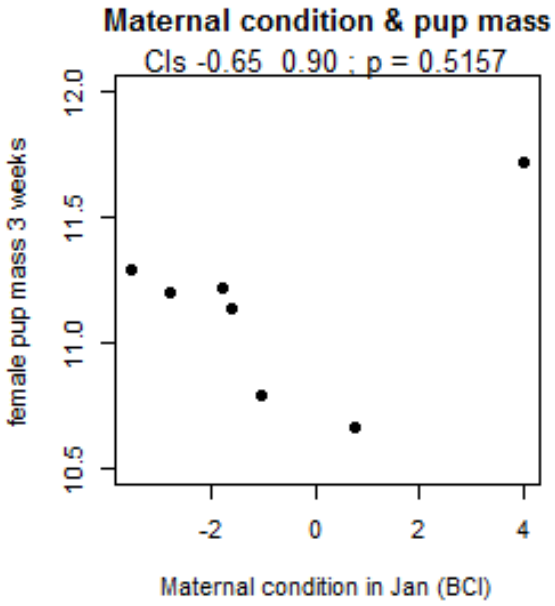
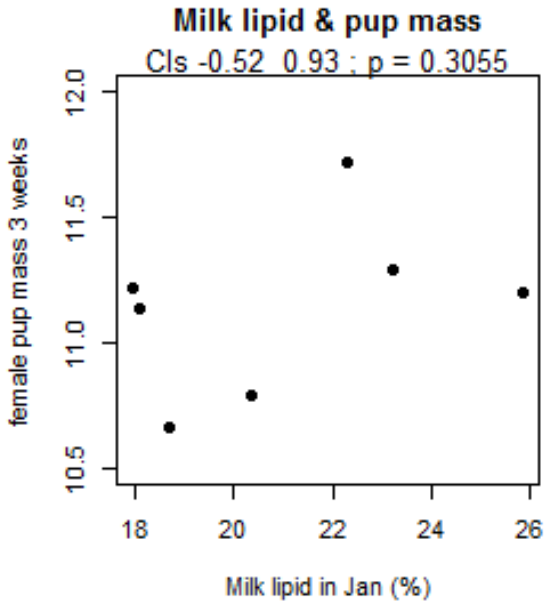
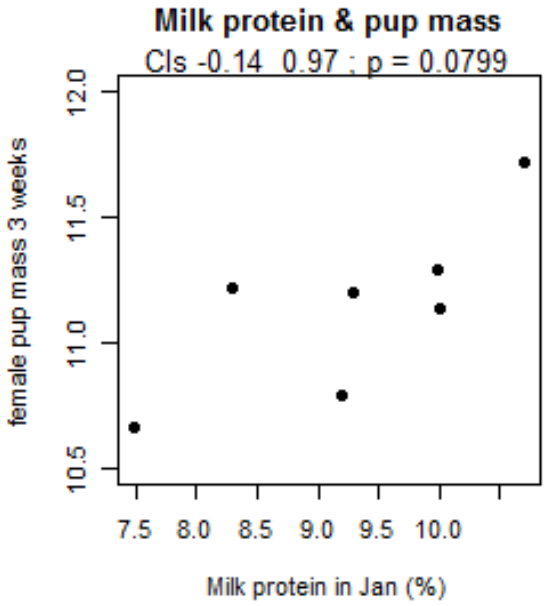
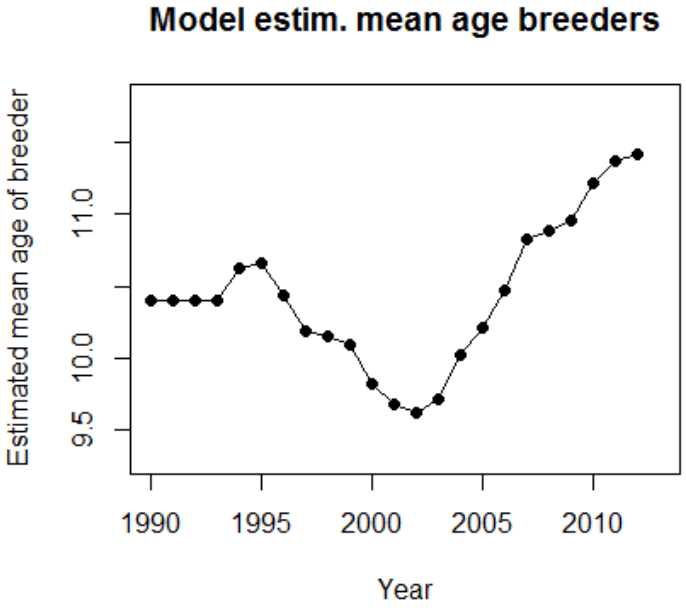
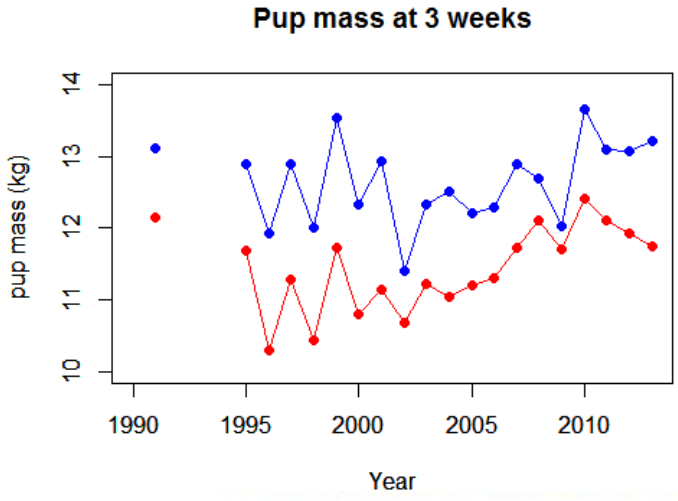






1e. Breeder age & **pup mass**





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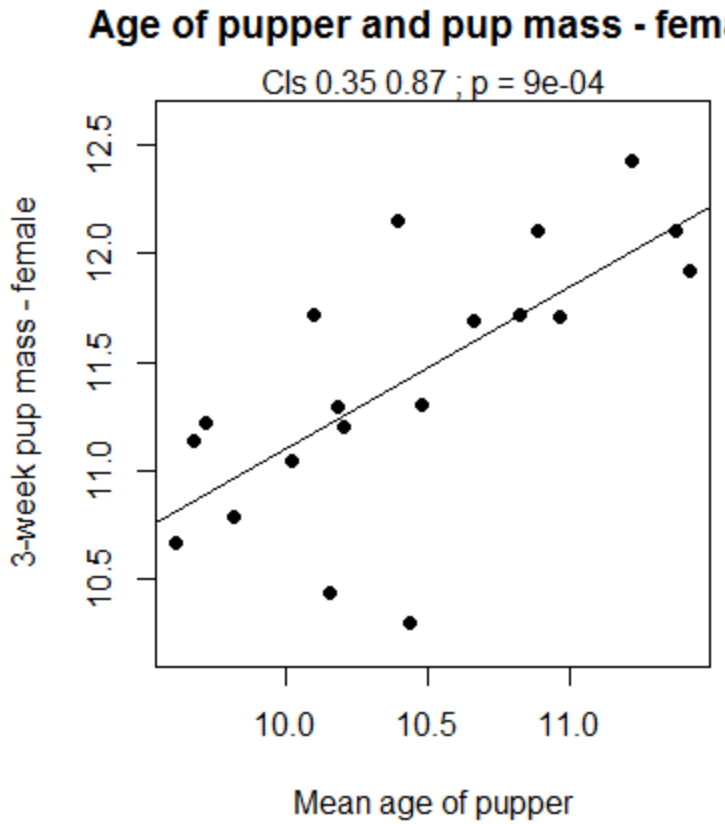
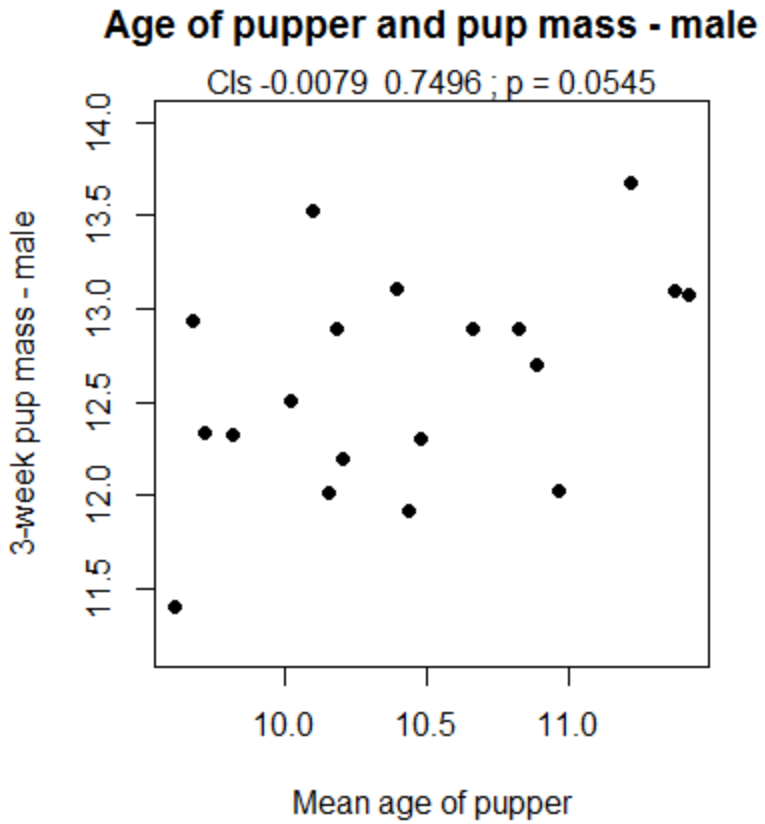
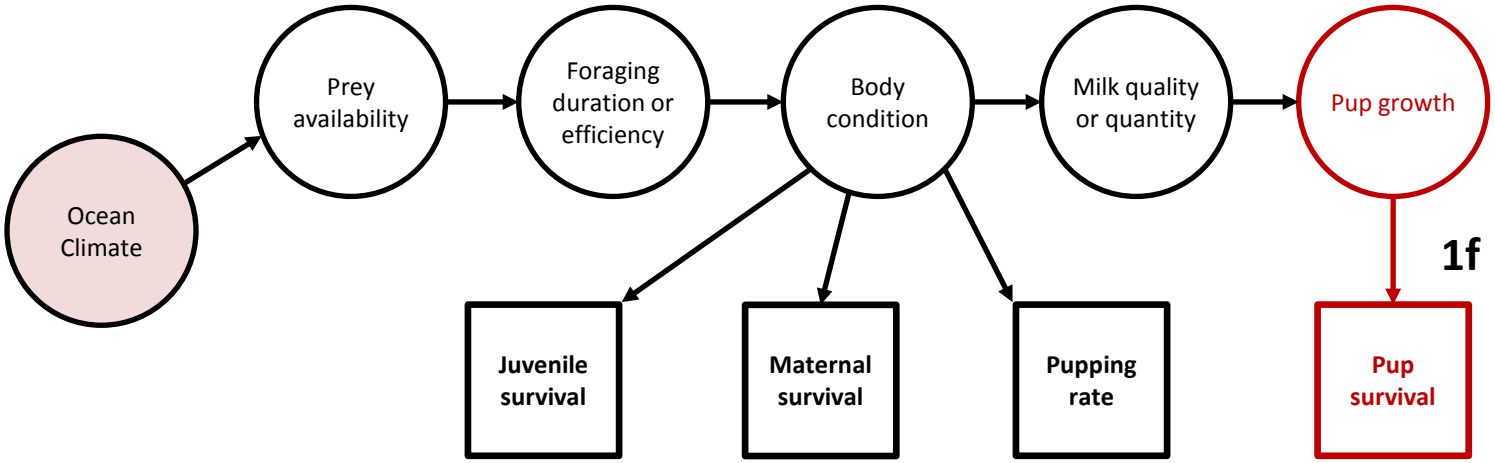




1f. pup mass & **pup survival**



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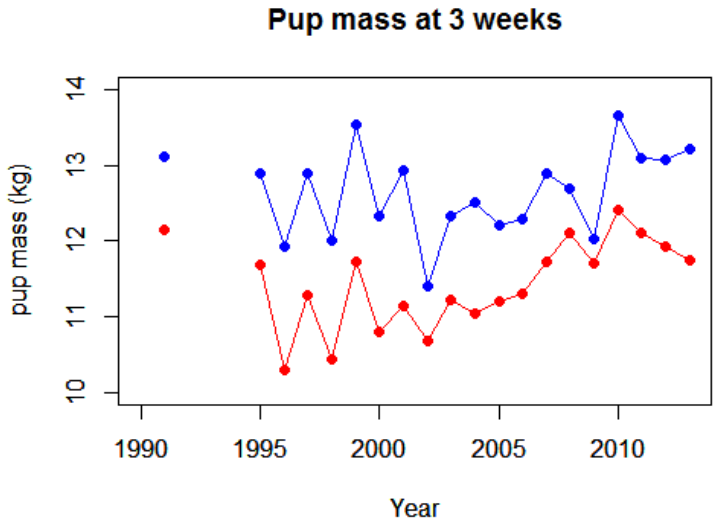

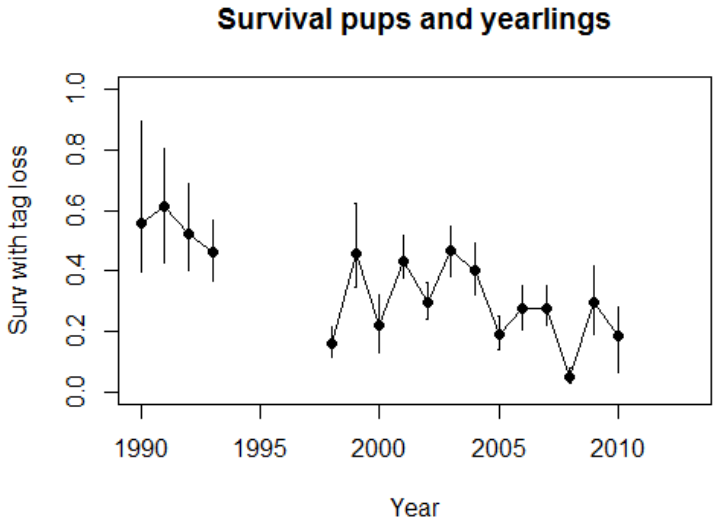

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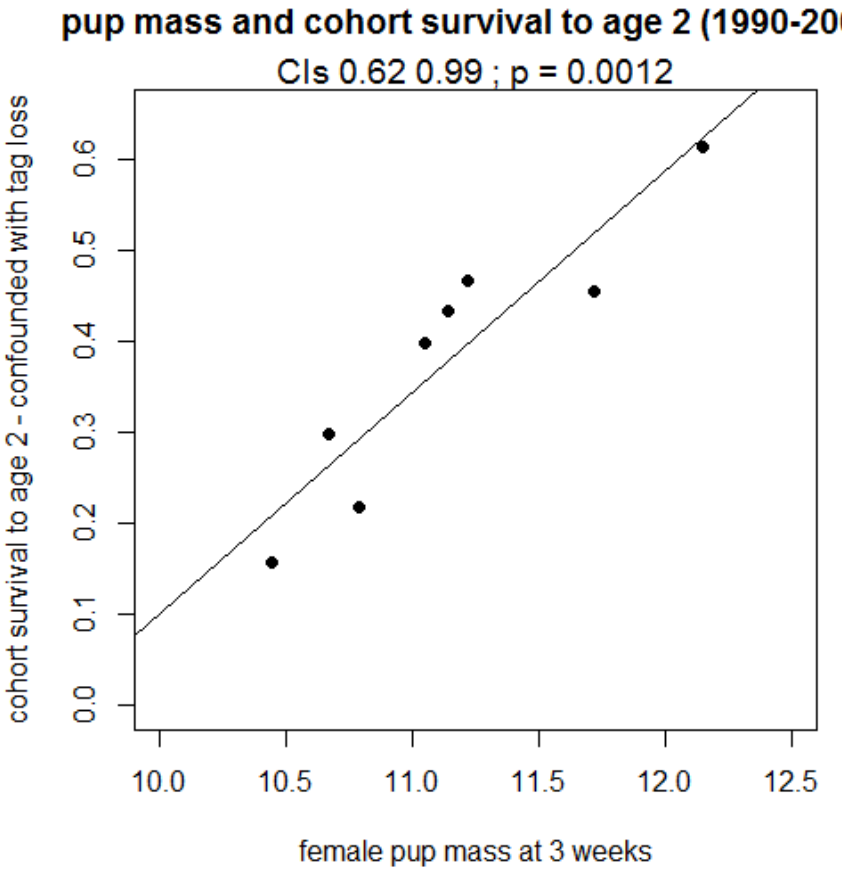
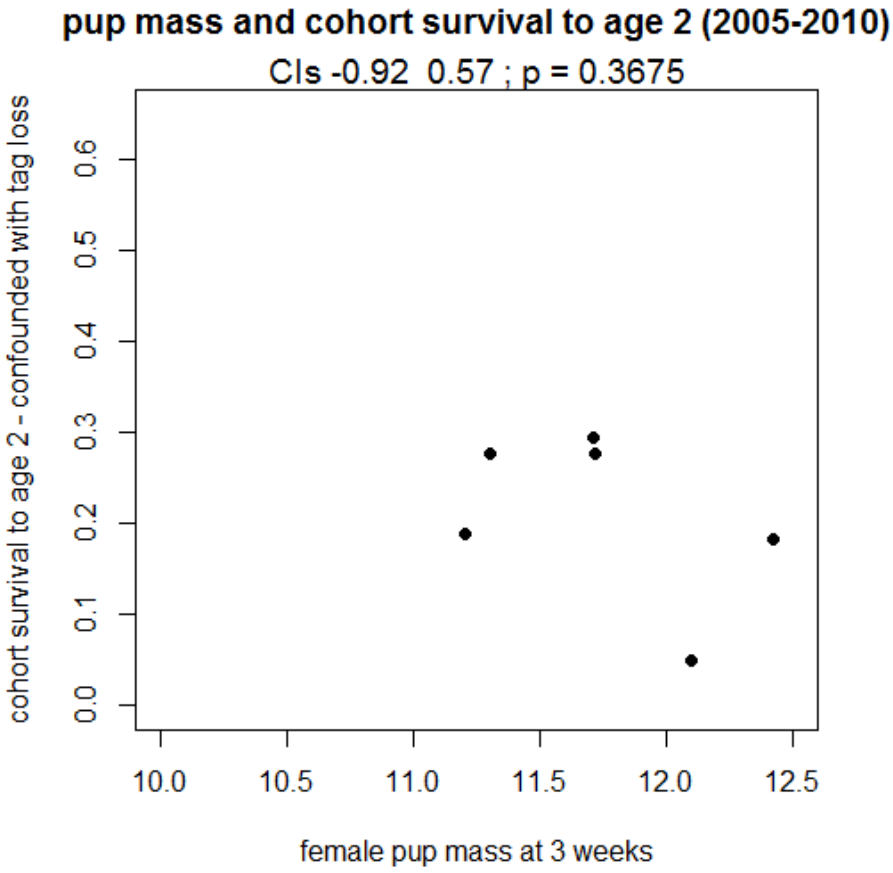
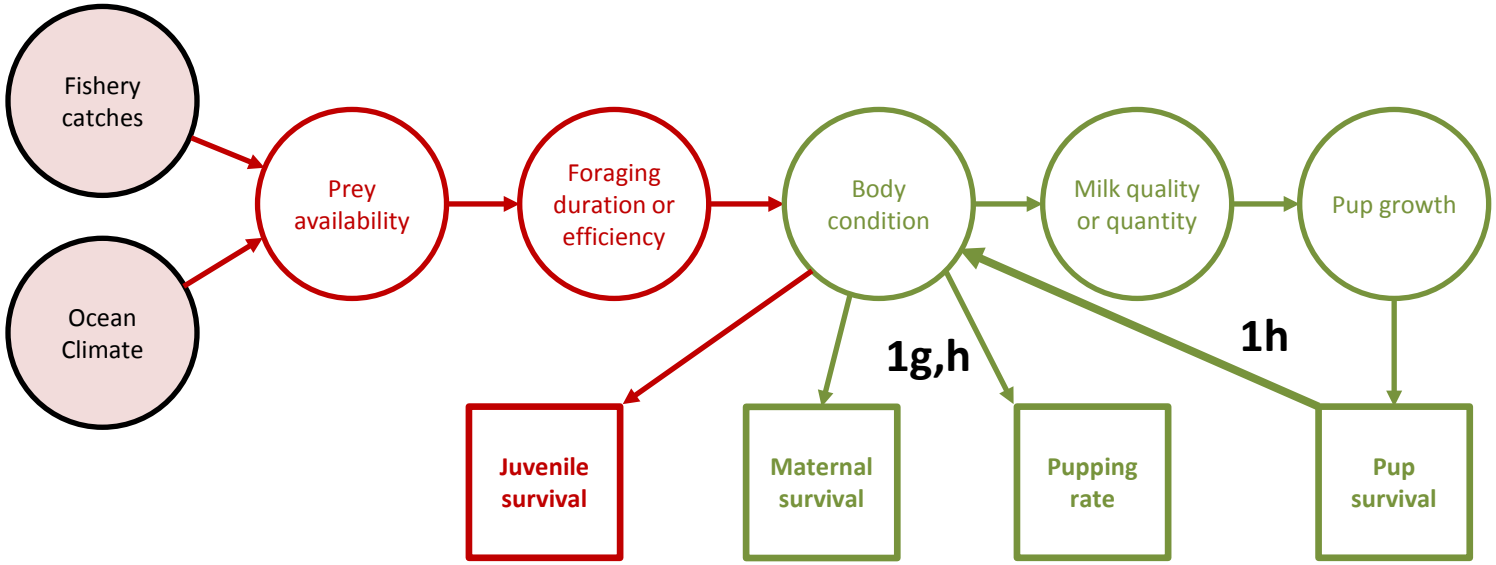


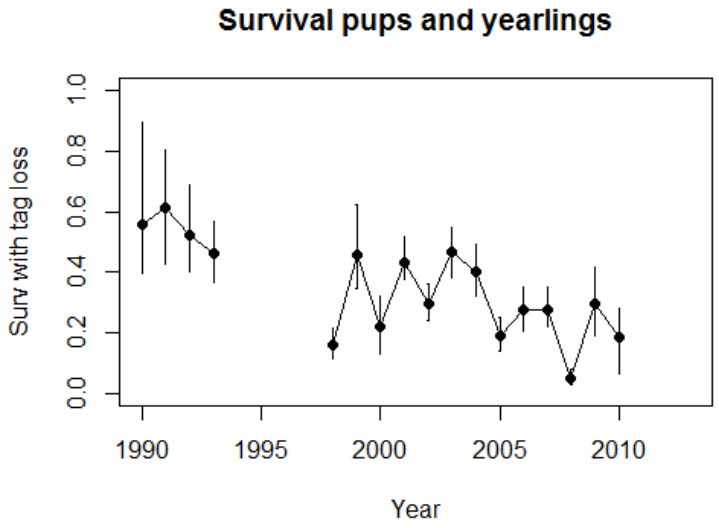


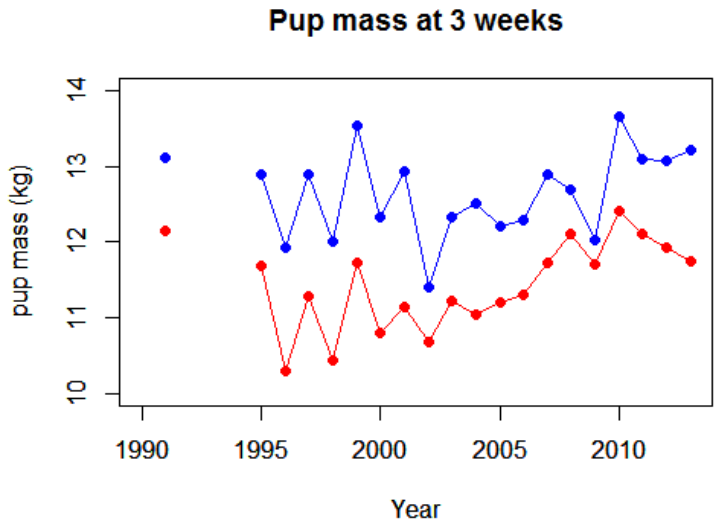
1h. Pup/yearling survival & **response in year+1**



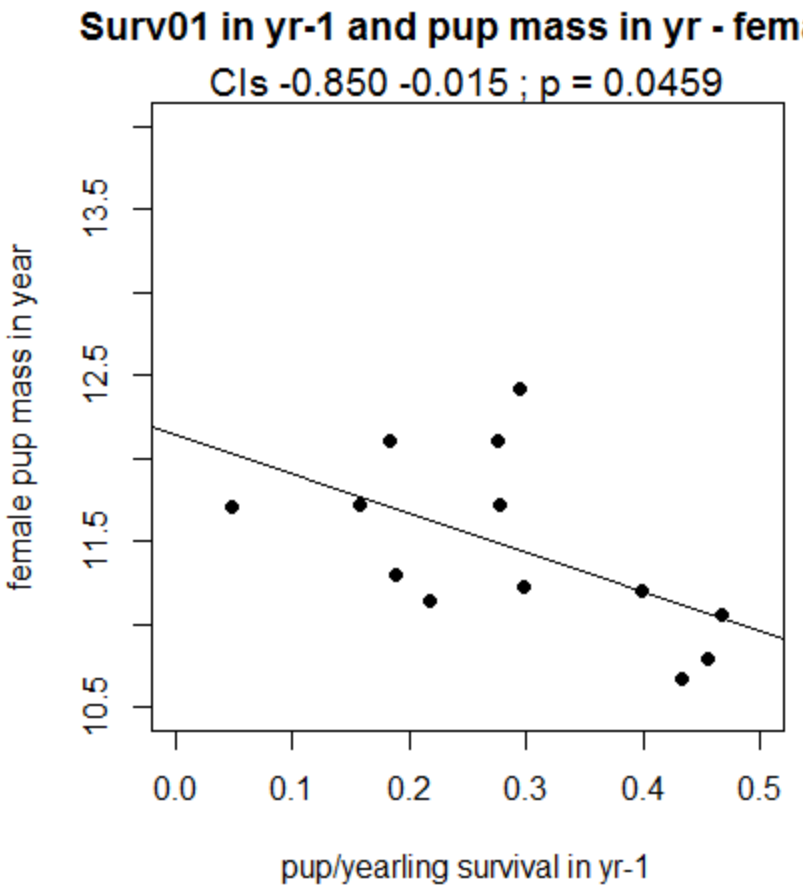
- If pup lost early then mother able to recover condition (intermediate stress)
- Positively affects maternal survival, pupping rate, pup growth in the next year

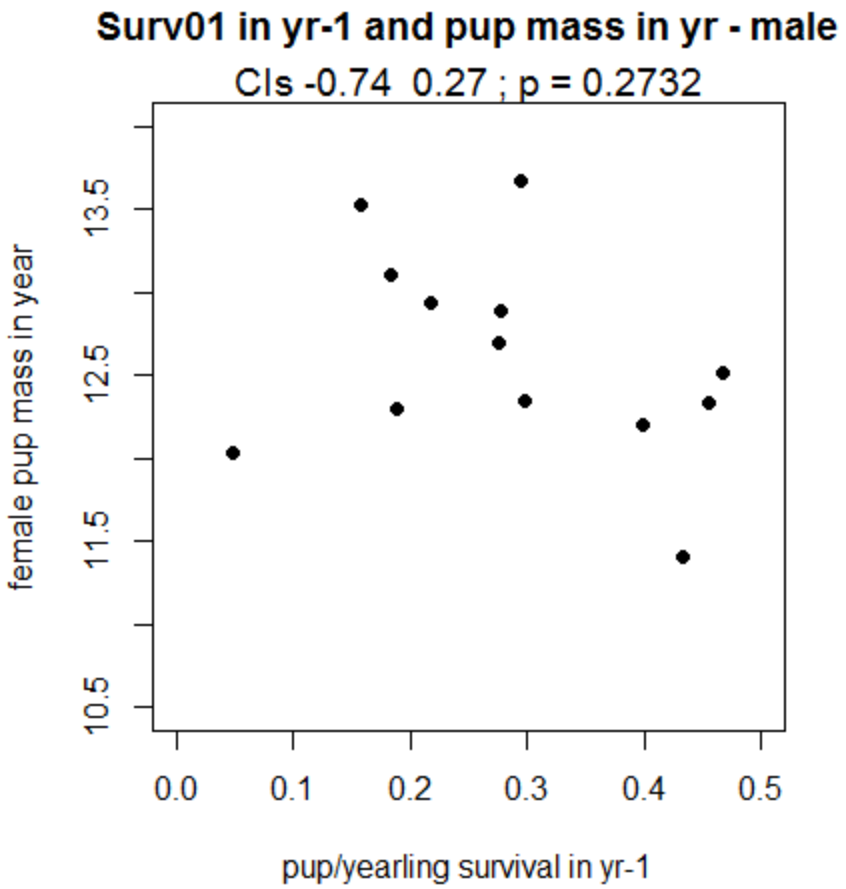
1h. Pup/yearling survival & **pup mass in yr+1**



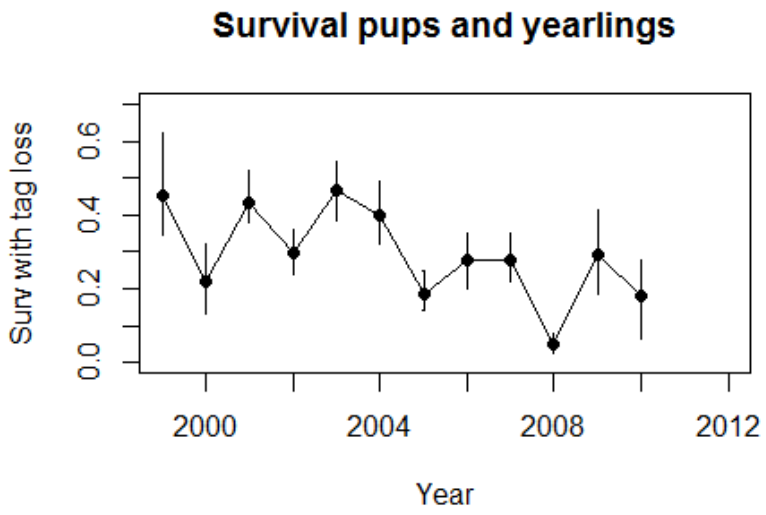


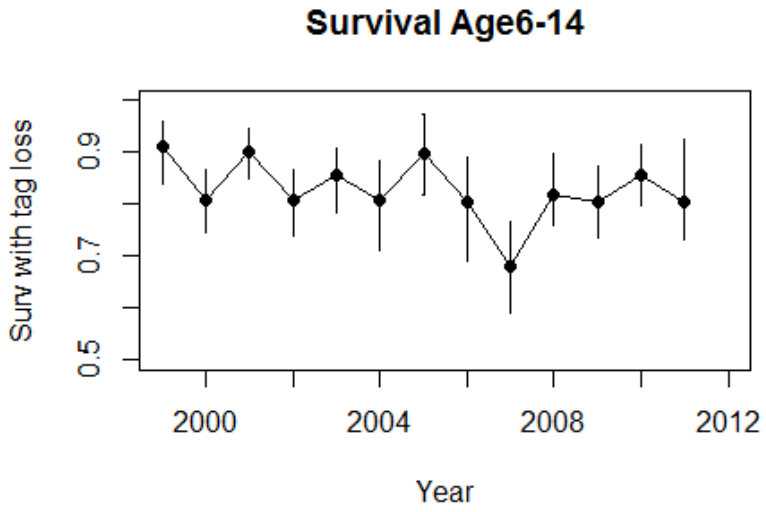
1h. Pup/yearling survival & **pup mass in yr+1**



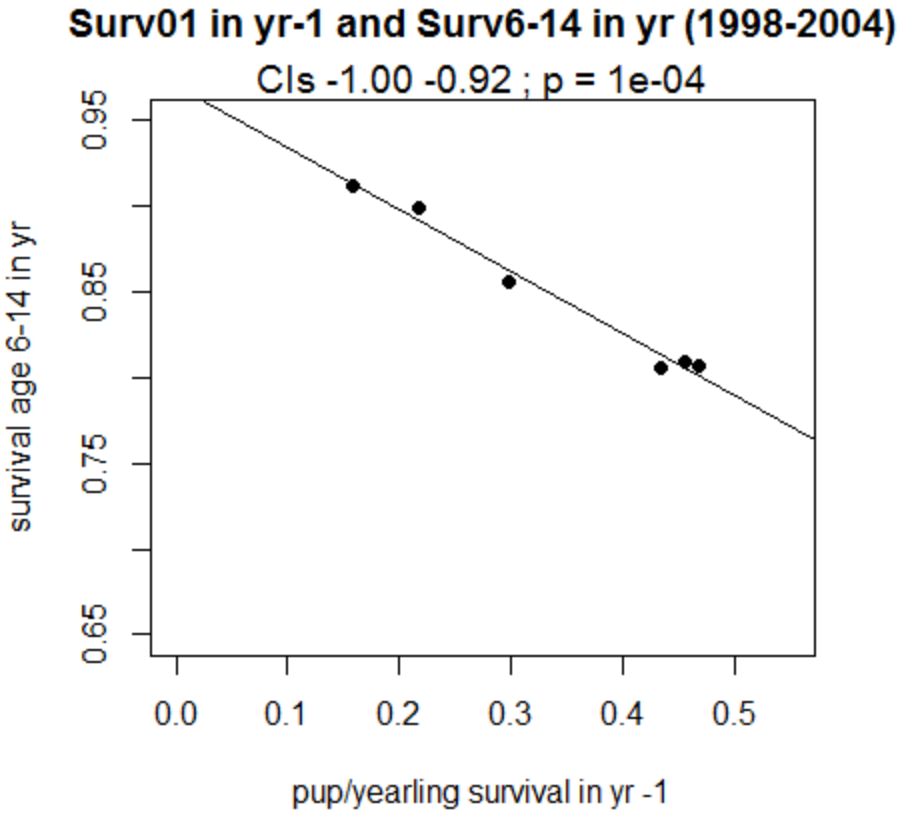


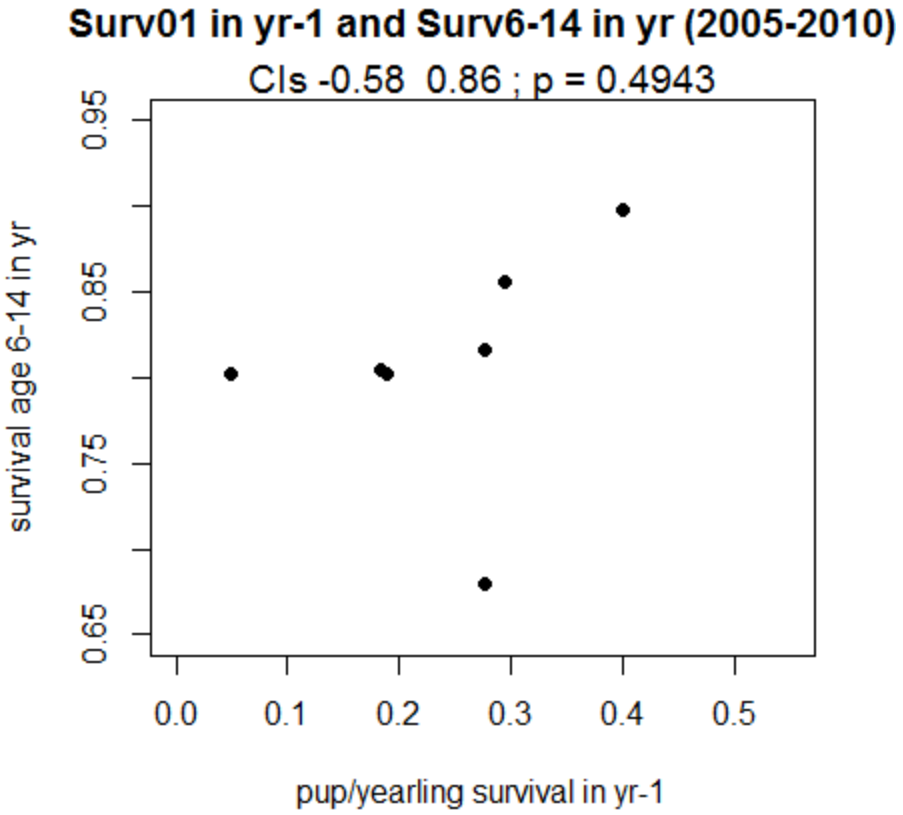
1h. Pup/yearling survival & **adult survival in yr+1**





1h. Pup/yearling survival & **adult survival in yr+1**

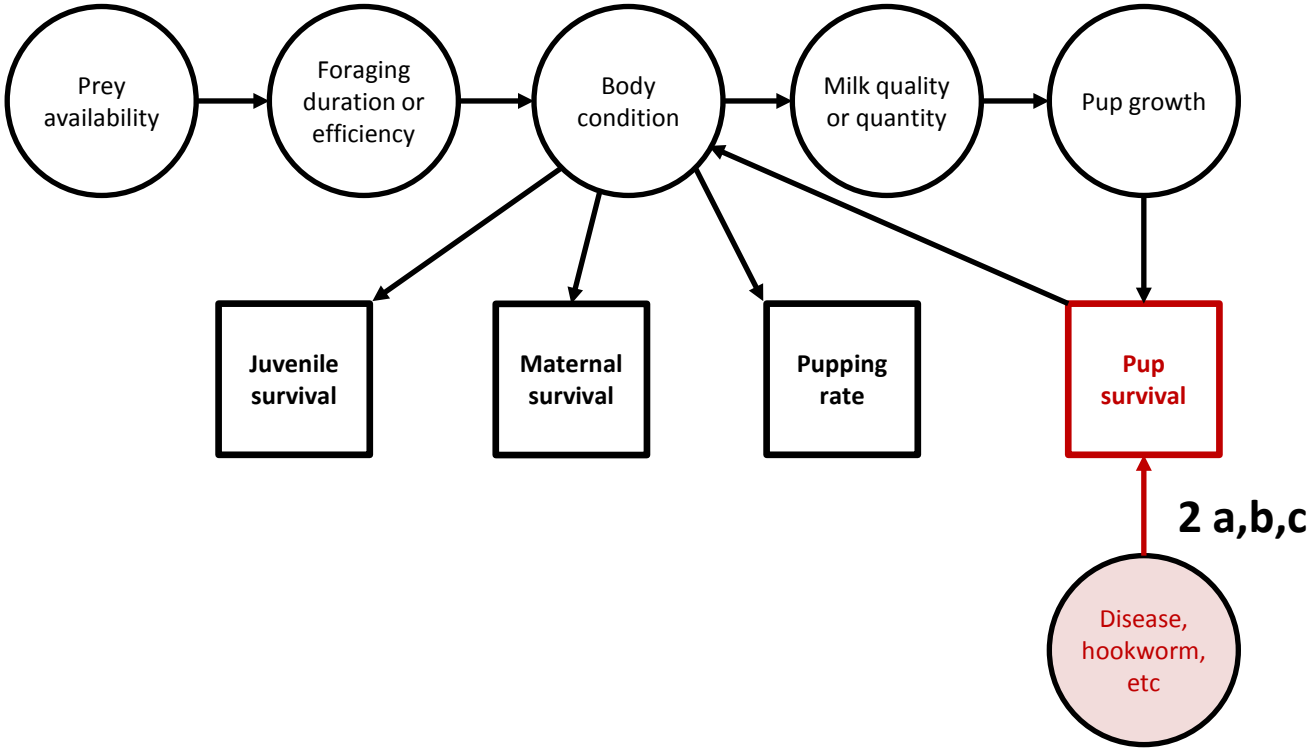




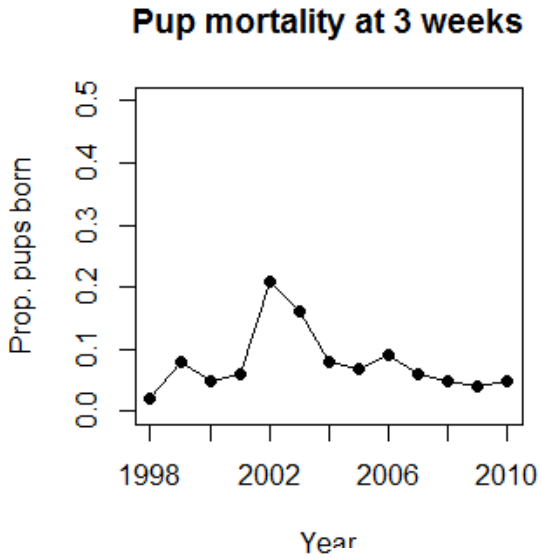
Summary of correlative assessment – nutritional stress-related

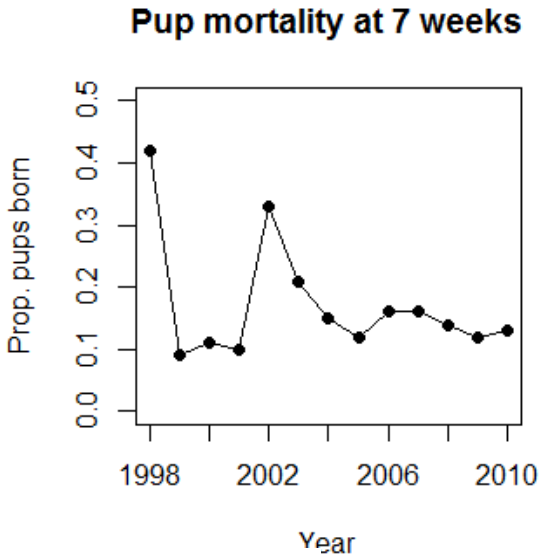
Candidate driver of population change	ID	Relationships assessed	Correlation
Nutritional stress	1a	Climate and diet	Yes (SSH, IPO)
	1b	Prey abundance and diet	Only one species
	1c	Diet and maternal condition	Only one species
	1d	Diet and milk quality	Only one species
	1e	Maternal condition/milk quality/breeder age and pup mass	Yes, between breeder age and pup mass
	1f	Pup mass and pup/yearling survival	Yes
	1g	Maternal condition and maternal survival/pupping rate	No
	1h	Pup/yearling survival and demographic response in yr+1	Yes, between pup/yearling survival and adult survival or pup mass

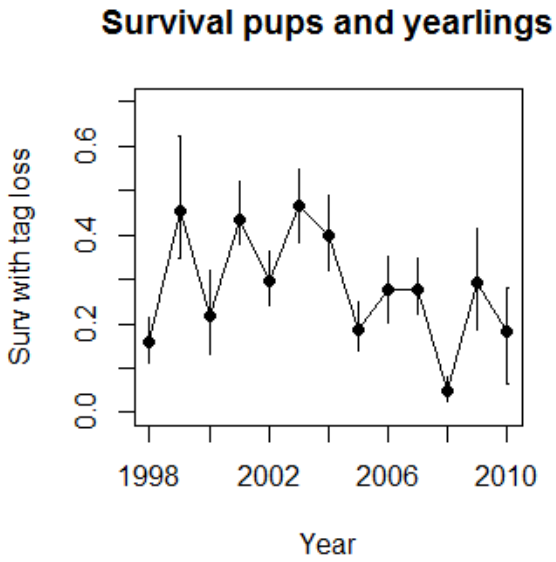
2. Pup mortality cause & **pup/yearling survival**



2a. Early pup mortality & **pup/yearling survival**







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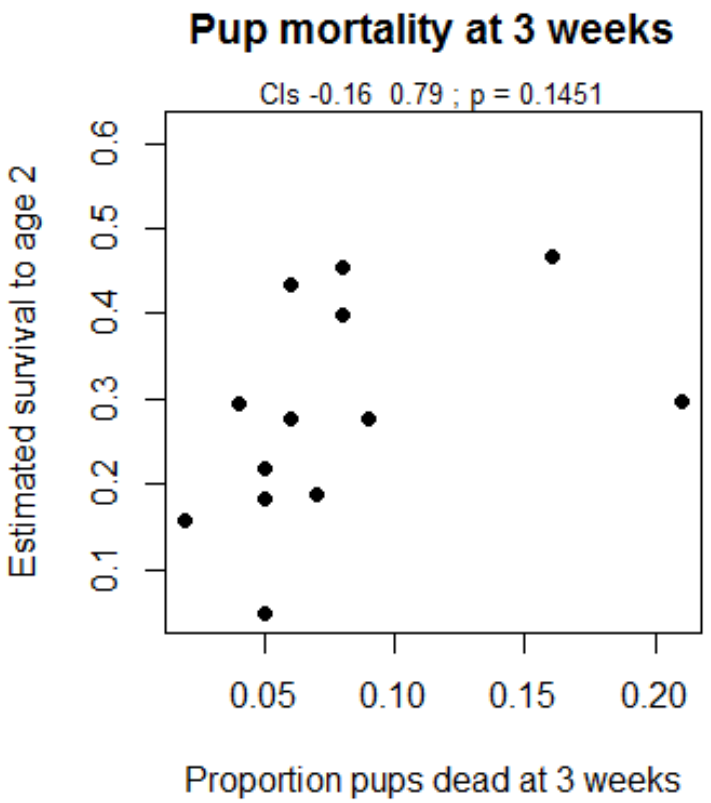
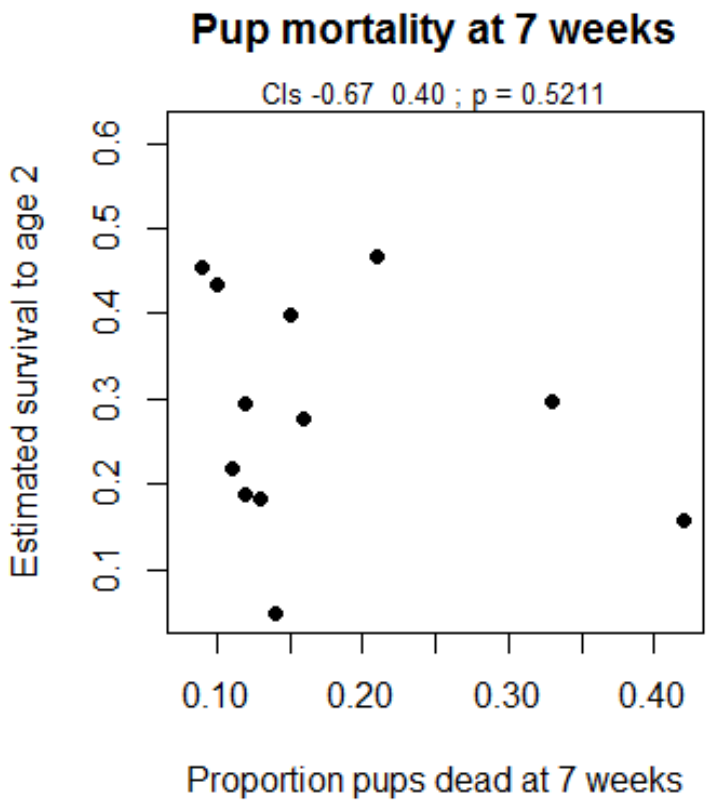
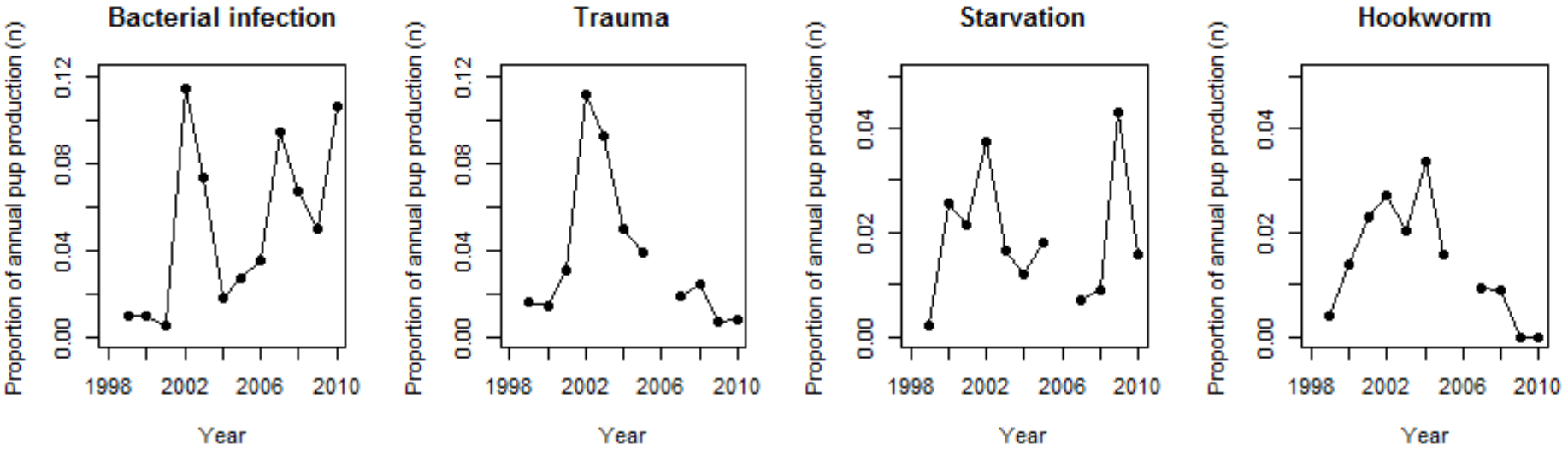
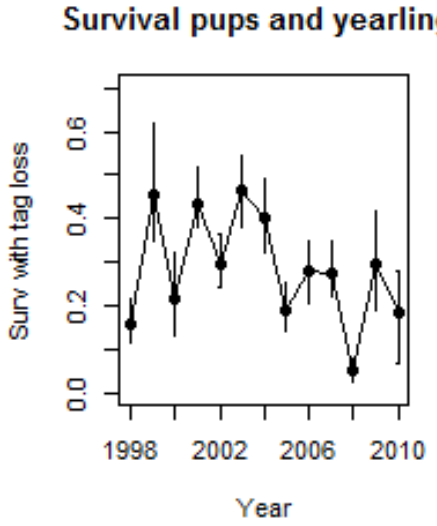


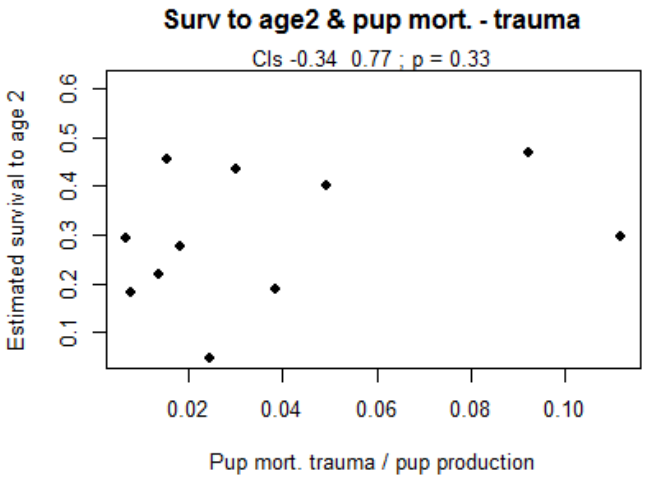


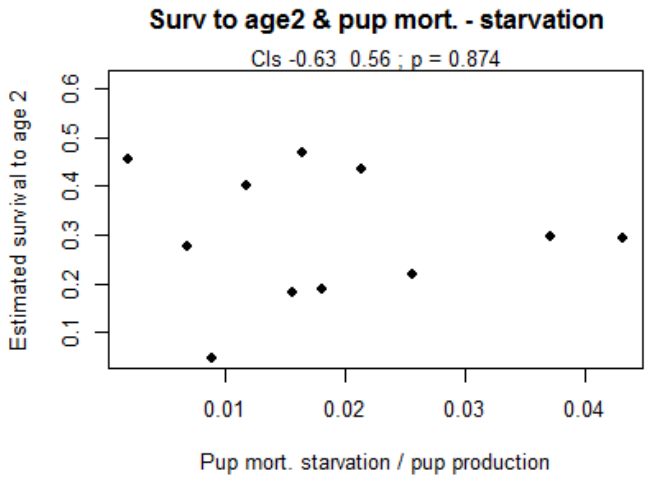
2b. Pup mortality cause & **pup/yearling survival**

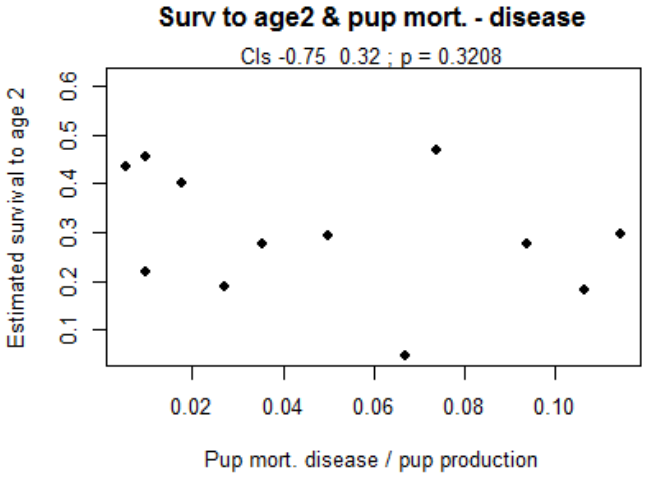


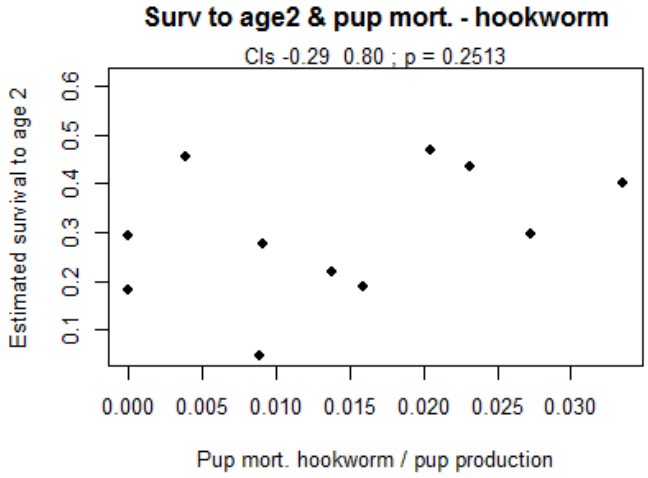


2b. Pup mortality cause & **pup/yearling survival**

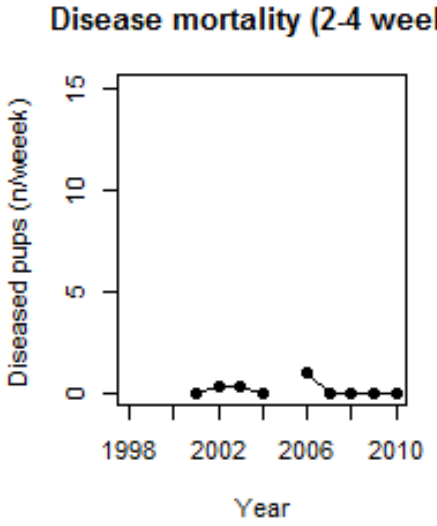


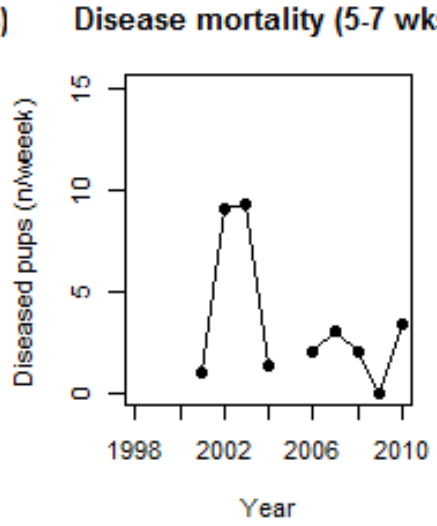


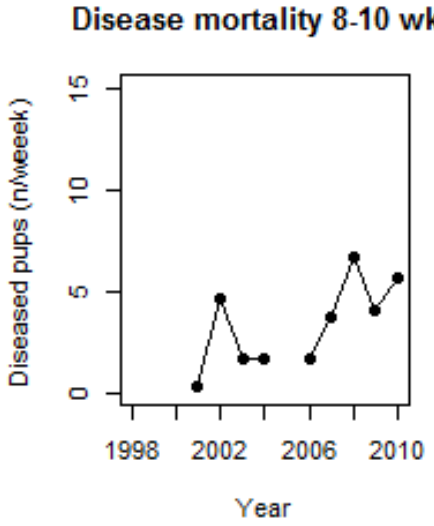


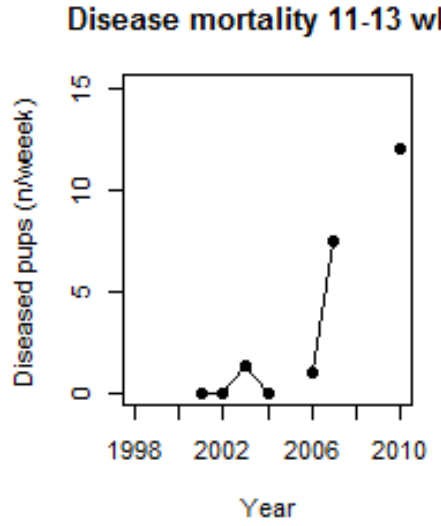


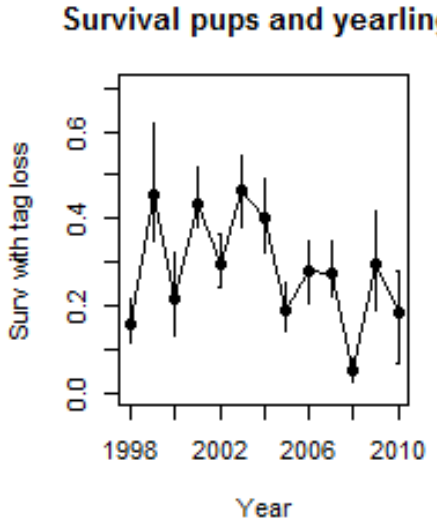
2c. Timing of disease mortality & **pup/yearling survival**



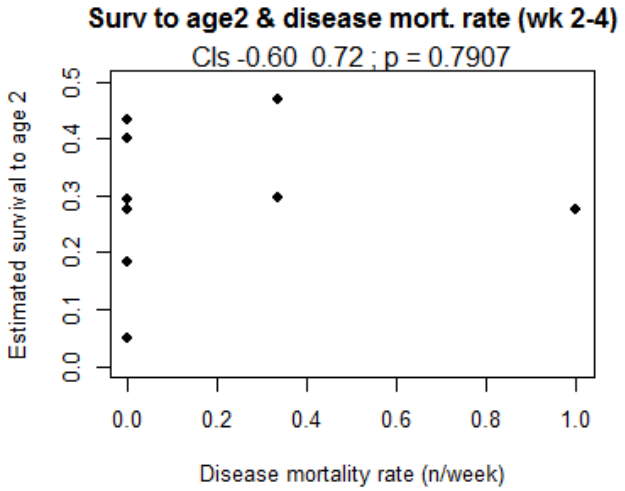


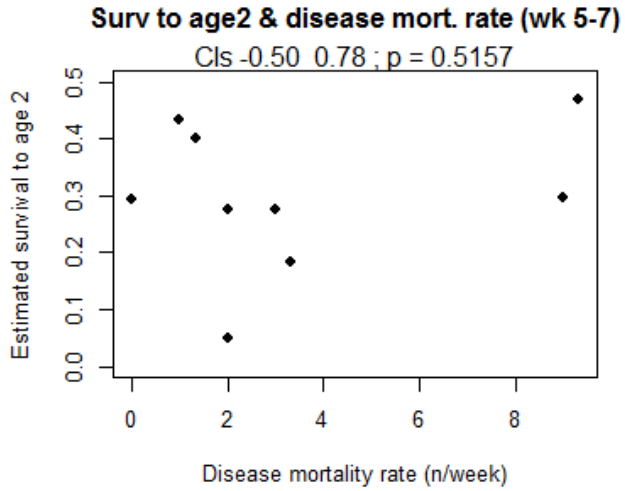


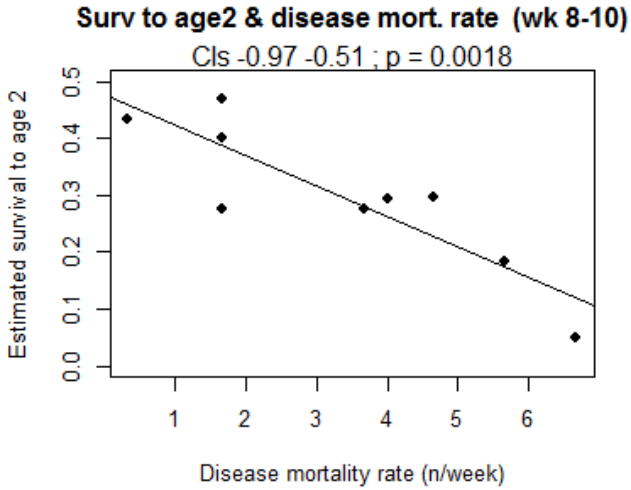


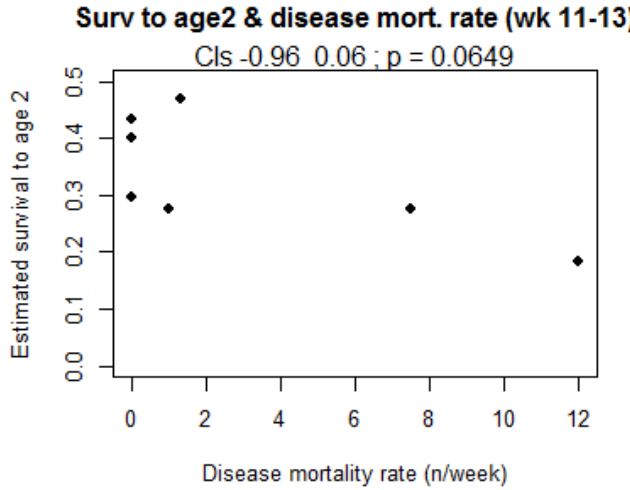


2c. Timing of disease mortality & **pup/yearling survival**





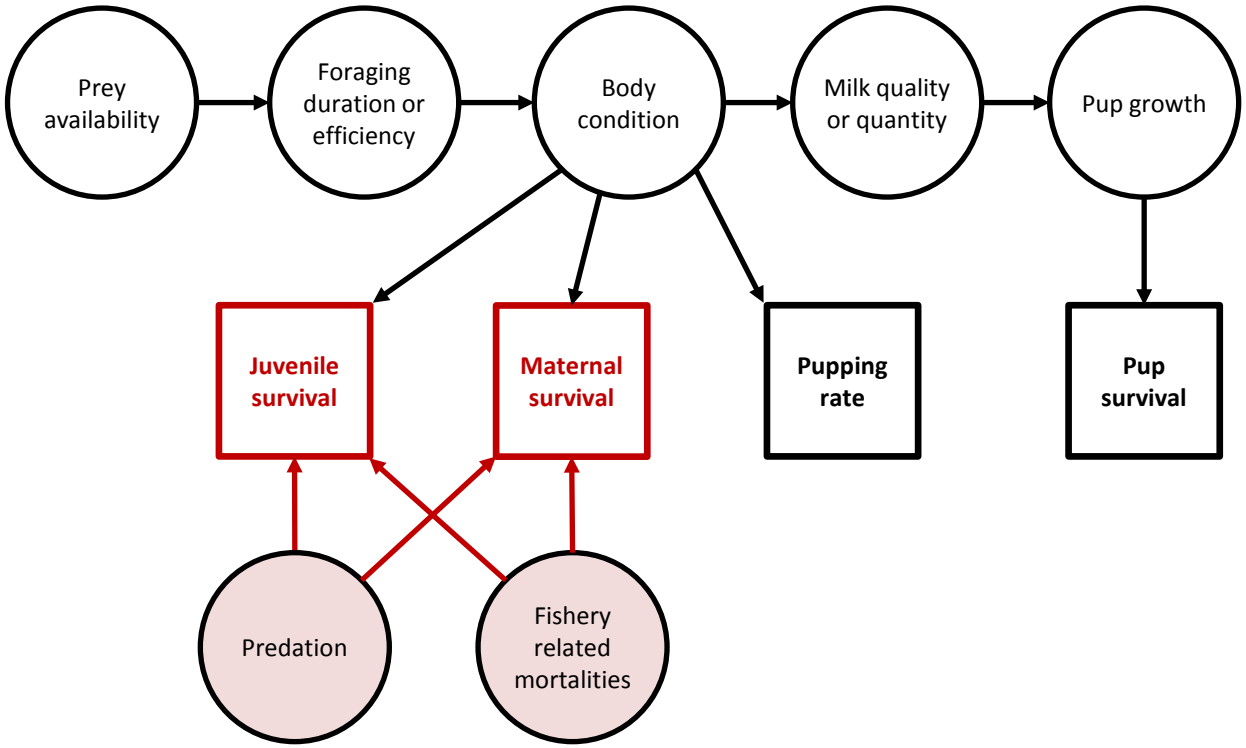




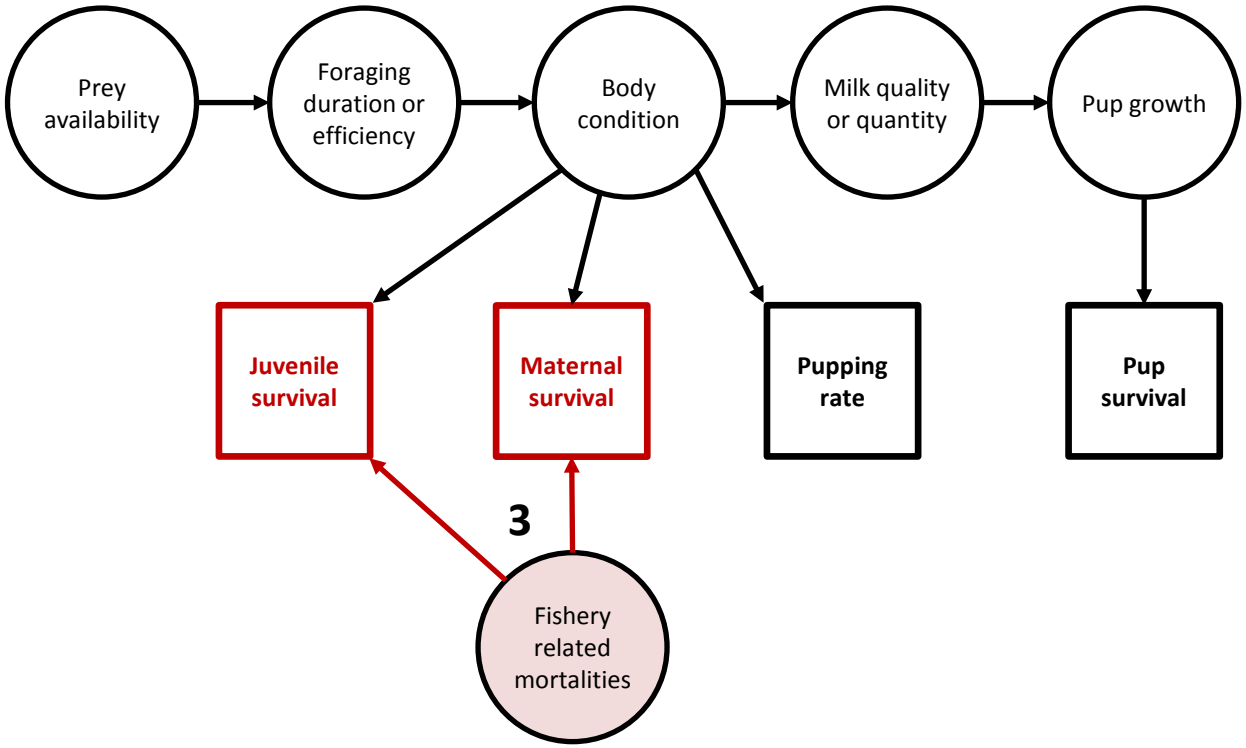
Summary of correlative assessment – disease-related pup mortality

Candidate driver of population change	ID	Relationships assessed	Correlation
Disease-related pup mortality	2a	Pup mortality at 3/7 weeks and pup/yearling survival	No
	2b	Pup mortality by cause and pup/yearling survival	No
	2c	Bacterial disease related mortality and pup/yearling survival	Yes (8-10 weeks)

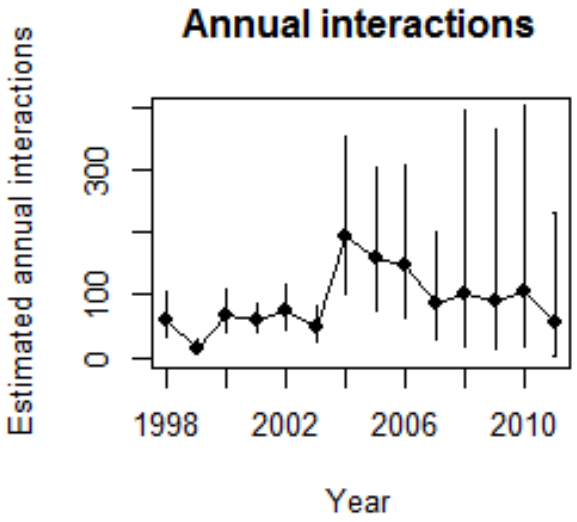
3. Predation or fishery-related mortalities & **juvenile/adult survival**

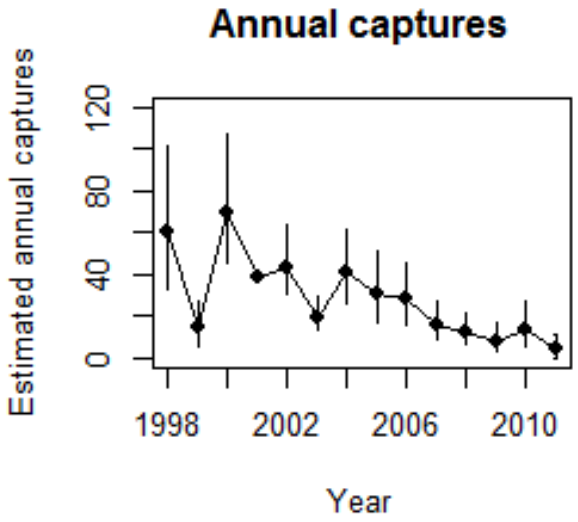


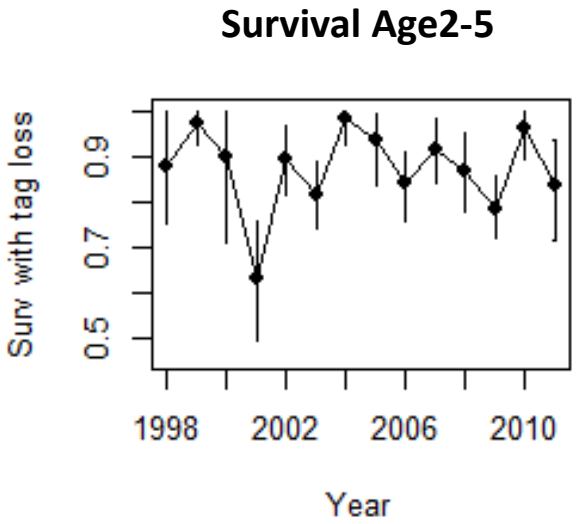
3. Fishery-related mortalities & **juvenile/adult survival**

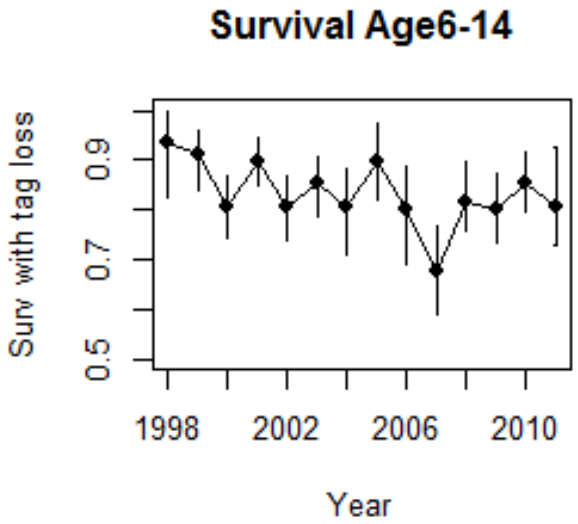


3. Fishery-related mortalities & **juvenile/adult survival**

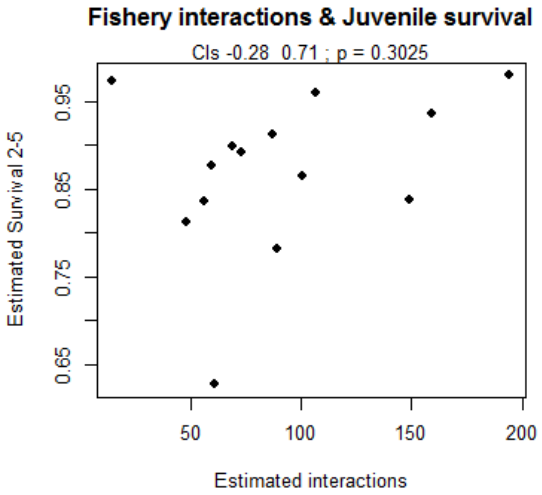


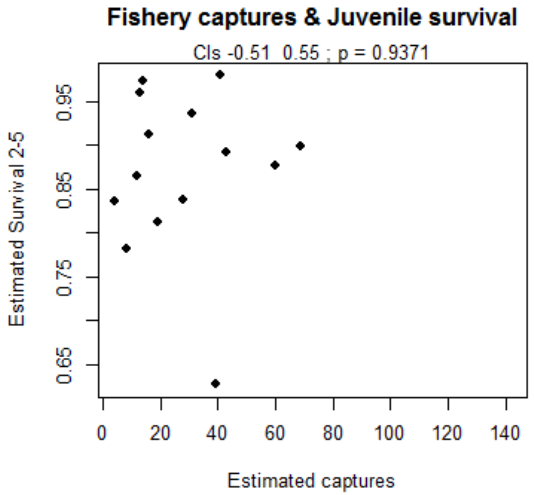


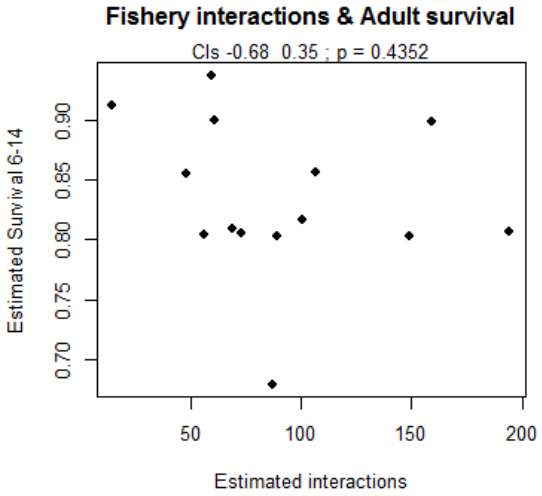


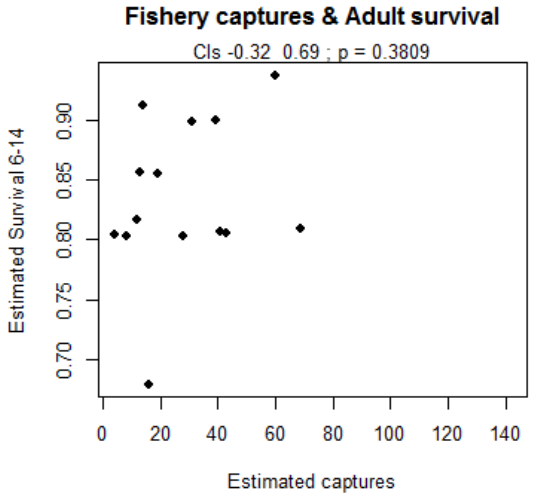


3. Fishery-related mortalities & **juvenile/adult survival**





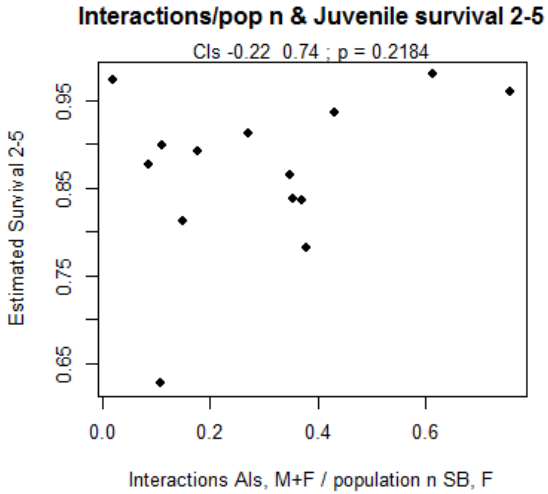


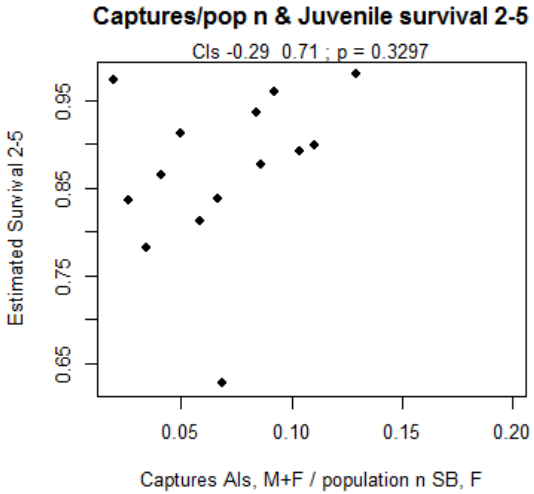


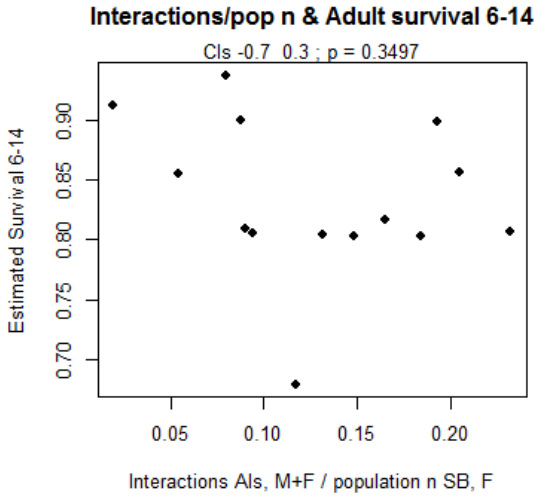
Simple test of correlation between estimated captures/interactions and survival estimates for ages 2-5 and 6-14 (confounded with tag loss)

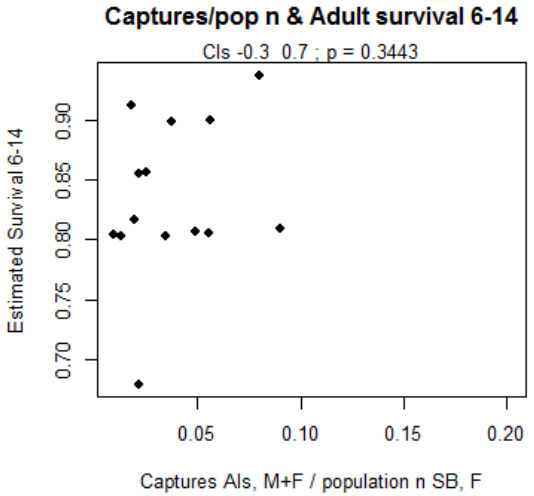
None significantly correlated

3. Fishery-related mortalities & **juvenile/adult survival**









Correlation between capture/interaction rate as a proportion of model estimated population *n* and survival estimates for ages 2-5 and 6-14 (confounded with tag loss)

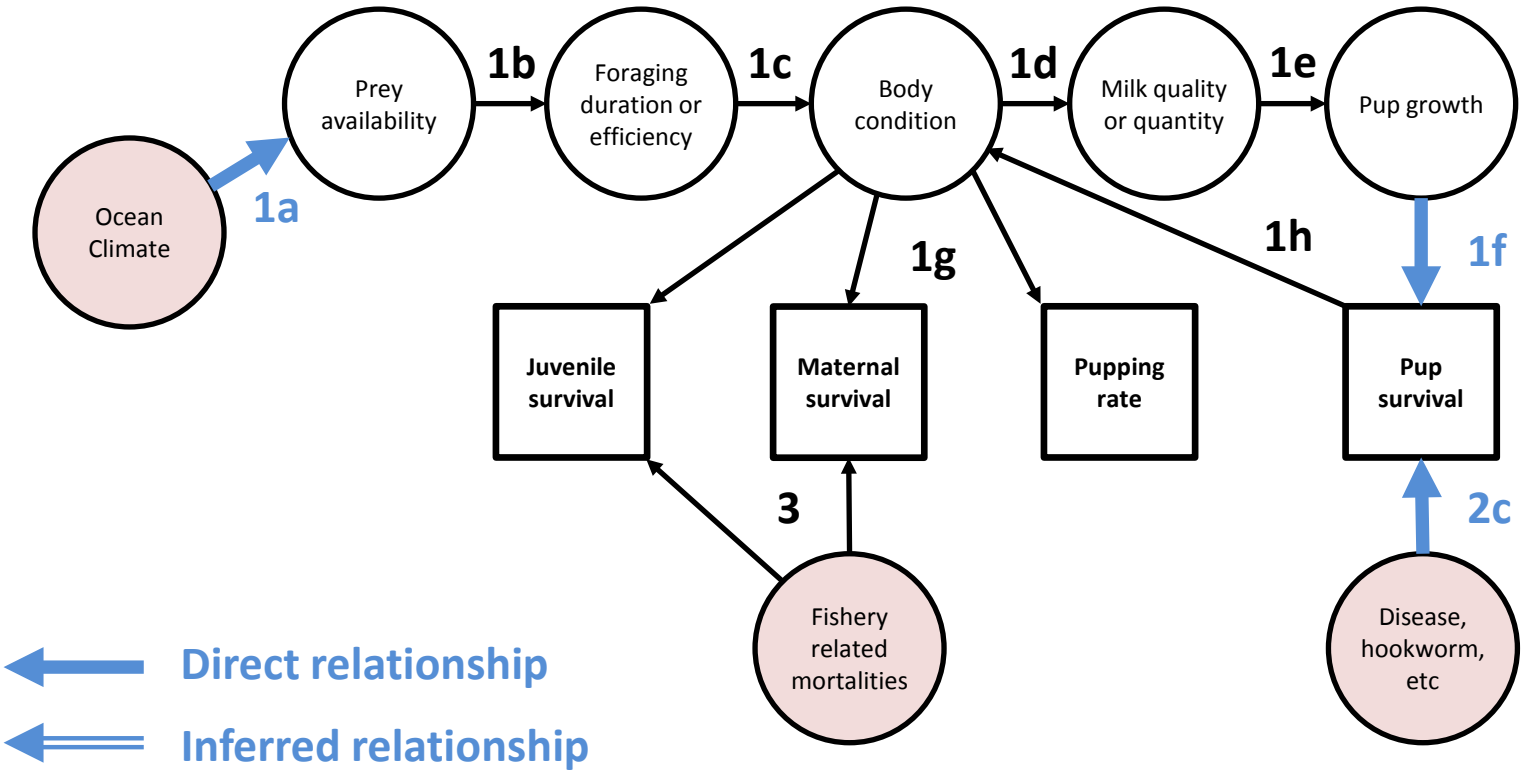
None significantly correlated, though not accounting for age or sex effects on interactions/captures

Summary of correlative assessment

Candidate driver of population change	ID	Relationships assessed	Correlation
Nutritional stress	1a	Climate and diet	Yes (SSH, IPO)
	1b	Prey abundance and diet	Only one species
	1c	Diet and maternal condition	Only one species
	1d	Diet and milk quality	Only one species
	1e	Maternal condition/milk quality/breeder age and pup mass	Yes – breeder age and pup mass
	1f	Pup mass and pup/yearling survival	Yes
	1g	Maternal condition and maternal survival/pupping rate	No
	1h	Pup/yearling survival and demographic response in yr+1	Yes between pup/yearling survival and adult survival as well as pup mass
Disease-related pup mortality	2a	Pup mortality at 3/7 weeks and pup/yearling survival	No
	2b	Pup mortality by cause and pup/yearling survival	No
	2c	Bacterial disease related mortality and pup/yearling survival	Yes
Direct fishery-related mortality	3	Estimated fishery interactions/captures and juvenile/adult survival	No

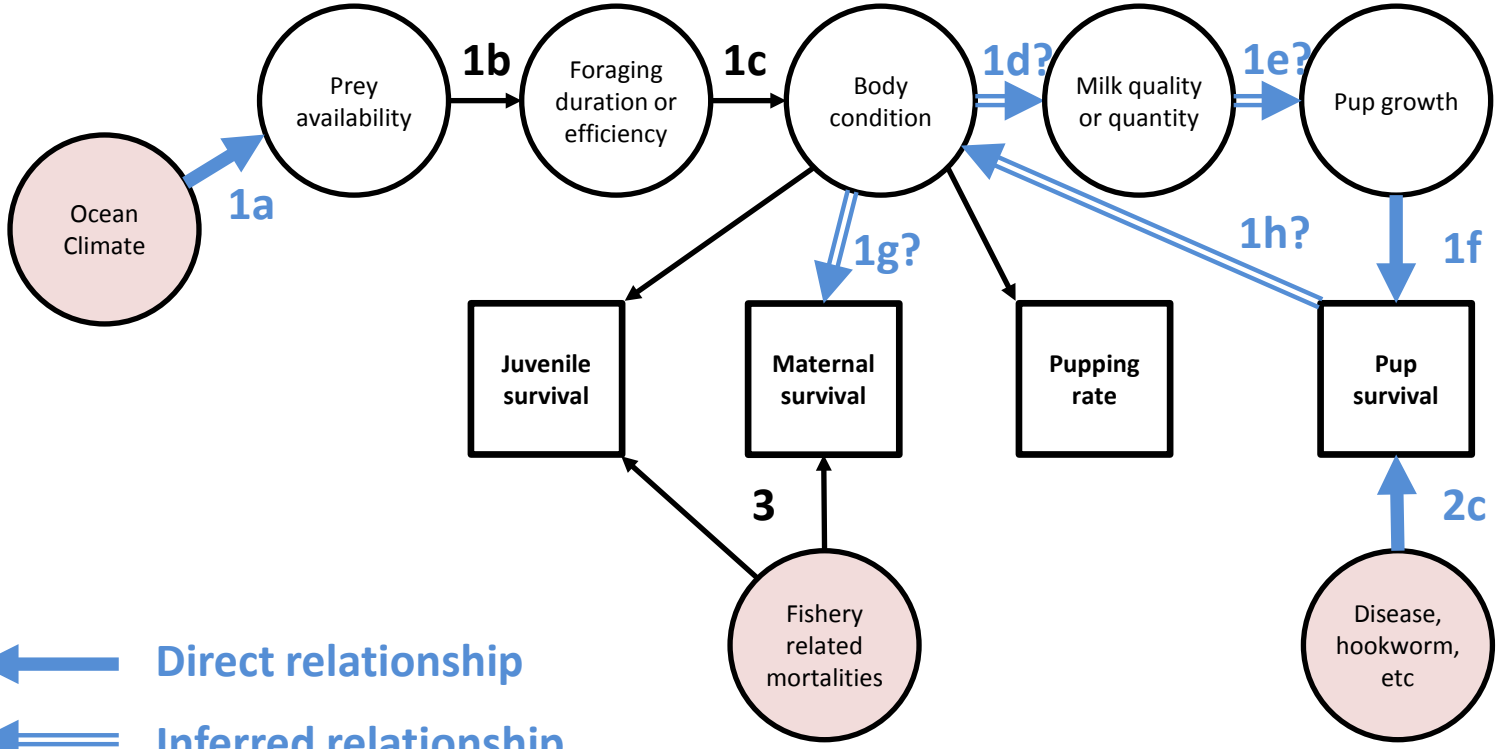
Hypothetical model
Which relationships supported by assessment?

- Only three direct effects upheld by correlative assessment



Hypothetical model
Which relationships supported by assessment?

- Only three direct effects upheld by correlative assessment
- Also inferred effects (need longer time series of maternal condition?)



Summary of biological/demographic responses to drivers of population change

Response variable	Predation or fishery captures	Nutritional stress (climate or fishery driven)	Pup disease (but non-nutritional stress driven)
Adult condition	No variation	Will vary in response to changing resources & reproductive success in yr-1	Will increase in response to reduced reproductive success in yr-1
Adult survival	Affects age classes vulnerable to fishery captures or predation	Will vary in response to changing resources & reproductive success in yr-1	Increased adult survival in response to reduced reproductive success in yr-1
Pupping rate (includes age at first pupping)	No variation	Will vary in response to changing resources & reproductive success in yr-1	Increased pupping rate in response to reduced reproductive success in yr-1
3-week pup mass (pup growth)	Reduced pup mass/growth of pups affected by mortality of mother	Will vary in response to changing resources & reproductive success in yr-1	No effect prior to infection
Milk quality	No variation	Will vary in response to changing resources & reproductive success in yr-1	Will vary in response to reduced reproductive success in yr-1
Pup/post-weaning survival	Reduced survival of pups affected by mortality of mother	Will vary in response to pup growth rate & resources available to pup on weaning (disease may be a consequence)	Reduced pup or post-weaning survival of affected cohort

Summary of biological/demographic responses to drivers of population change

Response variable	Predation or fishery captures	Nutritional stress (climate or fishery driven)	Pup disease (but non-nutritional stress driven)
Adult condition	~~**No variation**~~	Will vary in response to changing resources & reproductive success in yr-1	Will increase in response to reduced reproductive success in yr-1
Adult survival	Affects age classes vulnerable to fishery captures or predation	Will vary in response to changing resources & reproductive success in yr-1	~~**Increased adult survival in response to reduced reproductive success in yr-1**~~
Pupping rate (includes age at first pupping)	~~**No variation**~~	Will vary in response to changing resources & reproductive success in yr-1	Increased pupping rate in response to reduced reproductive success in yr-1
3-week pup mass (pup growth)	Reduced pup mass/growth of pups affected by mortality of mother	Will vary in response to changing resources & reproductive success in yr-1	No effect prior to infection
Milk quality	~~**No variation**~~	Will vary in response to changing resources & reproductive success in yr-1	Will vary in response to reduced reproductive success in yr-1
Pup/post-weaning survival	Reduced survival of pups affected by mortality of mother	Will vary in response to pup growth rate & resources available to pup on weaning (disease may be a consequence)	Reduced pup or post-weaning survival of affected cohort

Limitations of study

- Uncertainty in estimation of rates, e.g. diet - obscure relationships
- Demographic rates mostly from period of population decline
- Only passed through single climate cycle (for SSH and IPO)
- Annual estimates when individual effects are known to be large
- Many relationships not examined in great depth - simple correlations

Key results of assessment (1)

1. Changes in diet composition through time
2. Significant correlations between Sea Surface Height or Inter-decadal Pacific Oscillation Index and occurrence of many prey species in diet
3. Increased pup mass in years after low pup/yearling survival and with ageing breeder population
4. Pup mass a predictor of cohort survival, though not in disease epidemic years between 2007-2010
5. Adult survival negatively affected by high pup survival in the previous year - inability to successfully breed each year without compromising maternal survival
6. Nutritional stress a strong candidate driver of population decline

Key results of assessment (2)

7. Negative correlation between pup/yearling survival and pup disease-related mortality rate, though only from 8 weeks onward (beginning of Feb).
8. Disease-related mortality a candidate cause of decreased survival up to age 2 since 2005.
9. Poor correlations between estimates of Southern arrow squid commercial fishery captures/interactions (SQU6T) and estimated survival at vulnerable ages.

Research needs

- Thorough assessment of evidence for and potential population consequences of nutritional stress
- Description of seasonal diet composition, maternal condition, milk quality and pup mass to identify critical time periods (Autumn & Winter)
- Assessment of the causes pup disease-related mortality & population consequences of low pup survival
- Identify biological indicators of future population change
- Individual-based modelling to assess effect of:
  - maternal condition on survival/pupping rates;
  - maternal reproductive history on demographic rates of mother and pup (in different time periods)
  - pup mass on future survival & fecundity;
  - life history of successful v less successful breeders; and
  - relationships with environmental factors

Data needs

- Increased tag resighting effort and diet sample collection at Dundas, the largest sub-population
- Scat/regurgitate sampling, maternal condition, milk quality and pup mass in Autumn & Winter
- Longer time series of maternal condition data
- Extended pup mortality monitoring
- Collection of data required to assess the causes of disease-related pup mortality
- Mark-recapture data linked to biological observations

Acknowledgements

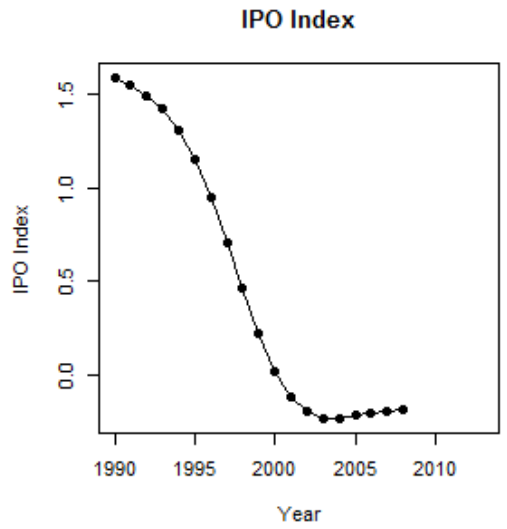
- Support from DOC, MPI and the Deepwater Group
- Marine mammal and apex predator experts in NZ and overseas
- Data and analyses kindly provided by:
  - DOC, MPI and DWG
  - Louise Chilvers
  - Laureline Meynier
  - Phoebe Stewart-Sinclair
  - Federico Riet-Sapriza
  - Wendi Roe
  - Martin Cawthorn
  - Simon Childerhouse

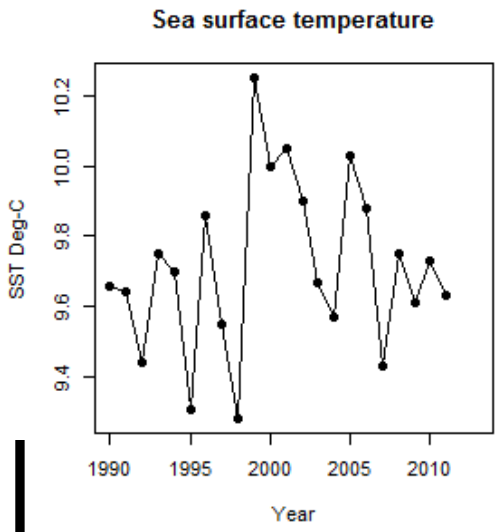
End of talk 3

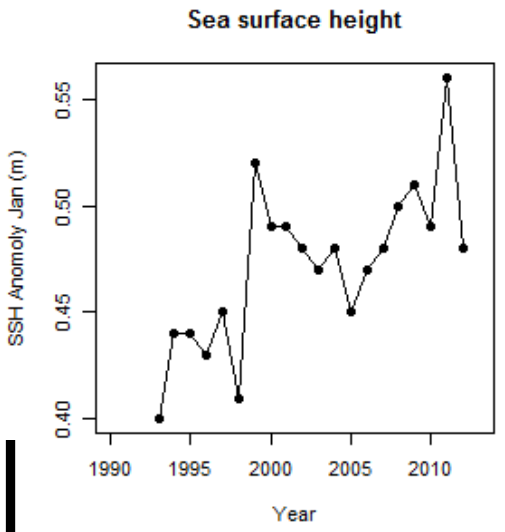
1. Intro & hypothetical model relating datasets
2. Presentation of datasets
3. **Correlative assessment**

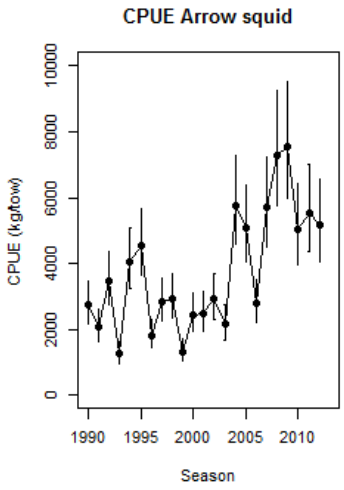
Supplementary analyses

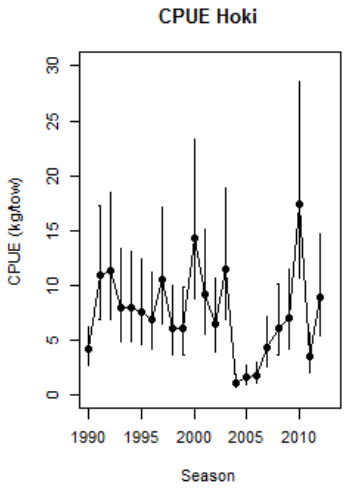
1a (i) Climate & **prey abundance**

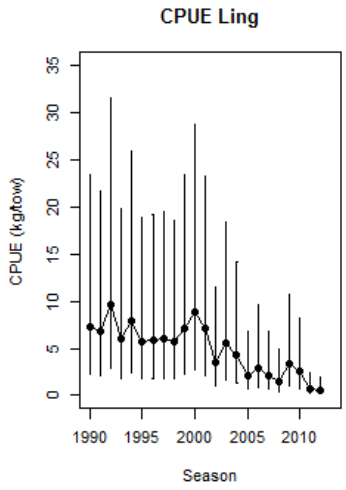


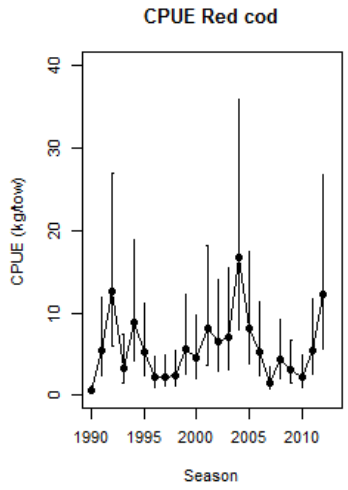


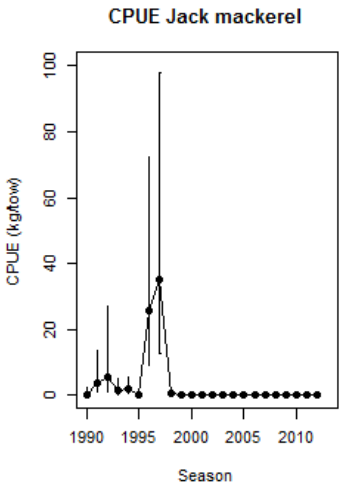




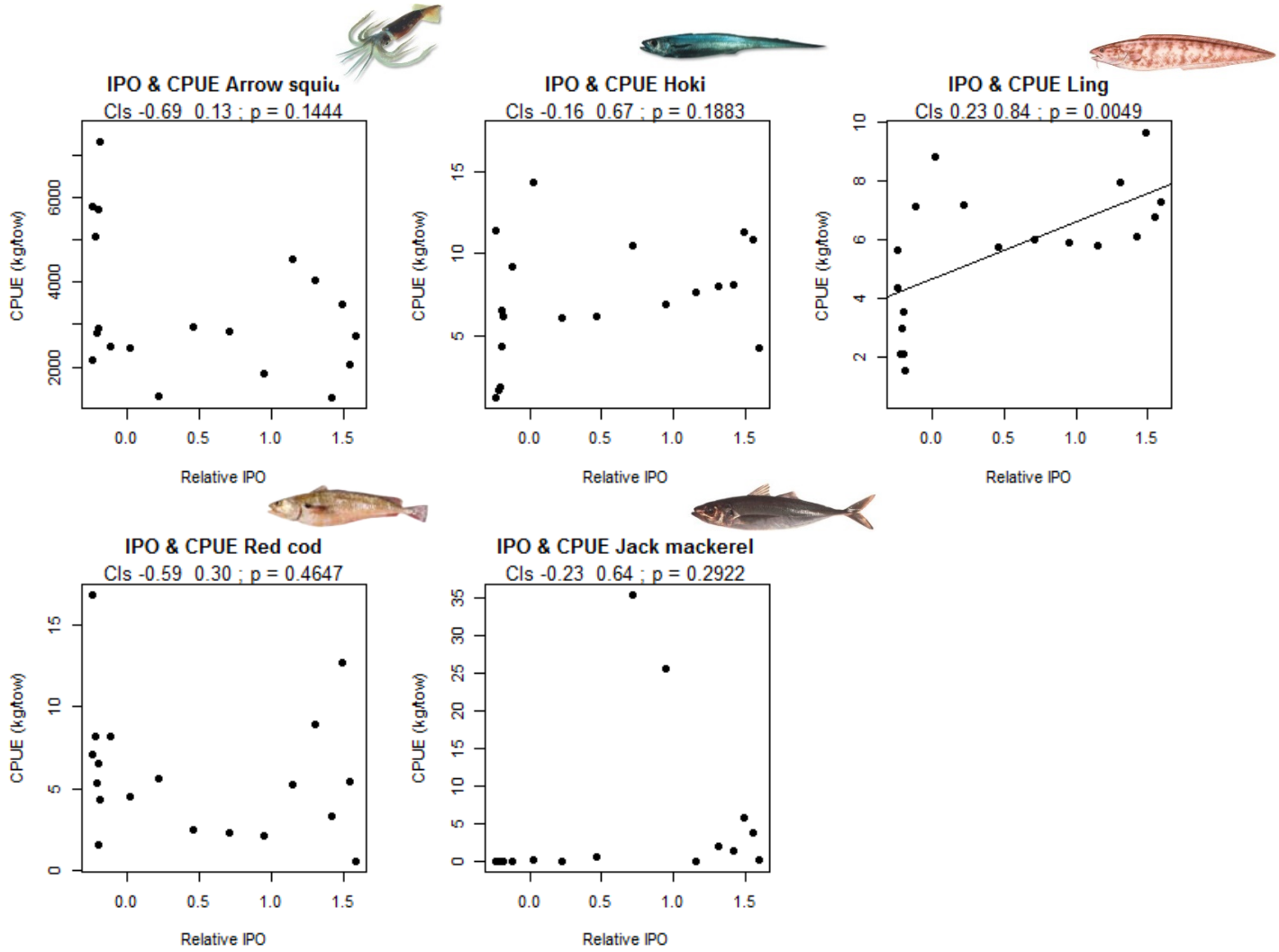




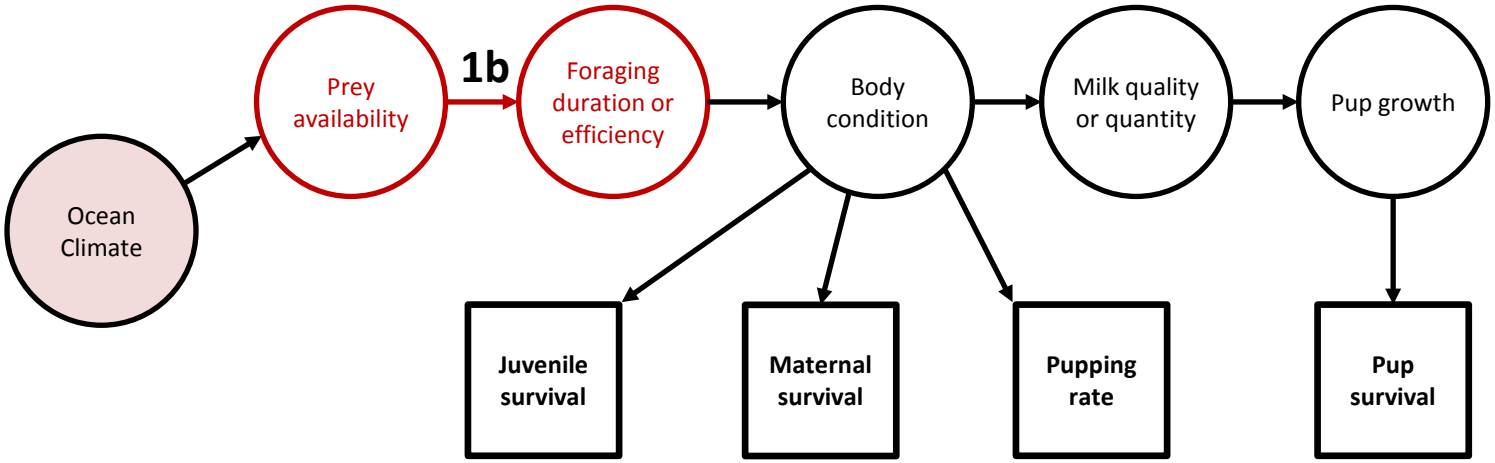




1a (i) Climate & **prey CPUE** – Inter-decadal Pacific Oscillation



1b. prey abundance/availability and **diet**



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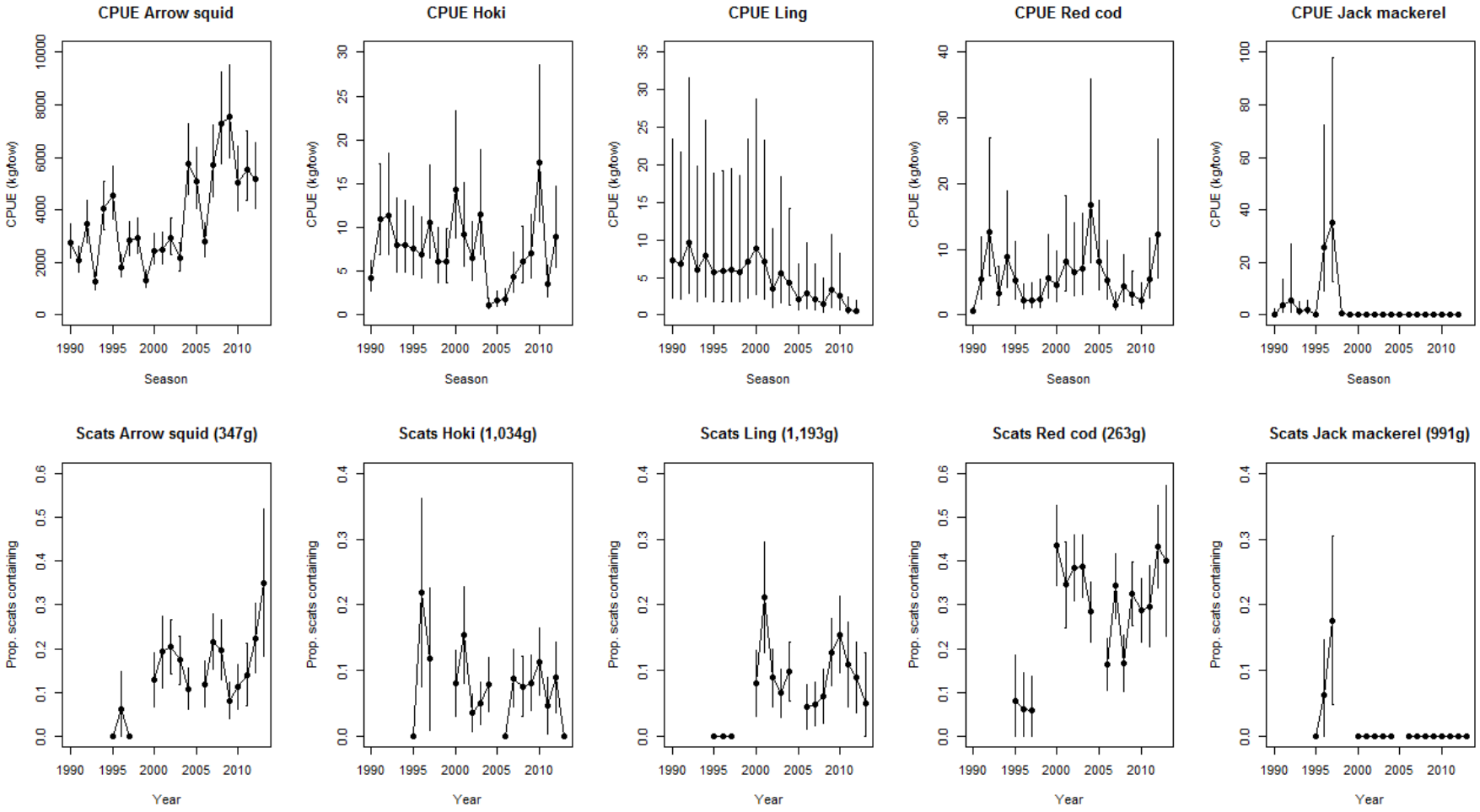
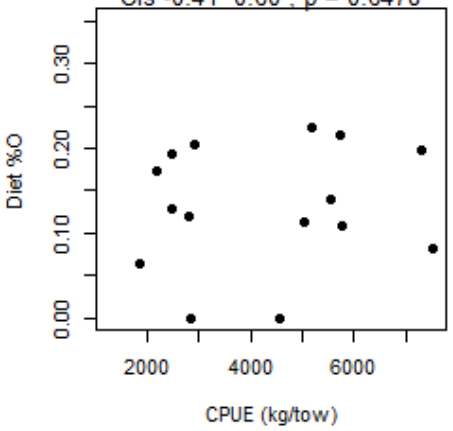


1b. prey abundance/availability and **diet**

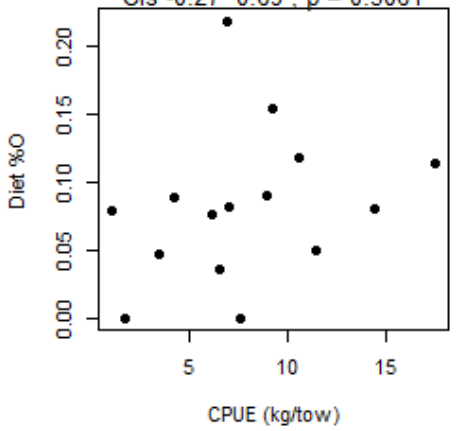
Arrow squid

Cls -0.41 0.60 ; p = 0.6478



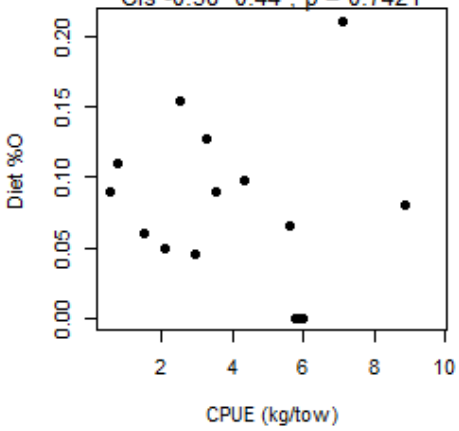
Hoki

Cls -0.27 0.69 ; p = 0.3061



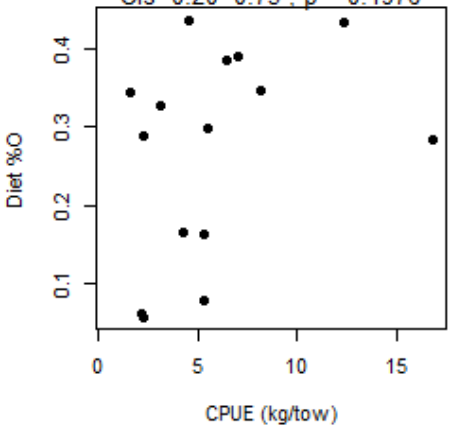
Ling

Cls -0.58 0.44 ; p = 0.7421



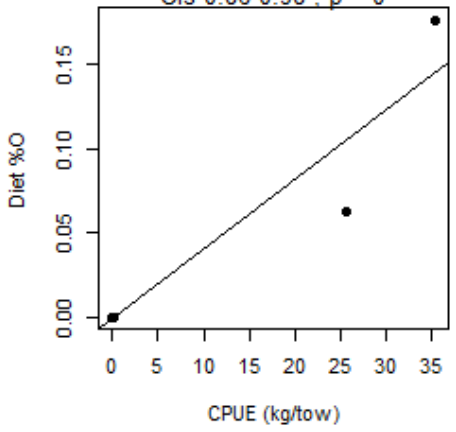
Red cod

Cls -0.20 0.73 ; p = 0.1976

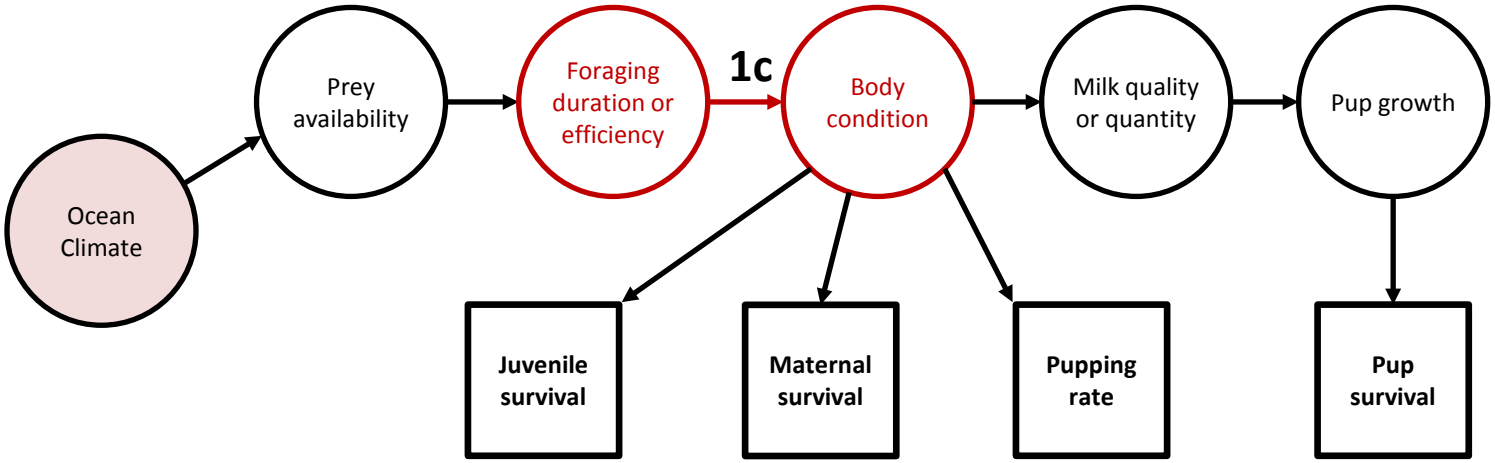


Jack mackerel

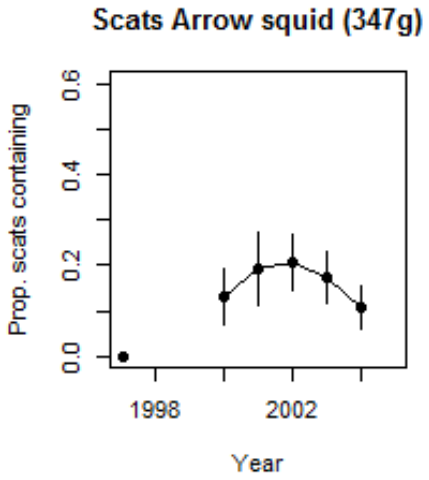
Cls 0.86 0.98 ; p = 0

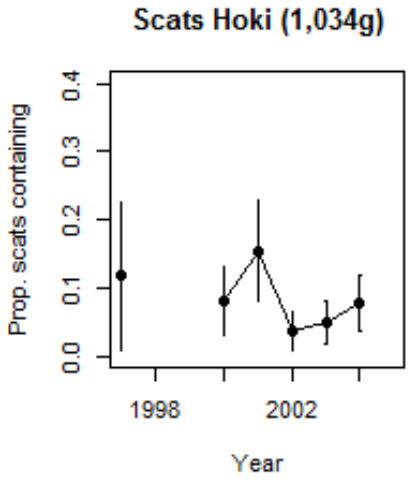


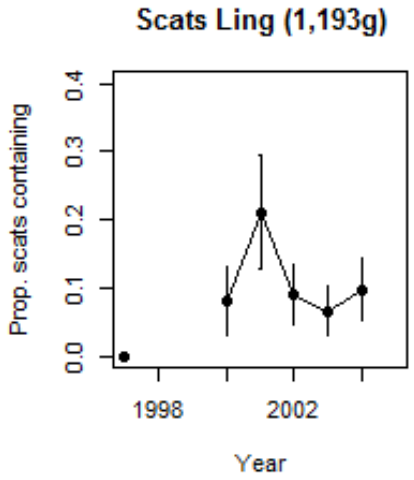
1c. Diet & **maternal condition**

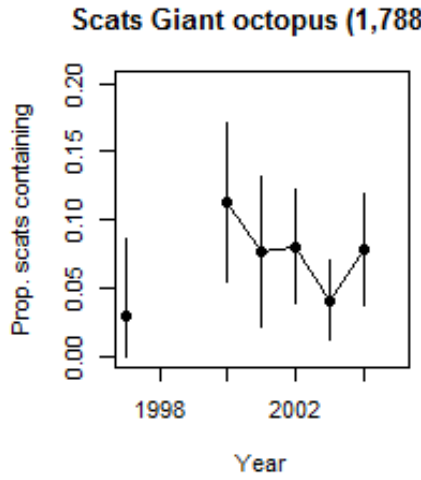


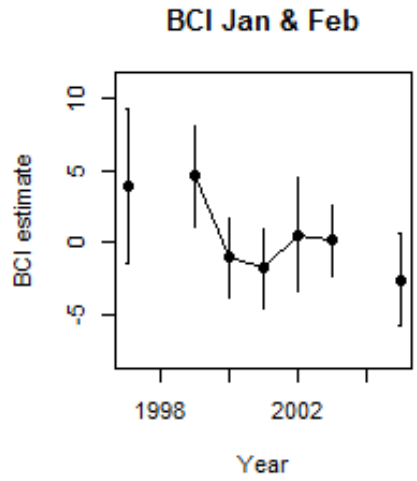
1c. Diet & **maternal condition**



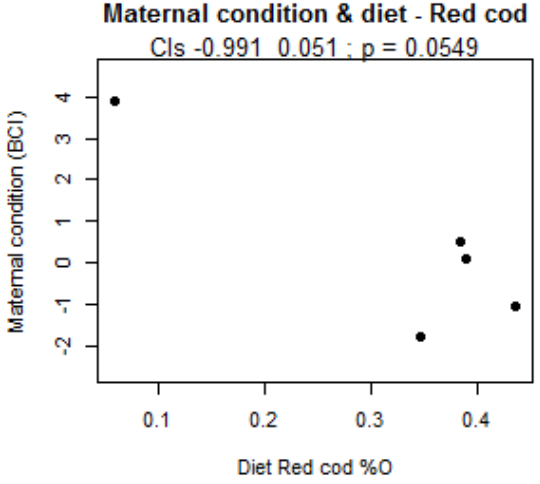


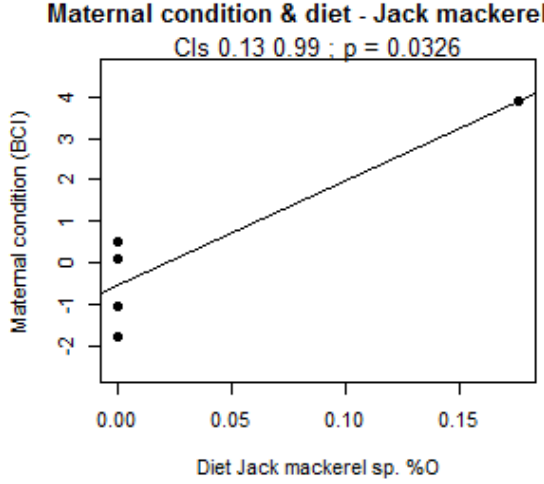


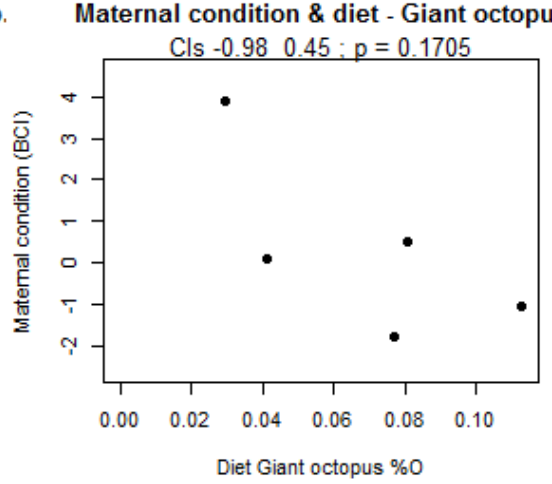




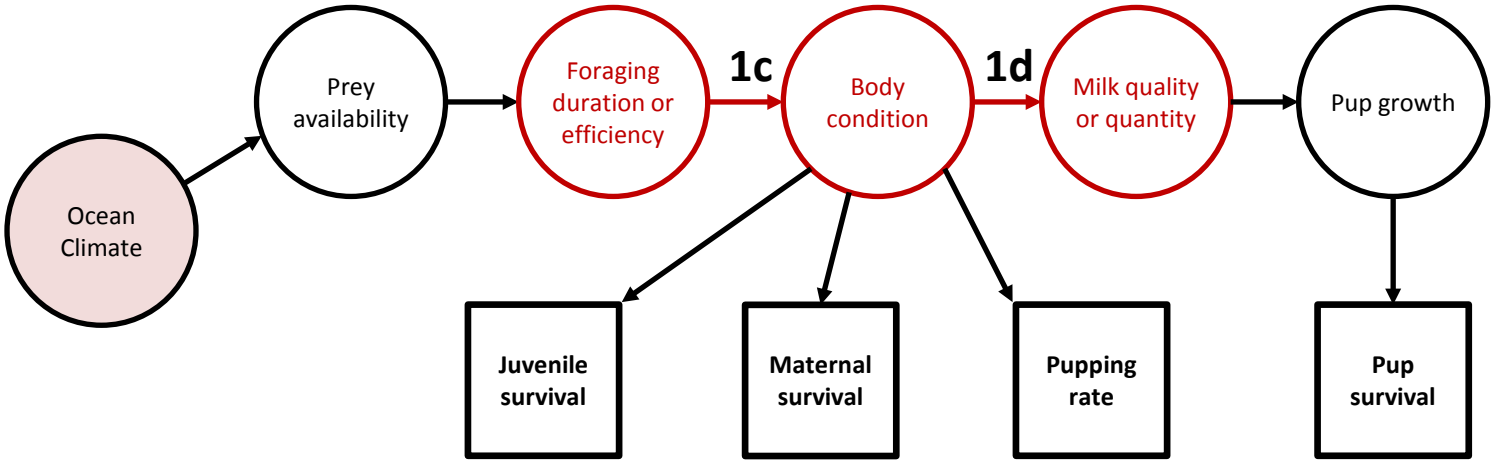
1c. Diet & **maternal condition**



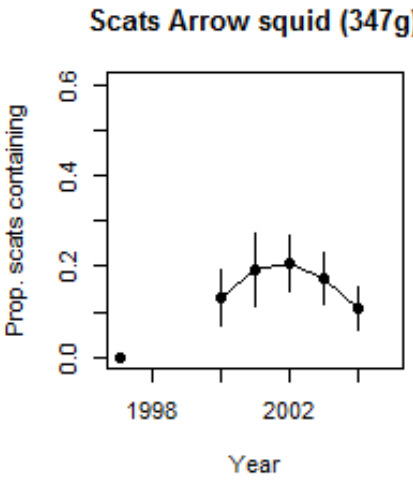


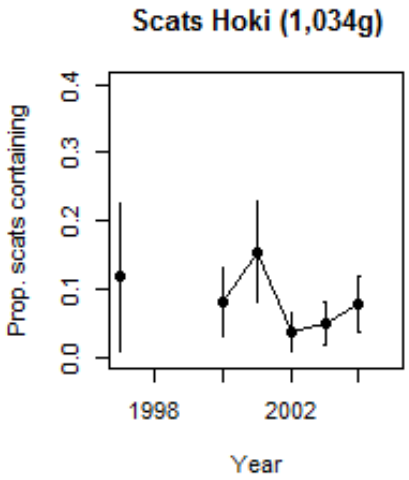


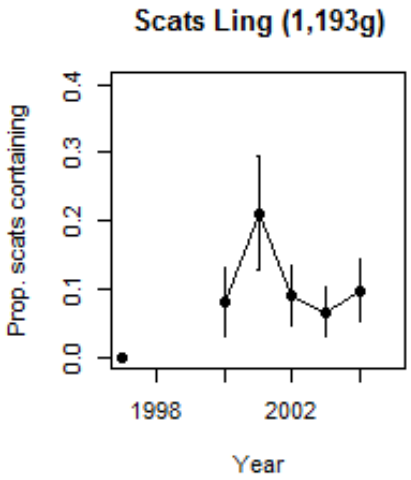
1d. Diet & **milk quality**

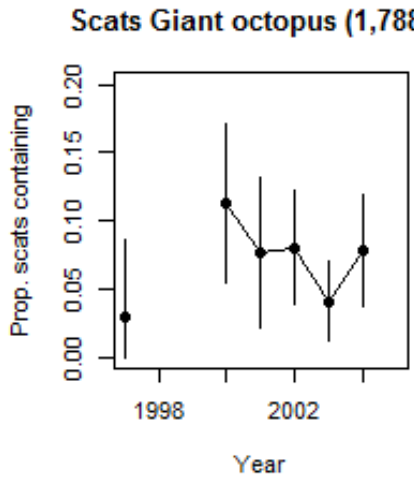


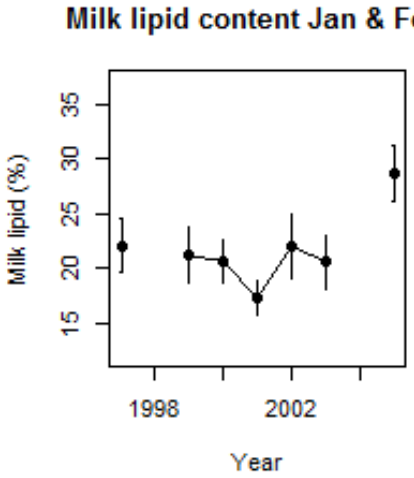
1d. Diet & **milk quality**

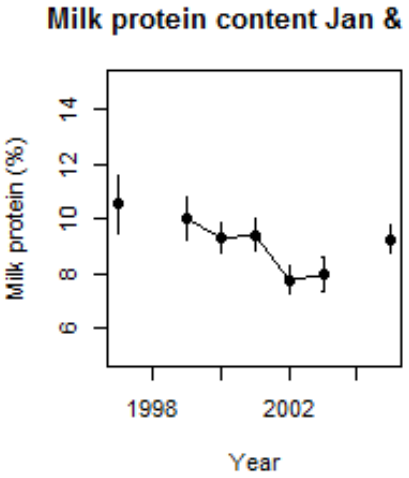




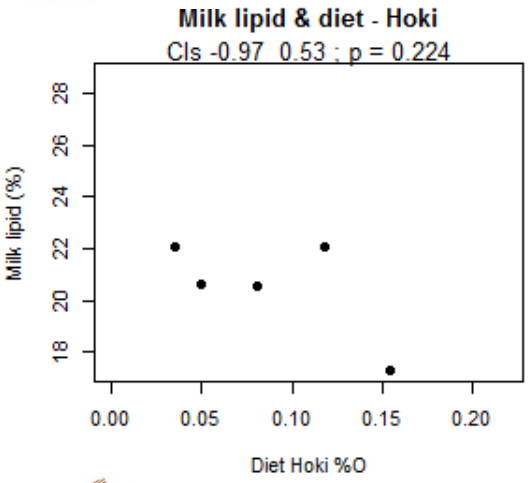


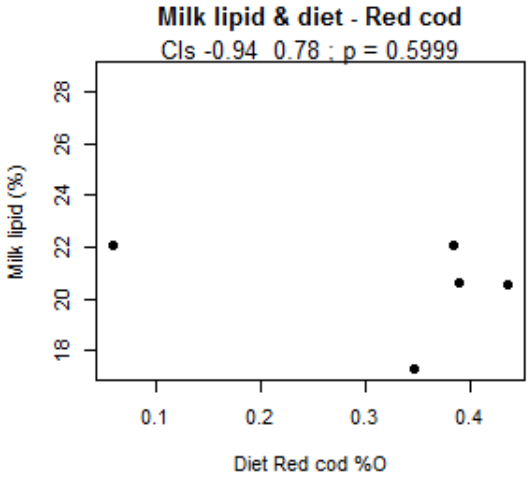


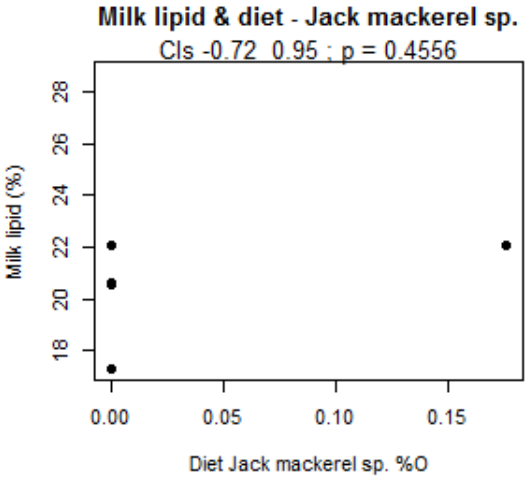


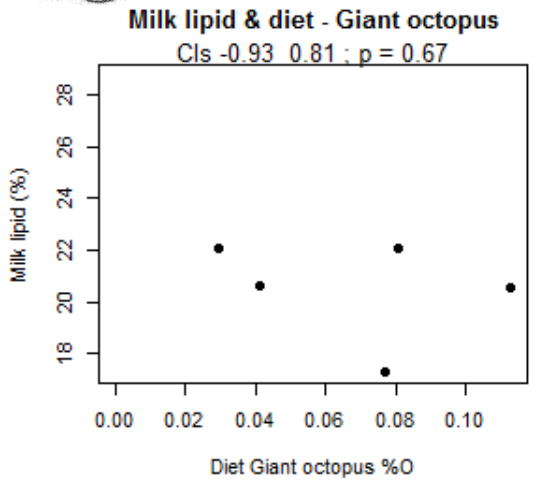


1d. Diet & **milk quality – lipid %**

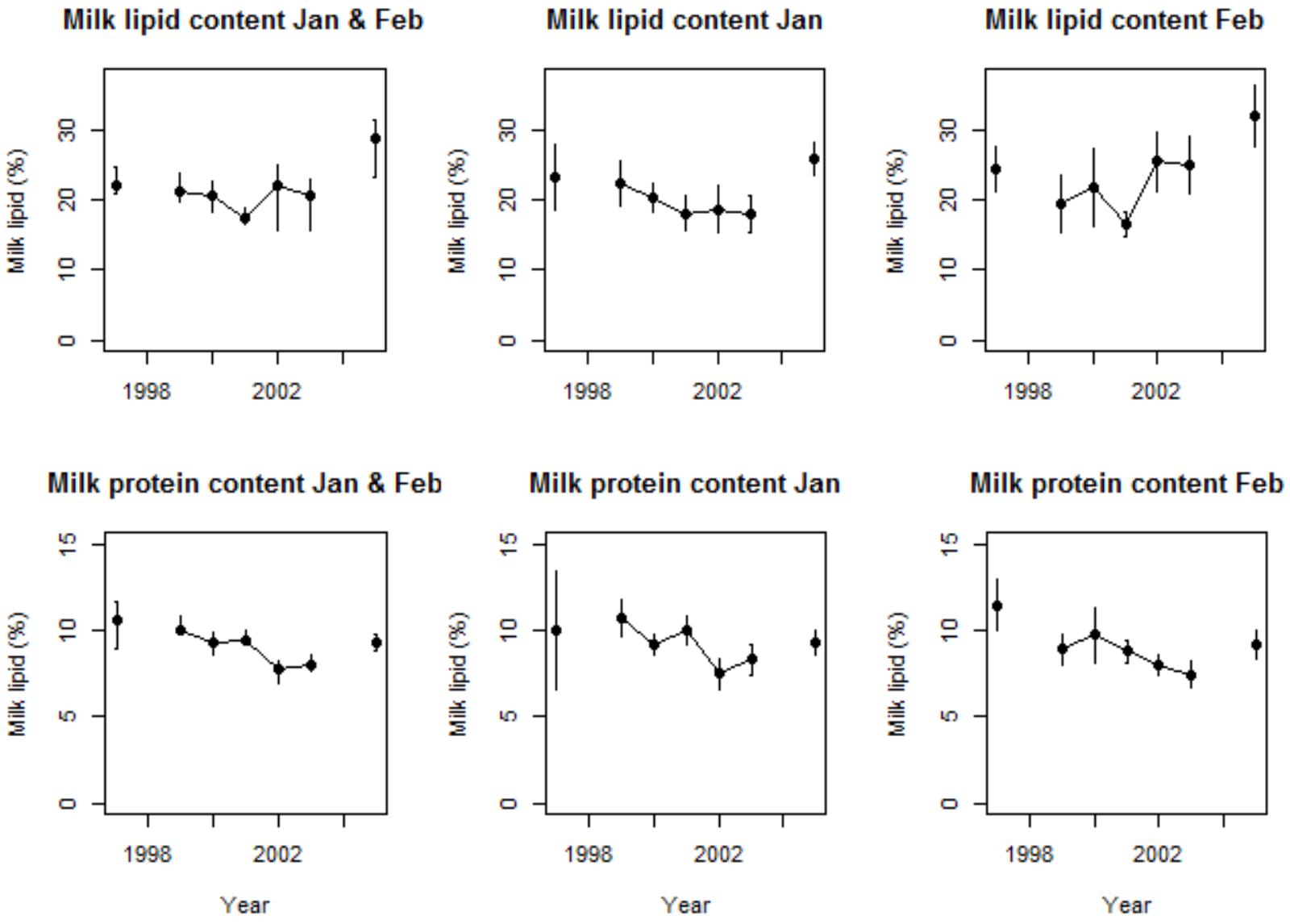




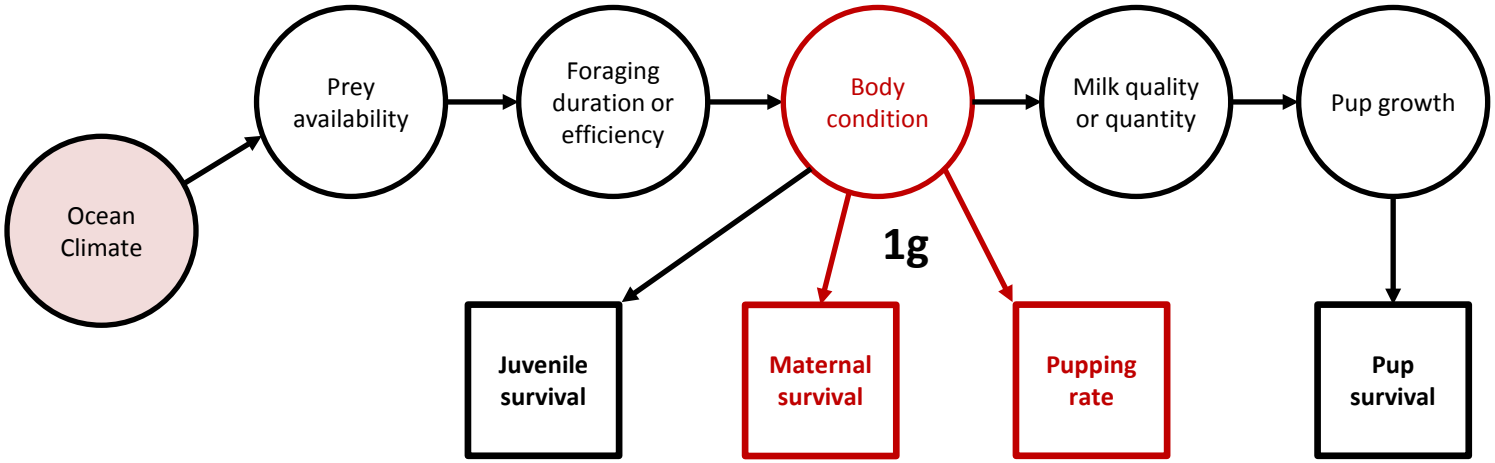




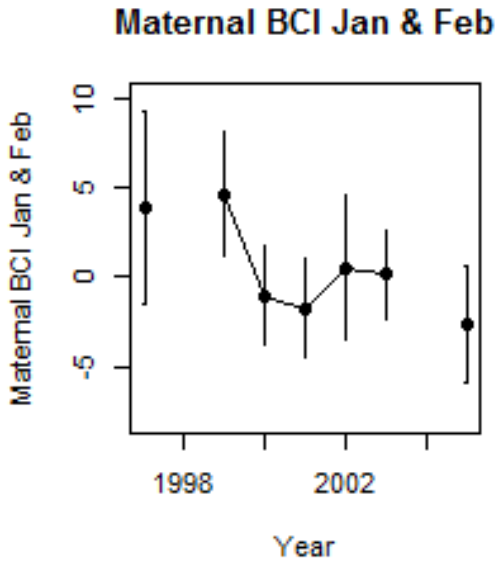
Month effect on **milk quality**

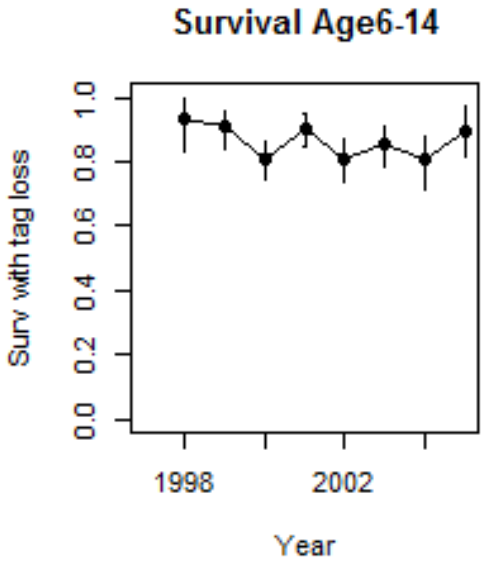


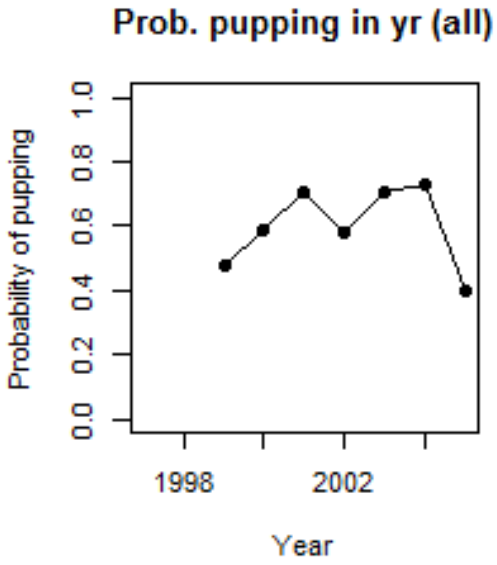
1g. Maternal condition and **pupping rate/maternal survival**



1g. Maternal condition and **pupping rate/maternal survival**







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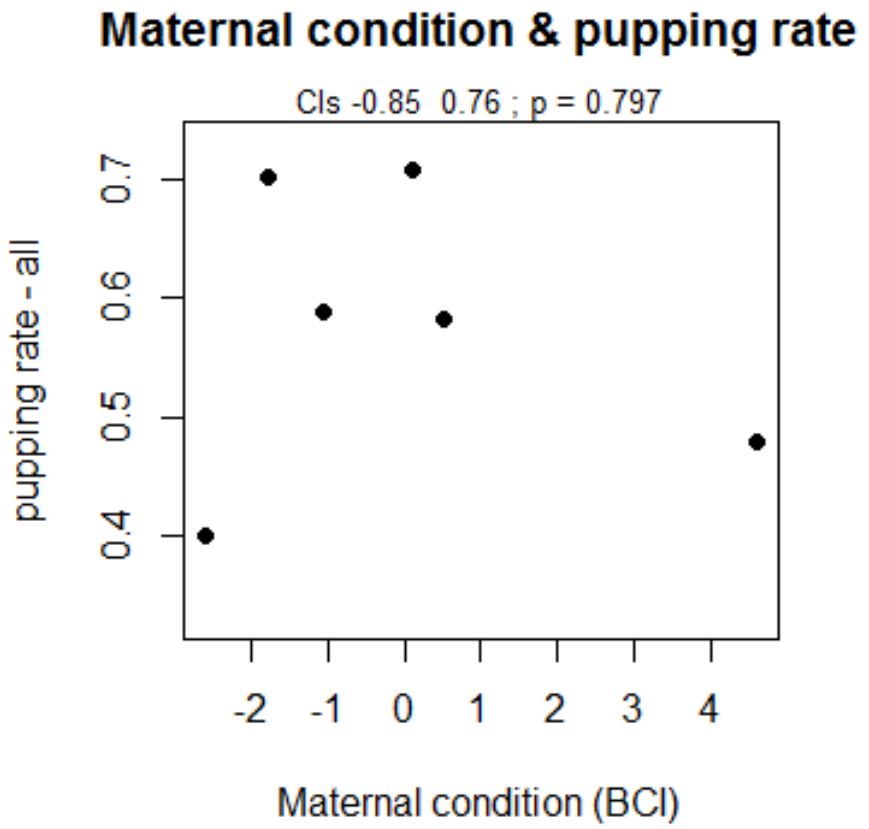
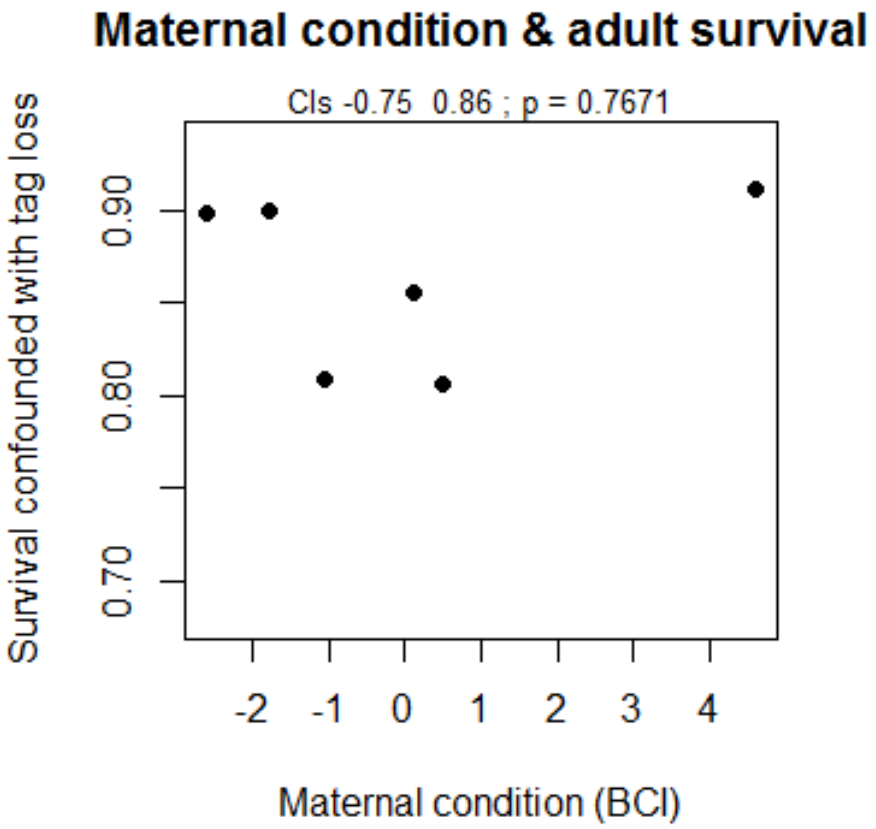
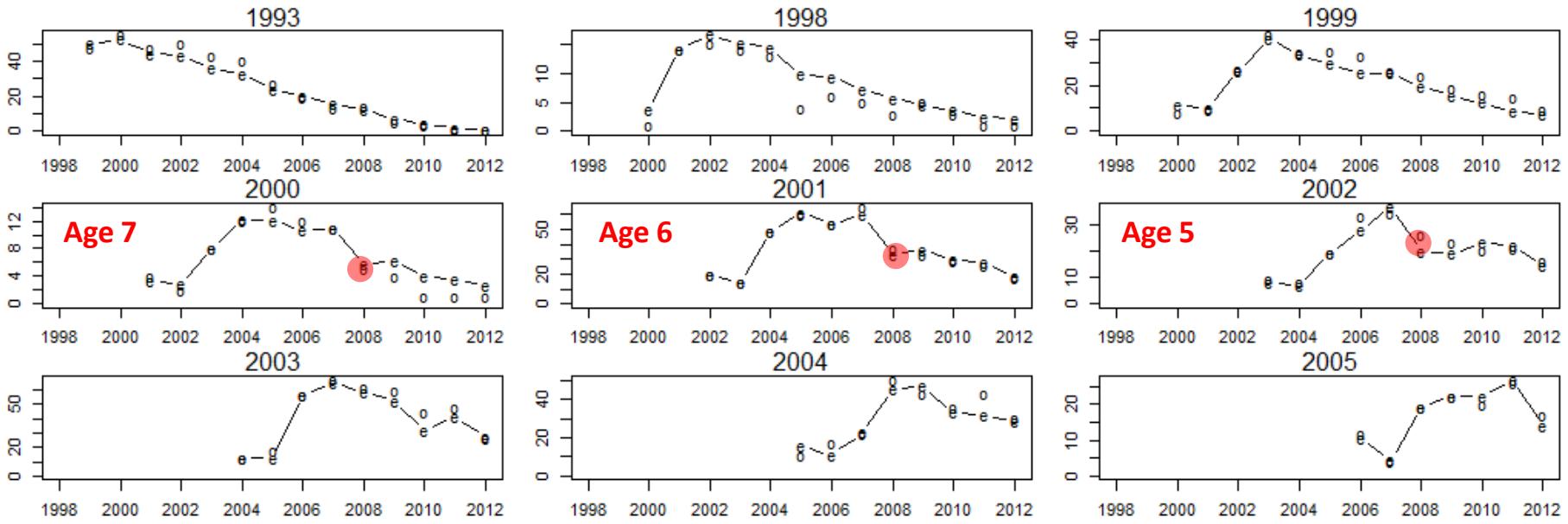
1g. Maternal condition and **pupping rate/maternal survival**



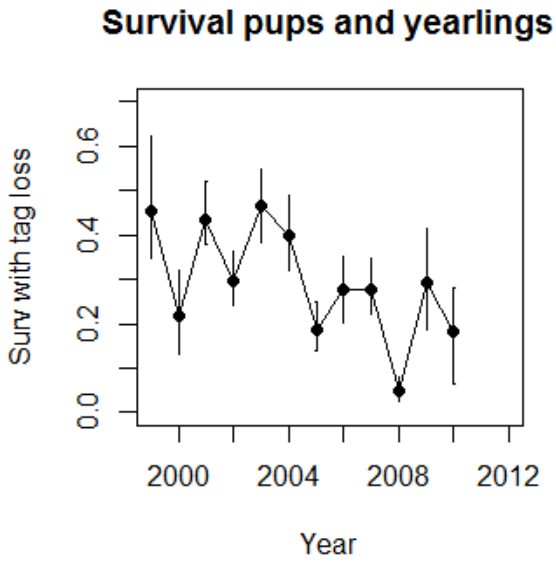


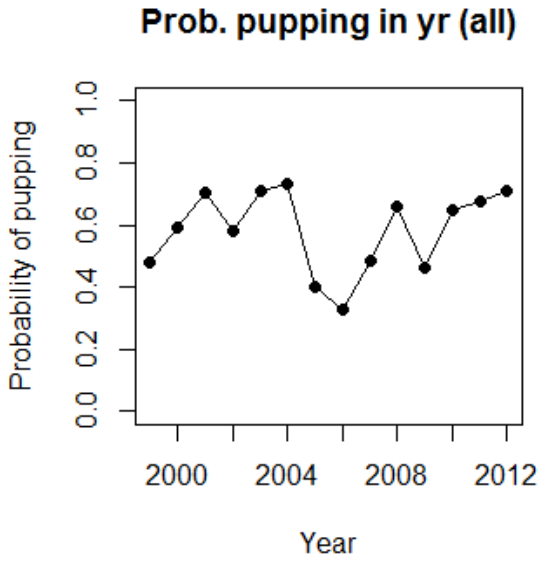
Low survival in 2007 – first-time puppers?

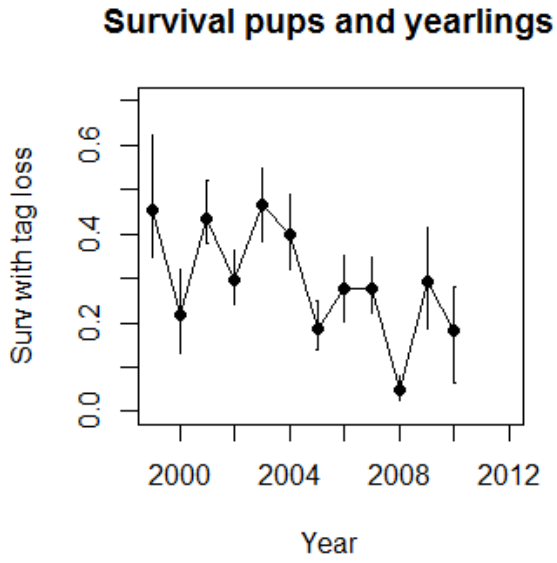


- Low survival in 2007 driven by three cohorts (born 2000-2002)
- Potentially first-time breeders in that year (aged 5-7).

1h. Pup/yearling survival & **pupping rate or pup survival in year+1**







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1h. Pup/yearling survival & **pupping rate (of puppers) or pup survival in year+1**