

POP2012-02



MS4 Correlative assessment (Presentation 3) Assessment results

Jim Roberts & Ian Doonan, NIWA

DOC CSP, May 2014

Scope of presentations

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

Purpose of correlative assessment

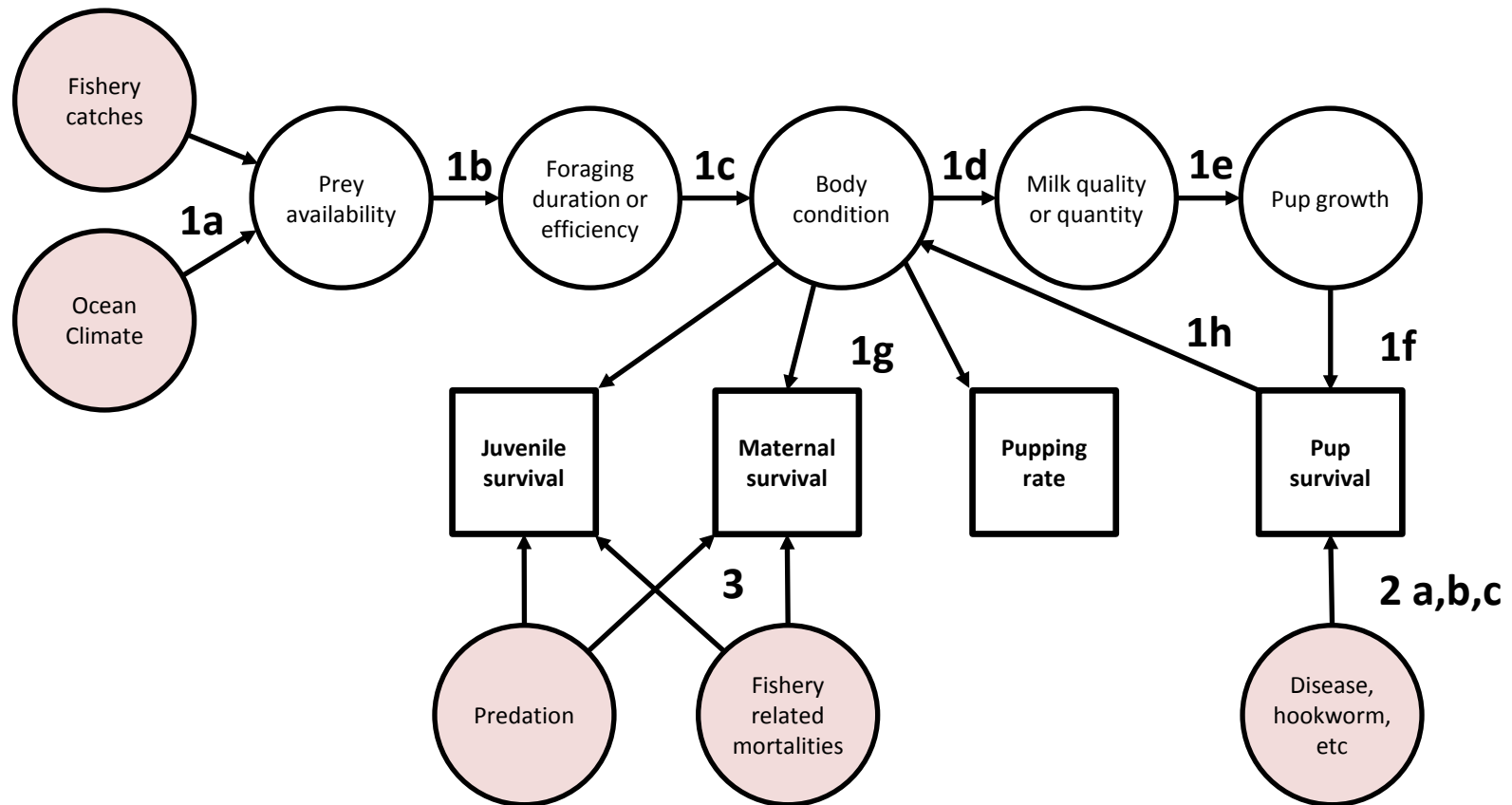
POP2012-02 Objectives to *“identify potential demographic mechanisms through which both direct and indirect effects of fishing can impact on sea lion population size at the Auckland Islands, or increase susceptibility of the population to such effects.”*

- 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

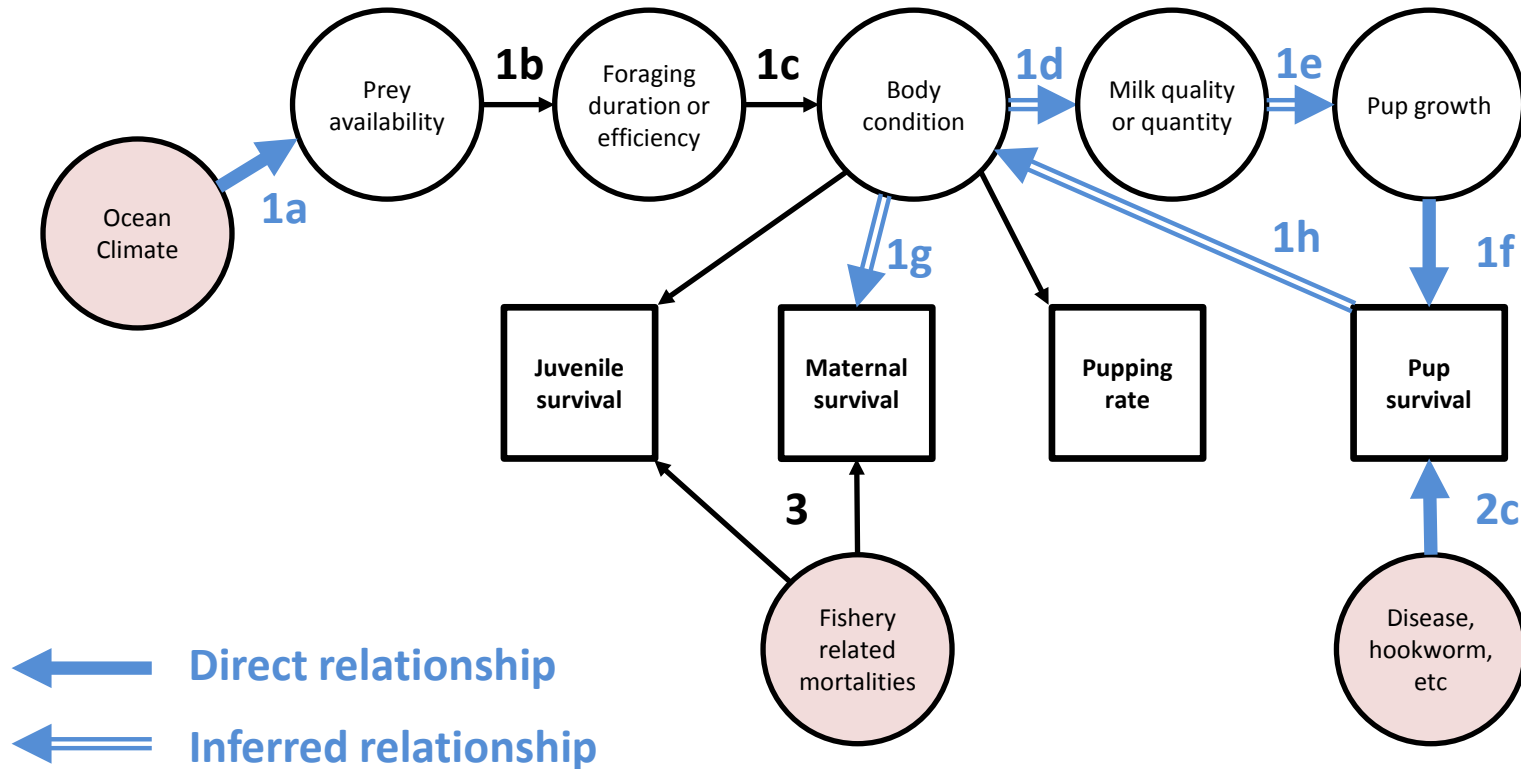
Candidate driver of population change	ID	Relationships assessed
Nutritional stress	1a	Climate and prey abundance/diet
	1b	Prey abundance and diet
	1c	Diet and maternal condition
	1d	Diet and milk quality
	1e	Maternal condition/milk quality/breeder age and pup mass
	1f	Pup mass and pup/yearling survival
	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

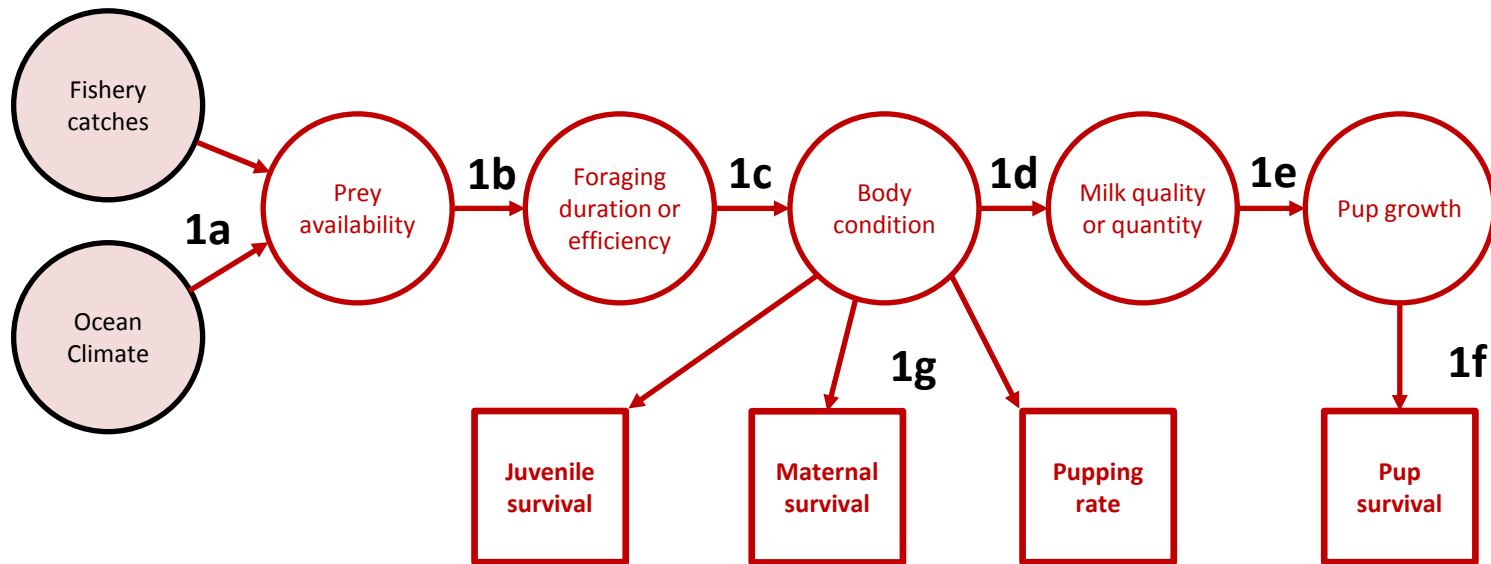


Hypothetical model

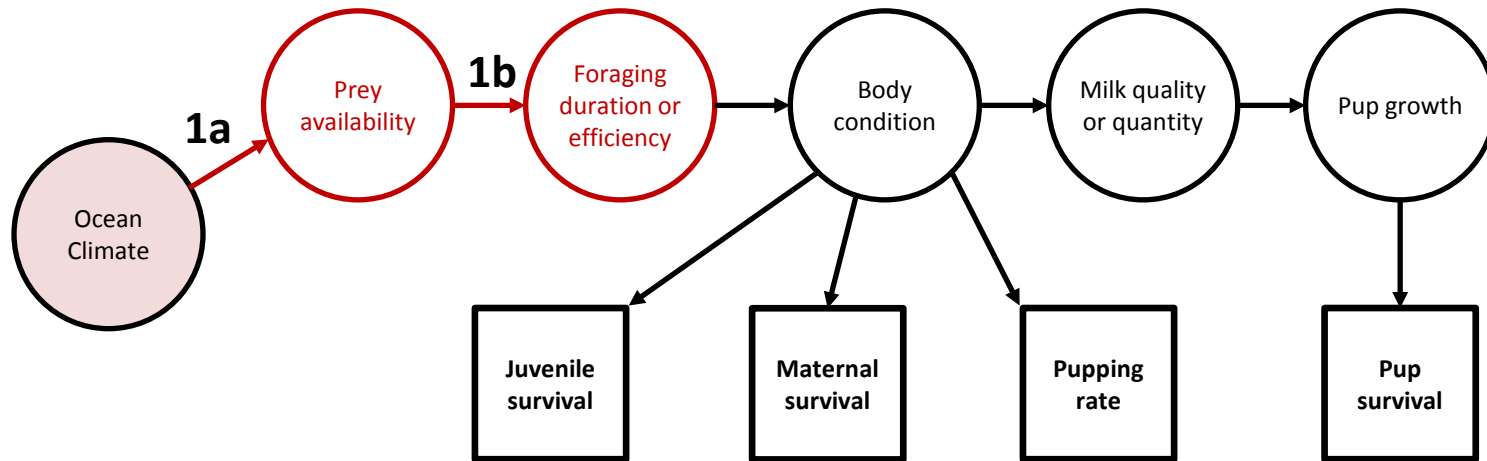
Which relationships supported by assessment?



1. Responses to variation in prey availability

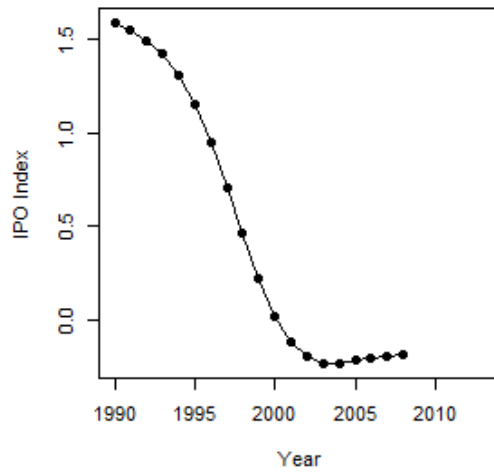


1a. Climate & prey abundance/diet

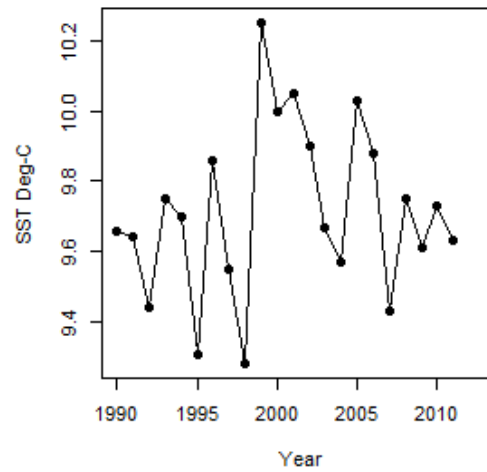


1a (ii) Climate & diet

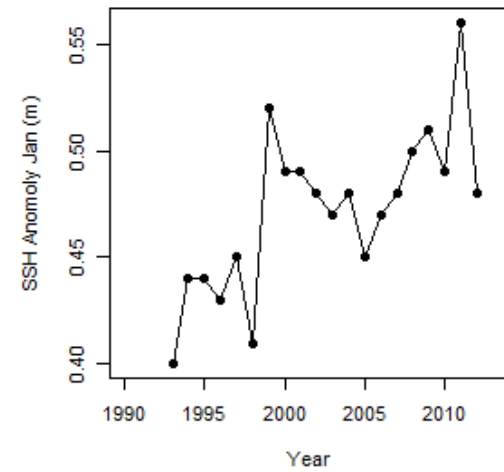
IPO Index



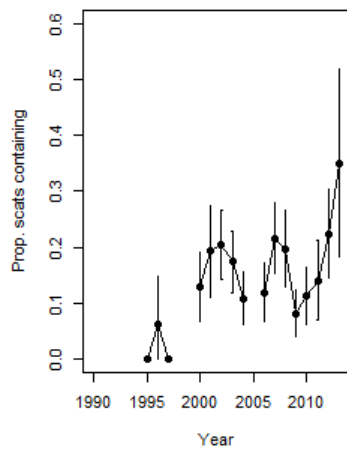
Sea surface temperature



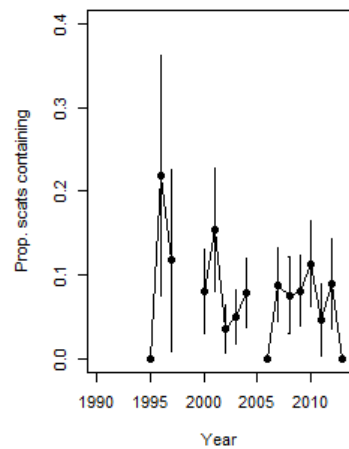
Sea surface height



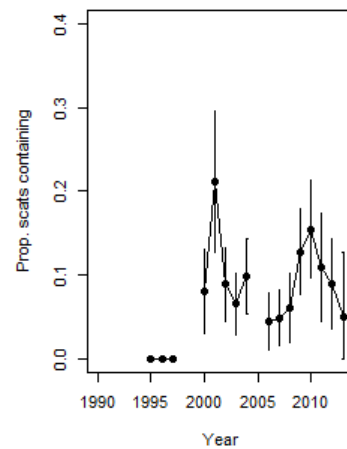
Scats Arrow squid (347g)



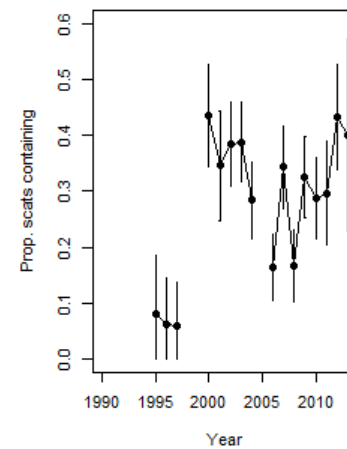
Scats Hoki (1,034g)



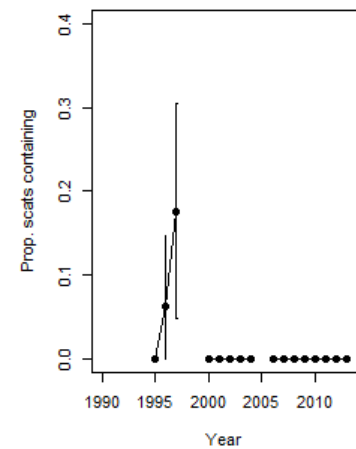
Scats Ling (1,193g)



Scats Red cod (263g)



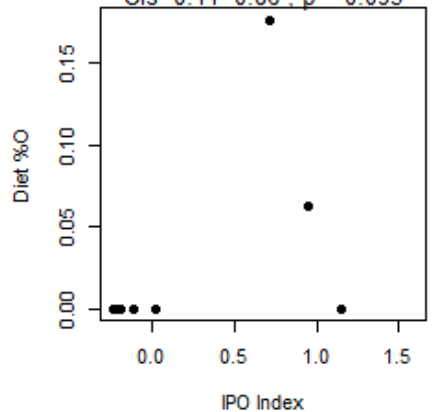
Scats Jack mackerel (991g)



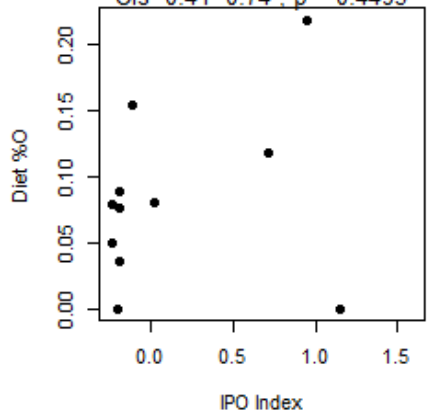
1a (ii) Climate & diet – Inter-decadal Pacific Oscillation



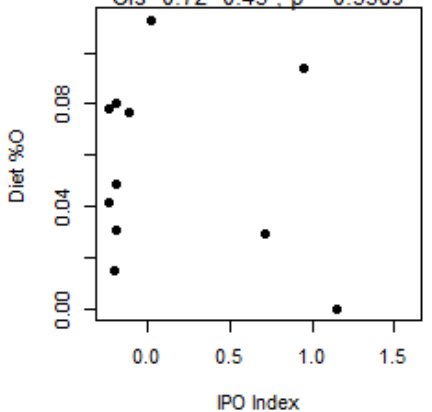
IPO & Diet Jack mackerel
Cls -0.11 0.86 ; p = 0.095



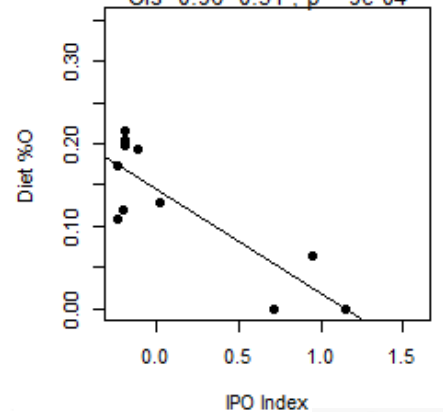
IPO & Diet Hoki
Cls -0.41 0.74 ; p = 0.4493



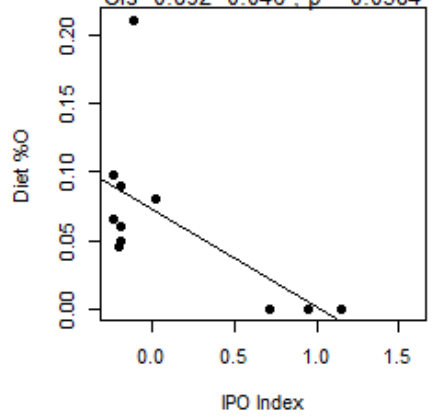
IPO & Diet Giant octopus
Cls -0.72 0.45 ; p = 0.5389



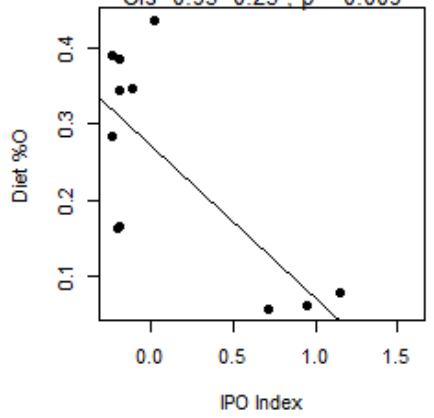
IPO & Diet Arrow squid
Cls -0.96 -0.51 ; p = 9e-04



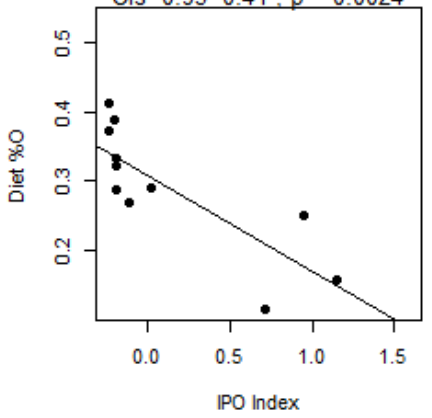
IPO & Diet Ling
Cls -0.892 -0.046 ; p = 0.0384



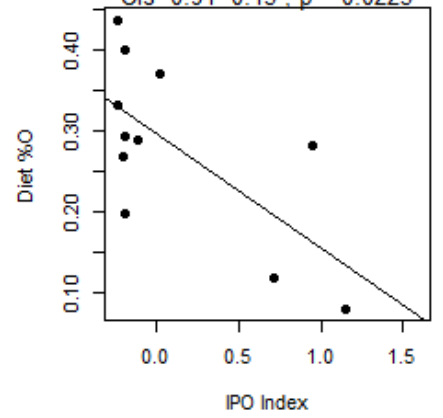
IPO & Diet Red cod
Cls -0.93 -0.25 ; p = 0.009



IPO & Diet Opalfish sp.
Cls -0.95 -0.41 ; p = 0.0024



IPO & Diet Rattail sp.
Cls -0.91 -0.13 ; p = 0.0223

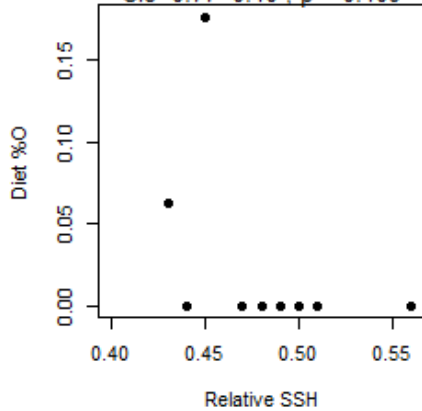


1a (ii) Climate & diet – Sea Surface Height



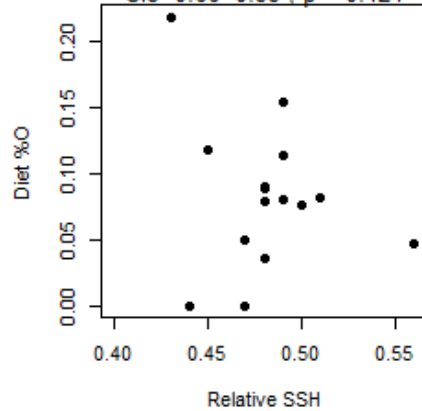
SSH & Diet Jack mackerel

CIs -0.77 0.10 ; p = 0.109



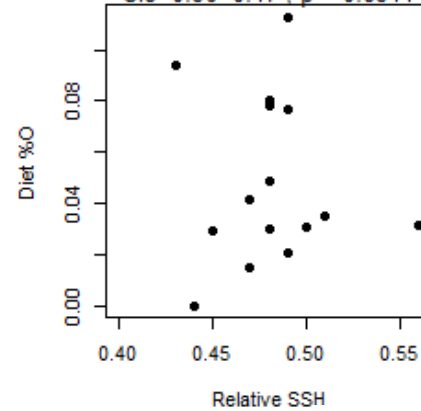
SSH & Diet Hoki

CIs -0.66 0.33 ; p = 0.421



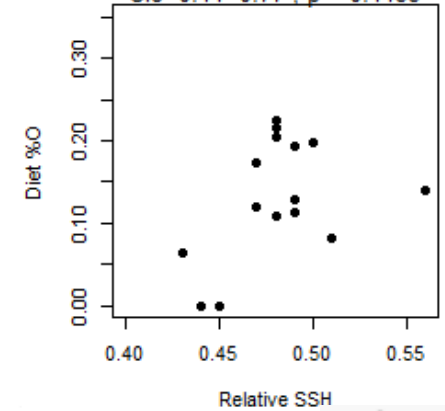
SSH & Diet Giant octopus

CIs -0.56 0.47 ; p = 0.8314



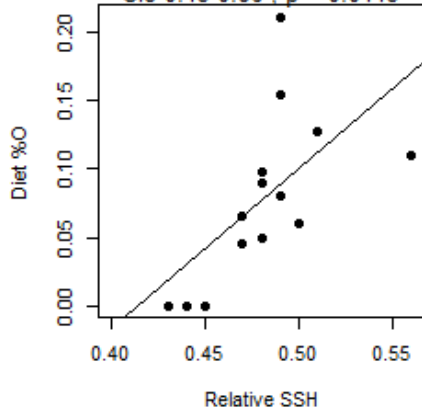
SSH & Diet Arrow squid

CIs -0.11 0.77 ; p = 0.1133



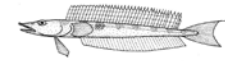
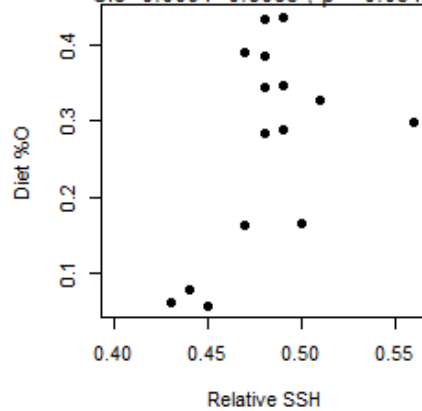
SSH & Diet Ling

CIs 0.15 0.86 ; p = 0.0143



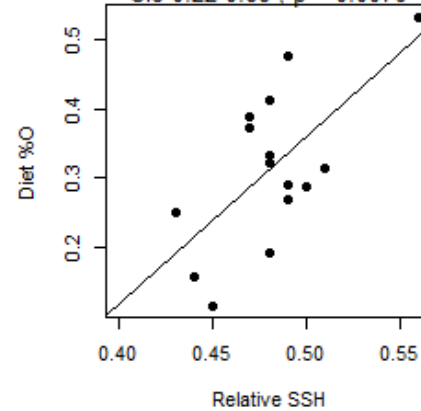
SSH & Diet Red cod

CIs -0.0094 0.8083 ; p = 0.0547



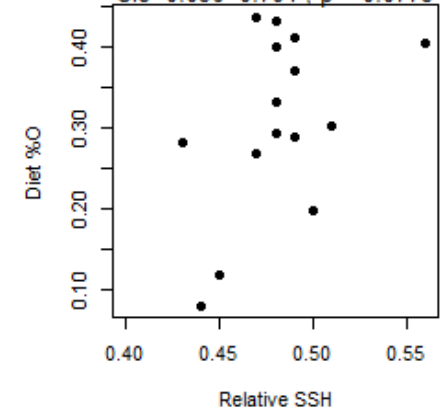
SSH & Diet Opalfish sp.

CIs 0.22 0.88 ; p = 0.0076

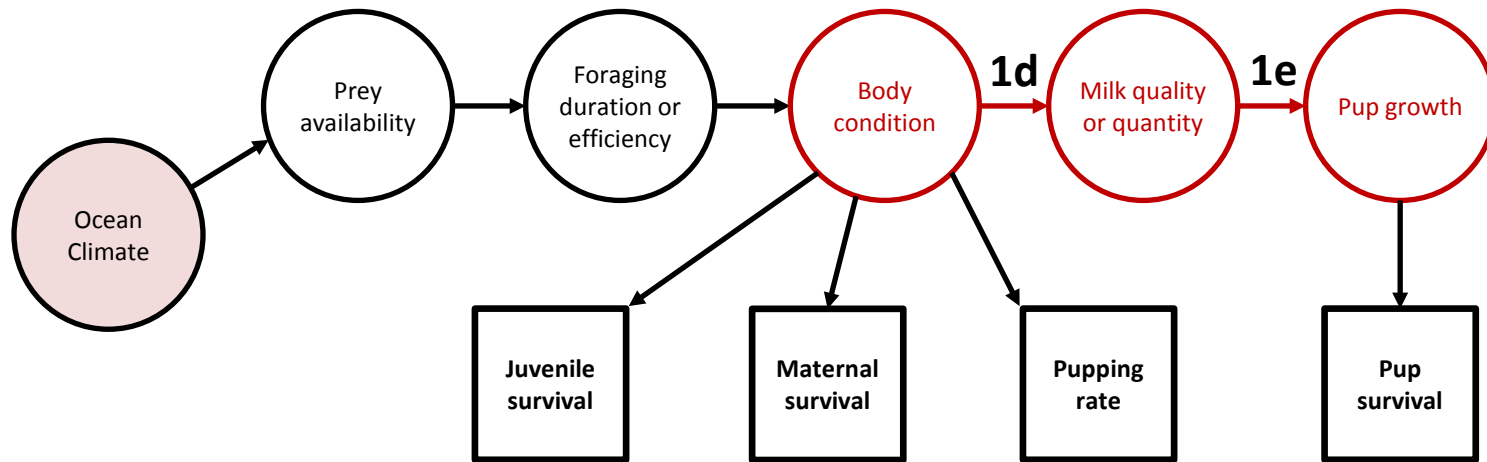


SSH & Diet Rattail sp.

CIs -0.056 0.791 ; p = 0.0775

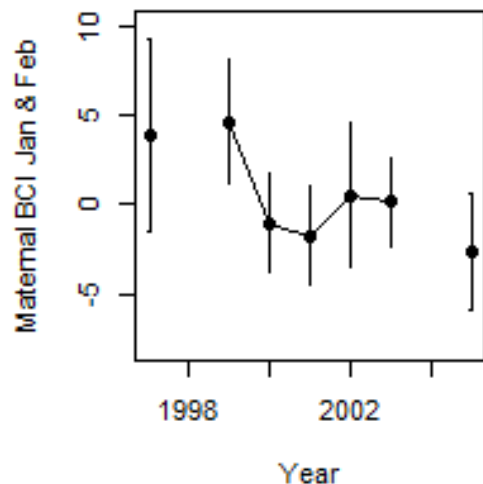


1e. Maternal condition/milk quality & pup mass

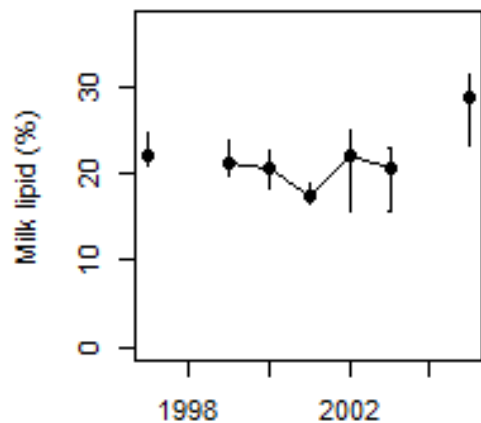


1e. Maternal condition/milk quality & pup mass

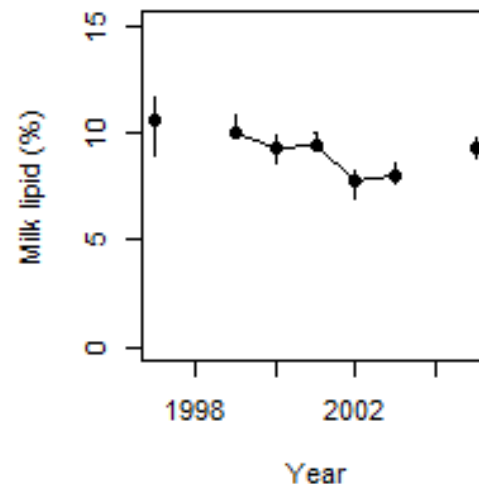
Maternal BCI Jan & Feb



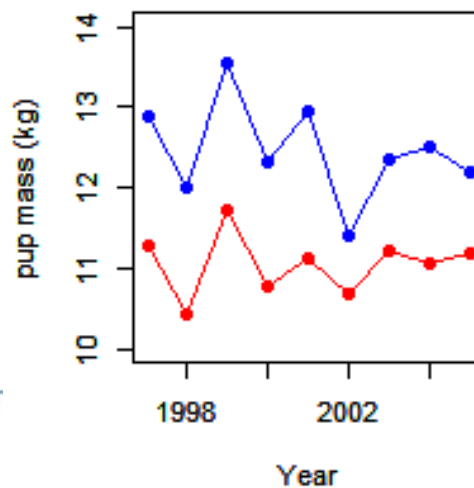
Milk lipid content Jan & Feb



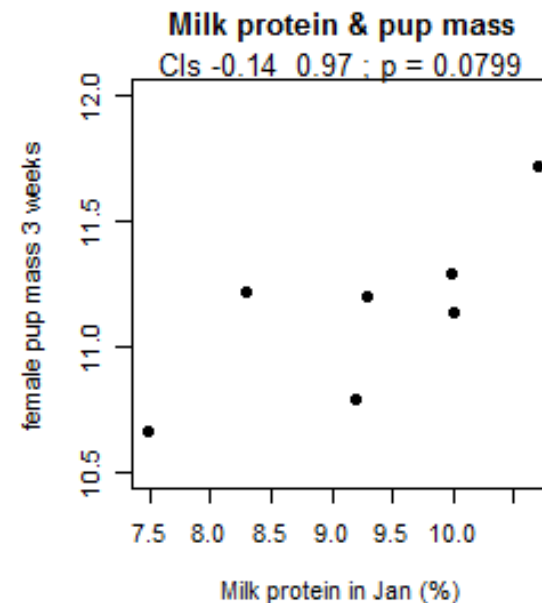
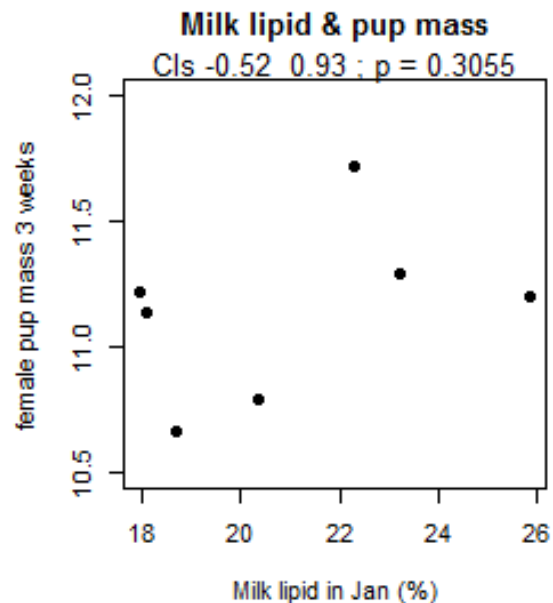
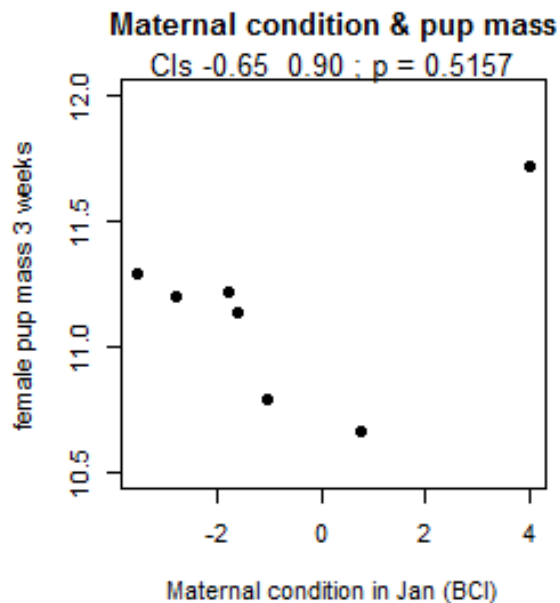
Milk protein content Jan & Feb



Pup mass at 3 weeks

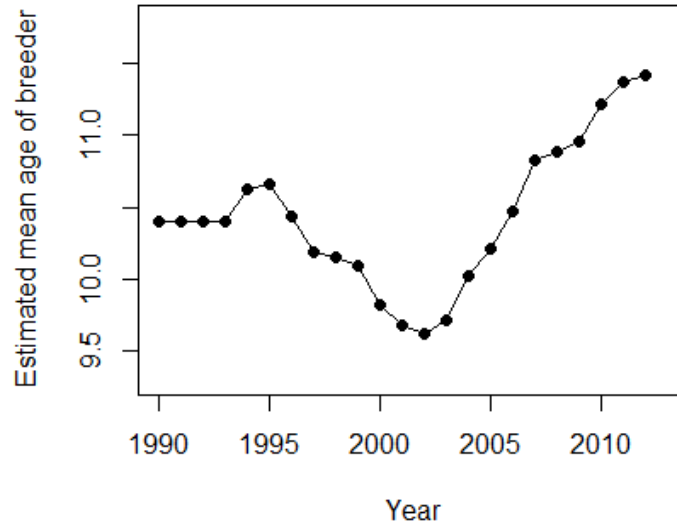


1e. Maternal condition/milk quality & pup mass

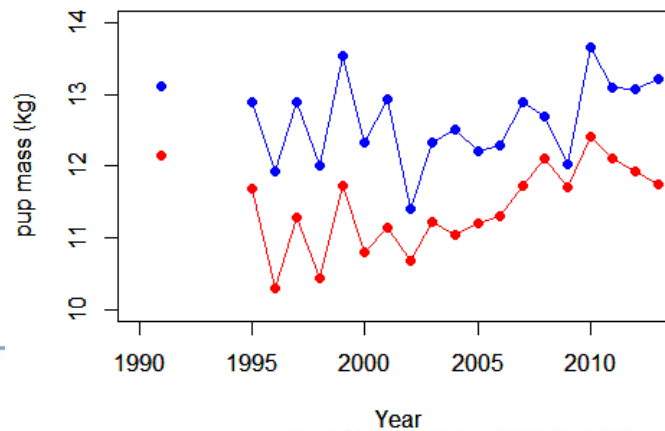


1e. Breeder age & pup mass

Model estim. mean age breeders

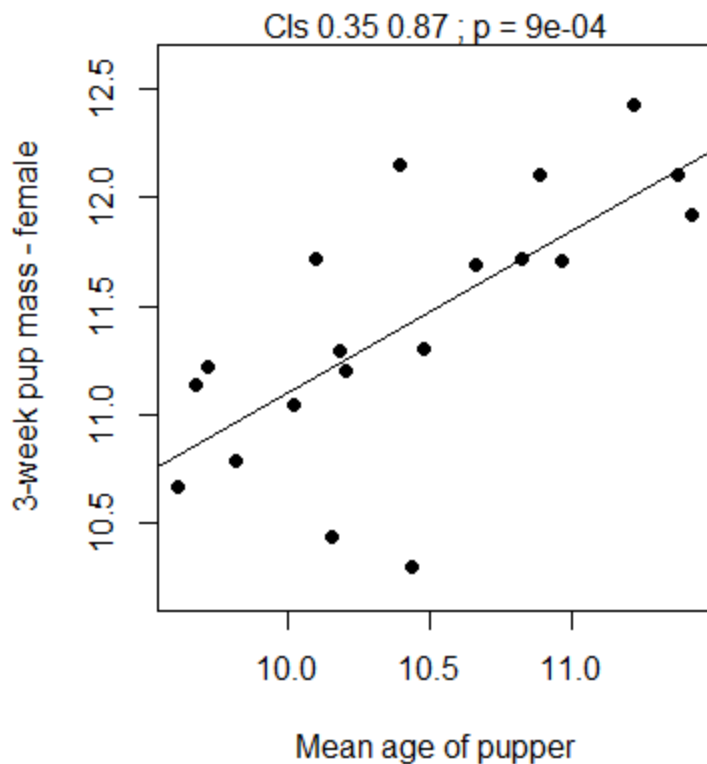


Pup mass at 3 weeks

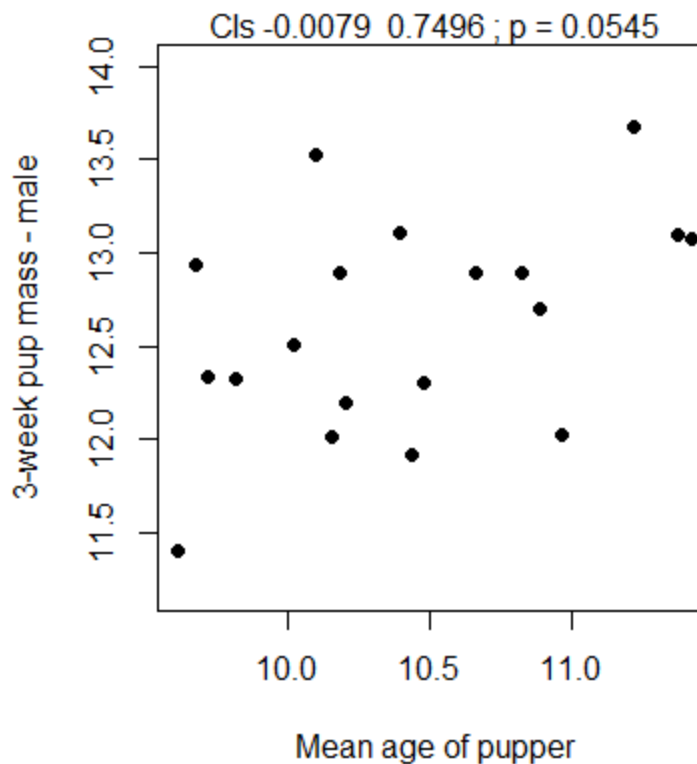


1e. Breeder age & pup mass

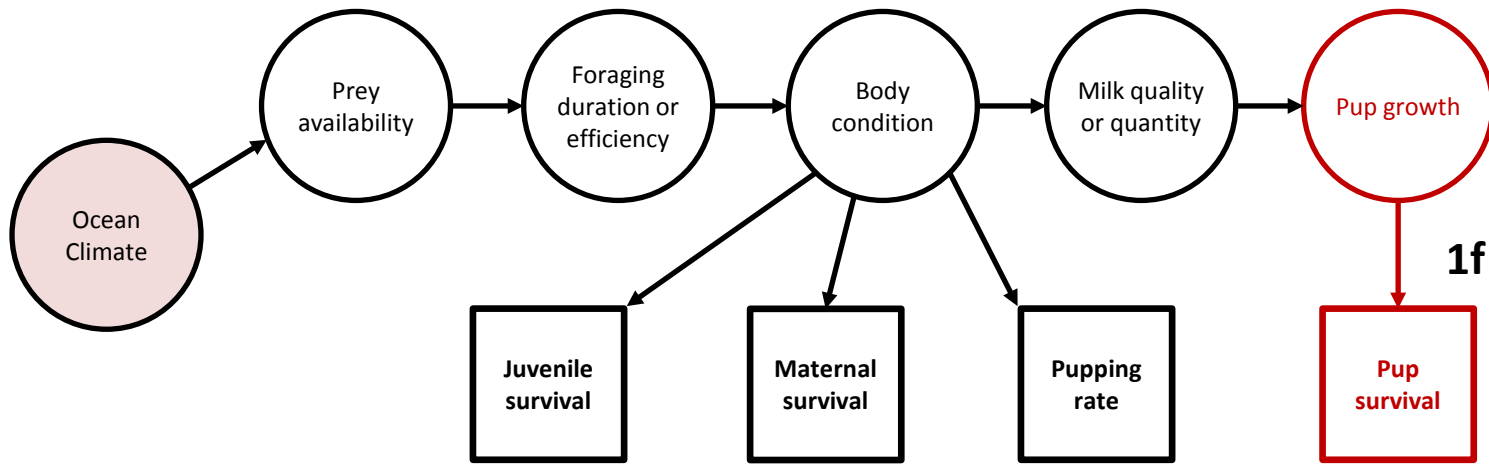
Age of pupper and pup mass - female



Age of pupper and pup mass - male

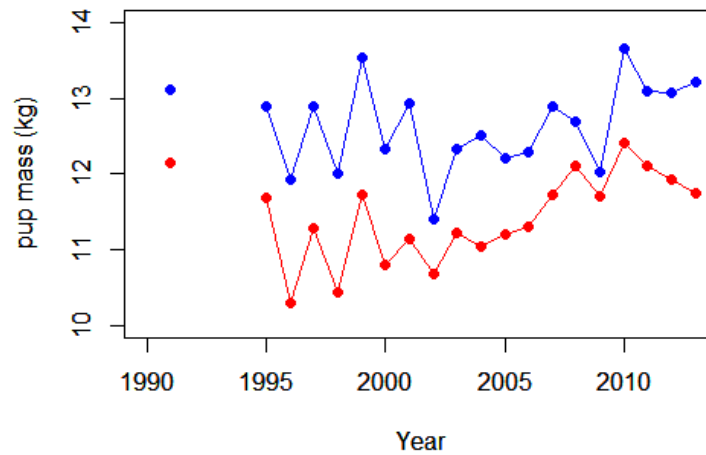


1f. pup mass & pup survival

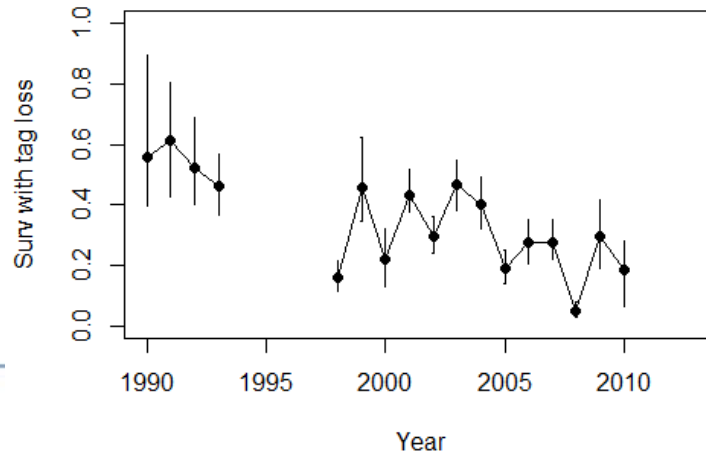


1f. pup mass & pup survival

Pup mass at 3 weeks



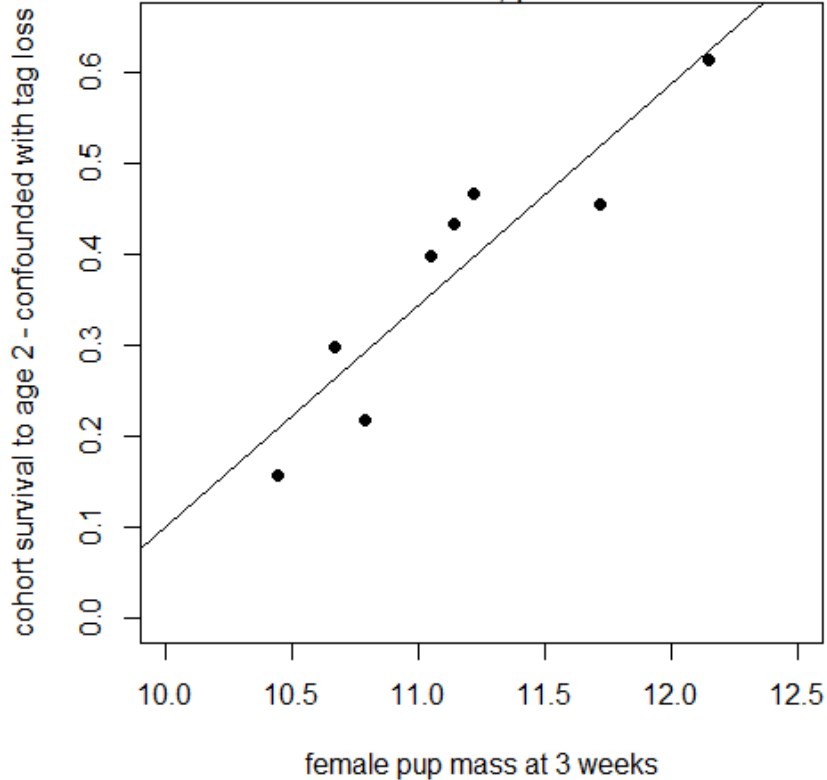
Survival pups and yearlings



1f. pup mass & pup survival

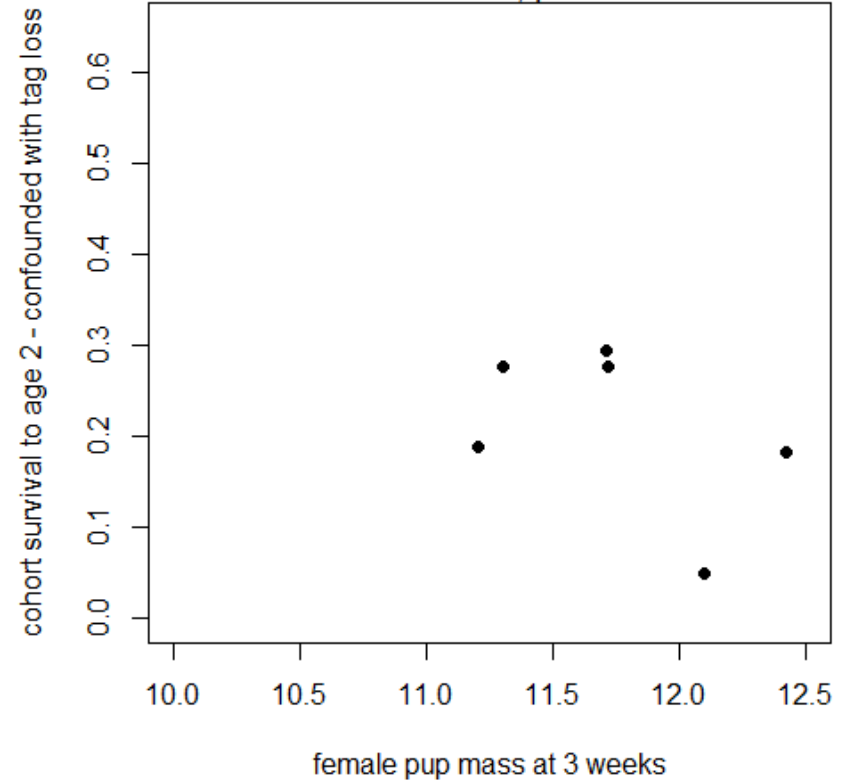
pup mass and cohort survival to age 2 (1990-2004)

CI's 0.62 0.99 ; p = 0.0012

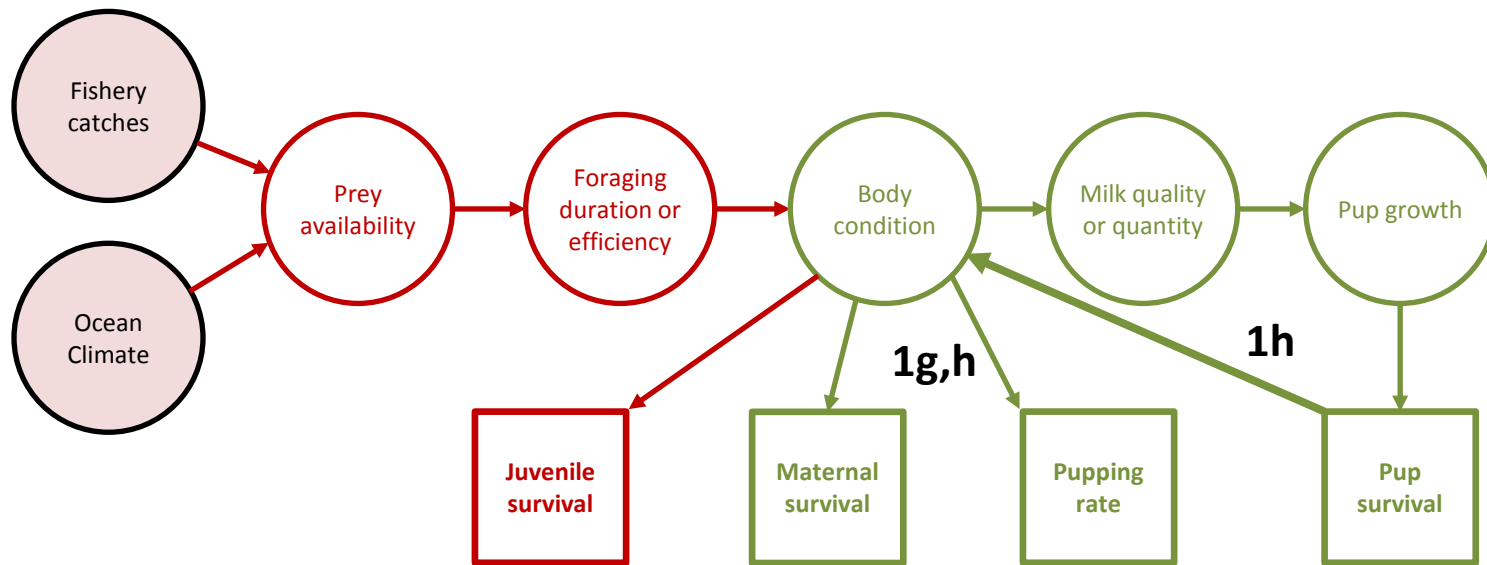


pup mass and cohort survival to age 2 (2005-2010)

CI's -0.92 0.57 ; p = 0.3675



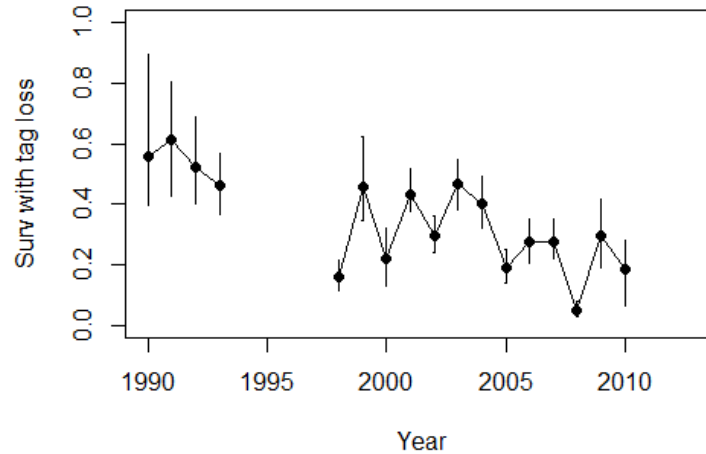
1h. Pup/yearling survival & response in year+1



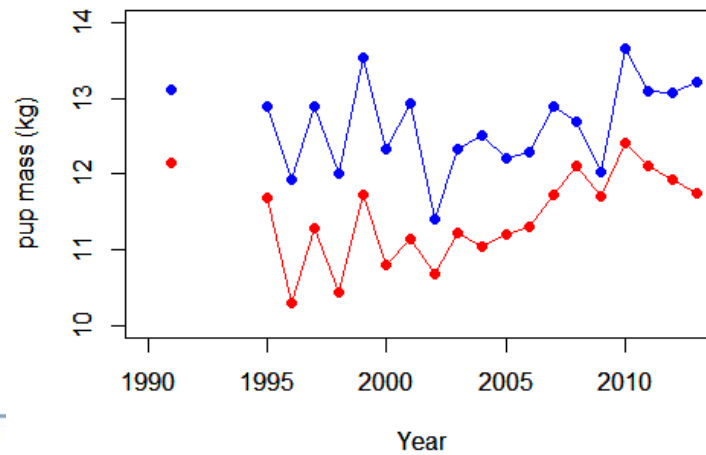
- If pup lost early then mother able to recover condition (intermediate stress)
- Positively affects maternal survival, pupping rate, pup growth in the next year

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

Survival pups and yearlings



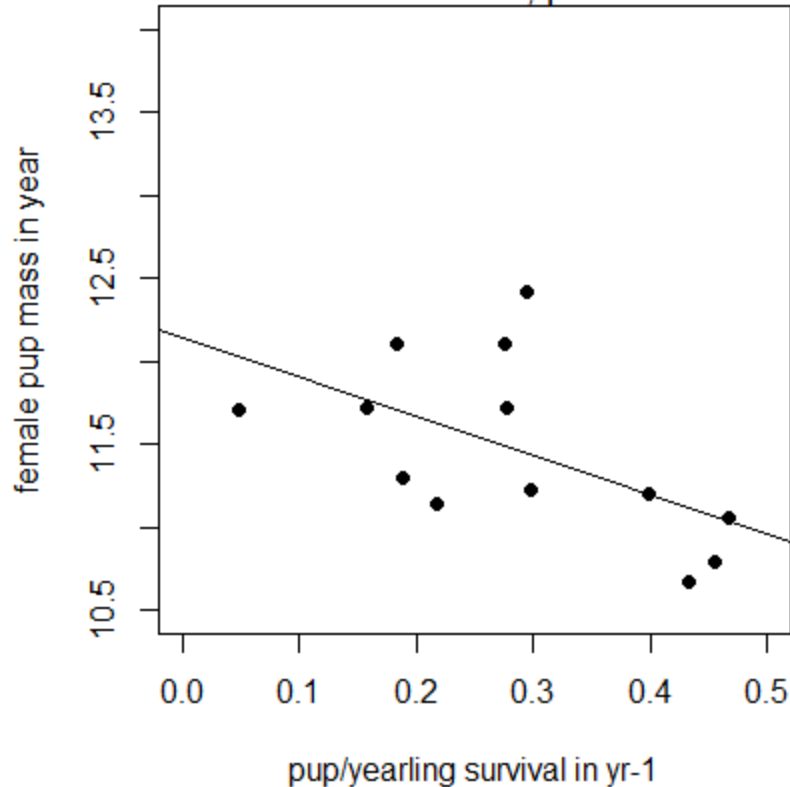
Pup mass at 3 weeks



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

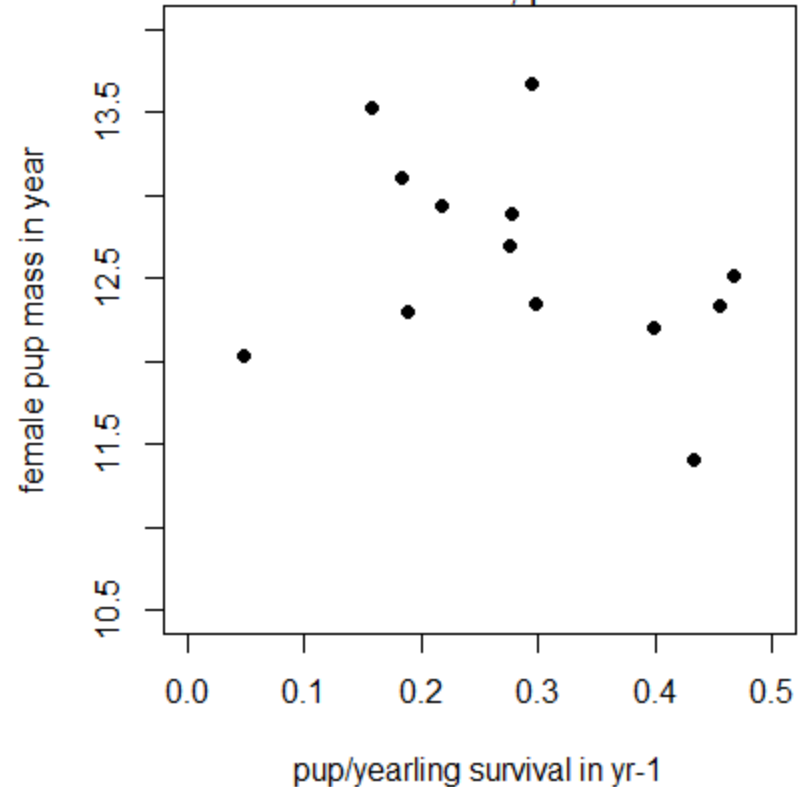
Surv01 in yr-1 and pup mass in yr - female

CI_s -0.850 -0.015 ; p = 0.0459



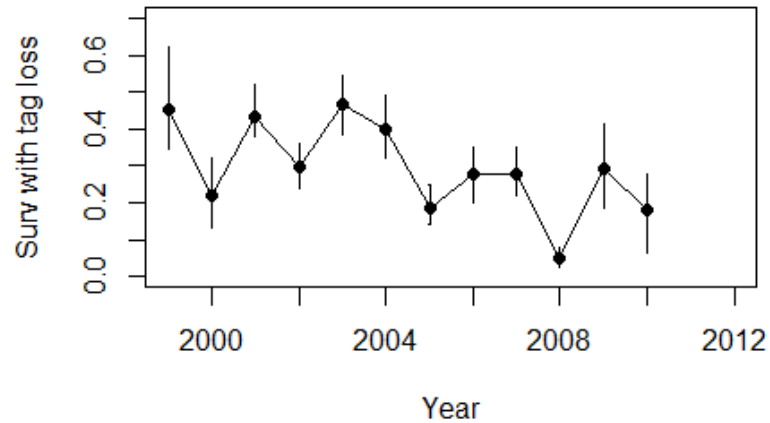
Surv01 in yr-1 and pup mass in yr - male

CI_s -0.74 0.27 ; p = 0.2732

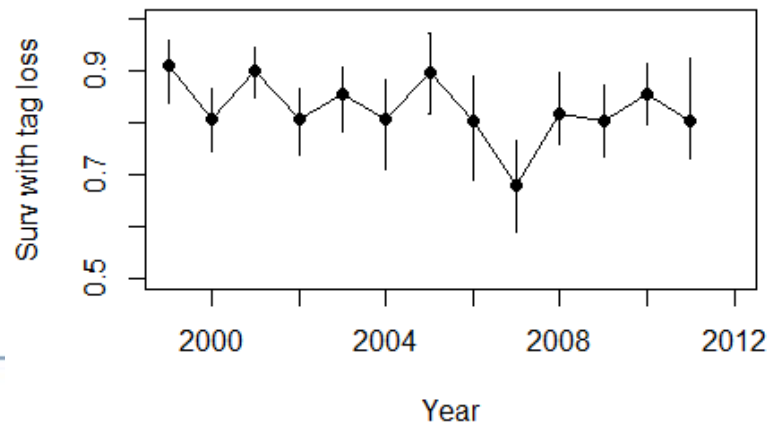


1h. Pup/yearling survival & adult survival in yr+1

Survival pups and yearlings

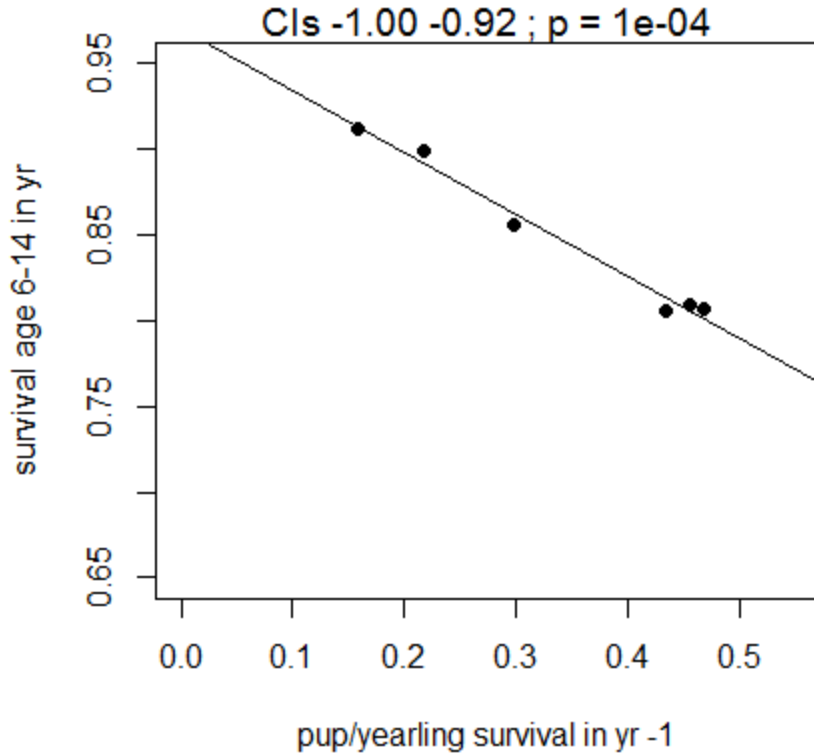


Survival Age6-14

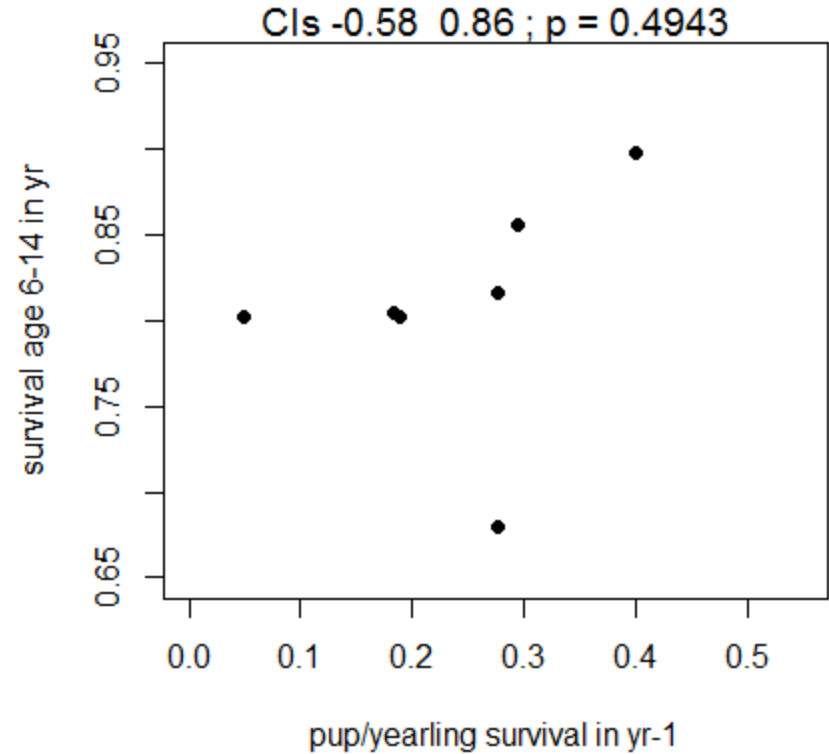


1h. Pup/yearling survival & adult survival in yr+1

Surv01 in yr-1 and Surv6-14 in yr (1998-2004)



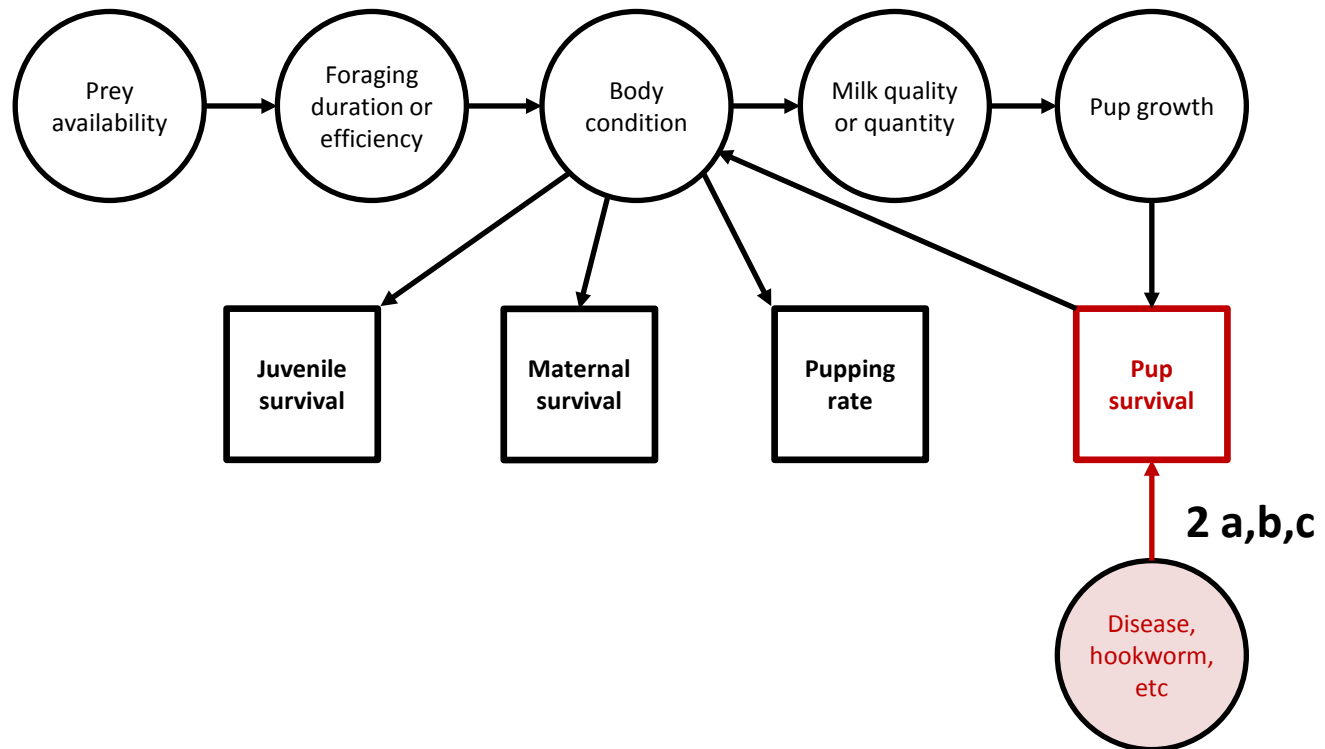
Surv01 in yr-1 and Surv6-14 in yr (2005-2010)



Summary of correlative assessment – nutritional stress-related

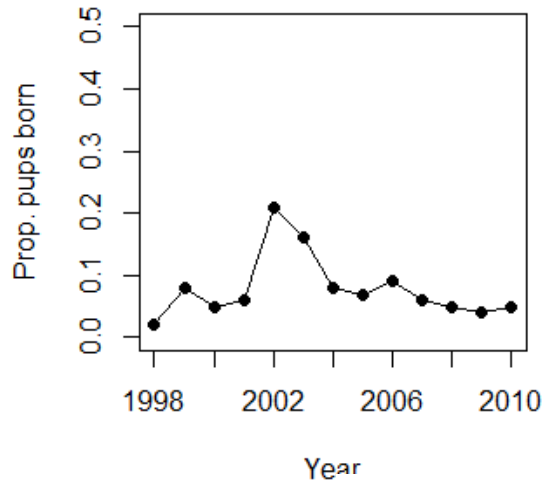
Candidate driver of population change	ID	Relationships assessed	Correlation
Nutritional stress	1a	Climate and diet	Yes (SSH, IPO)
	1b	Prey abundance and diet	Only one species
	1c	Diet and maternal condition	Only one species
	1d	Diet and milk quality	Only one species
	1e	Maternal condition/milk quality/breeder 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

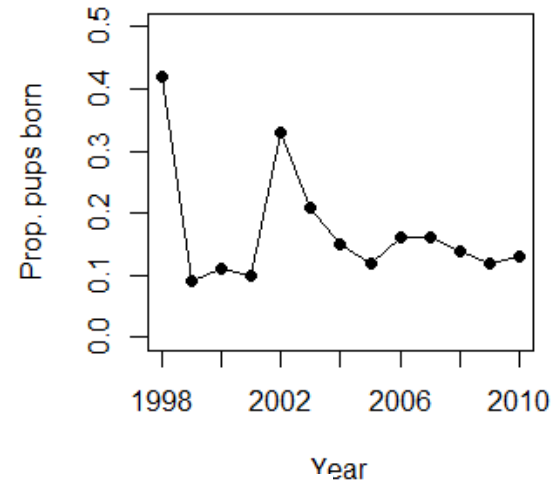


2a. Early pup mortality & pup/yearling survival

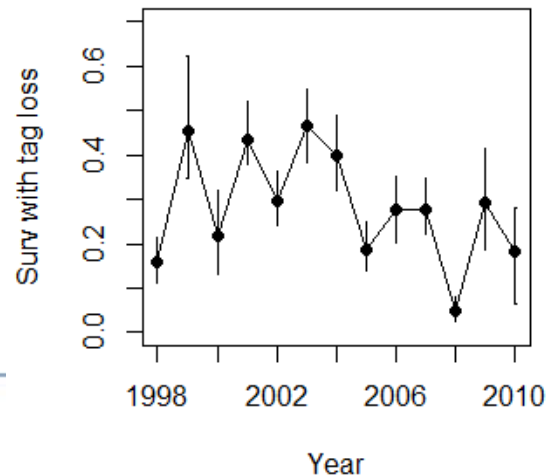
Pup mortality at 3 weeks



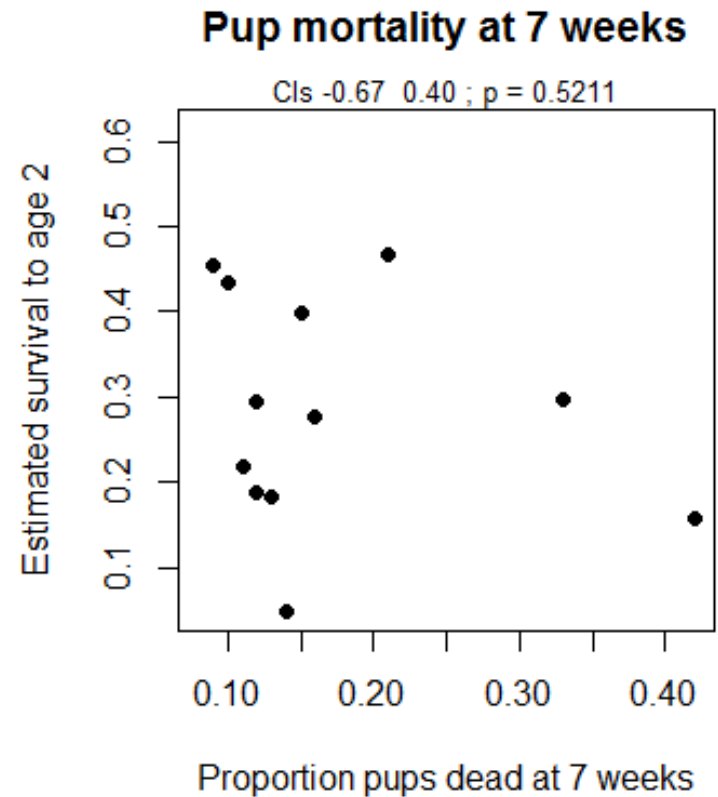
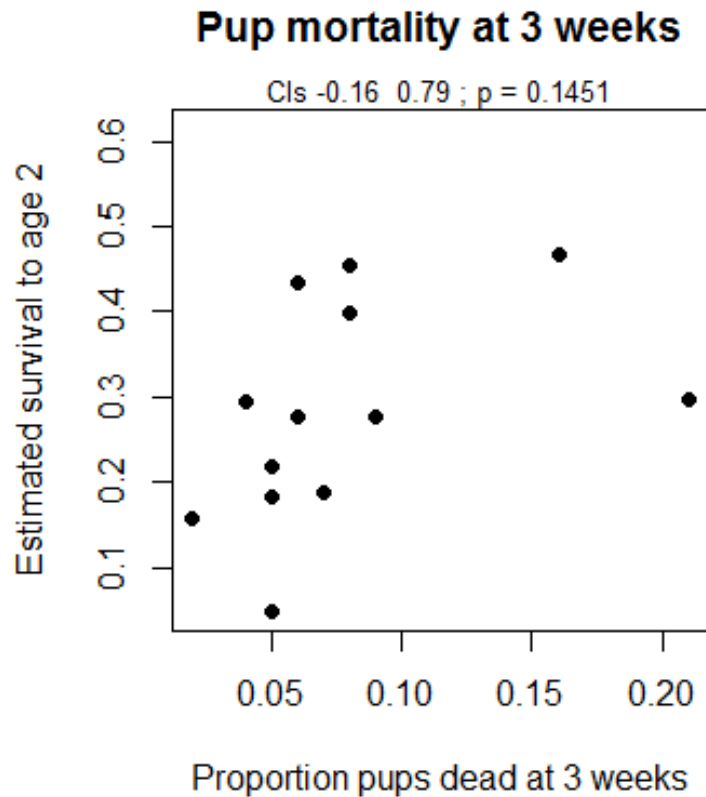
Pup mortality at 7 weeks



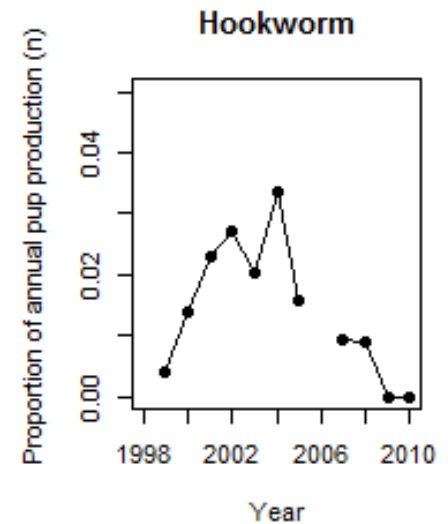
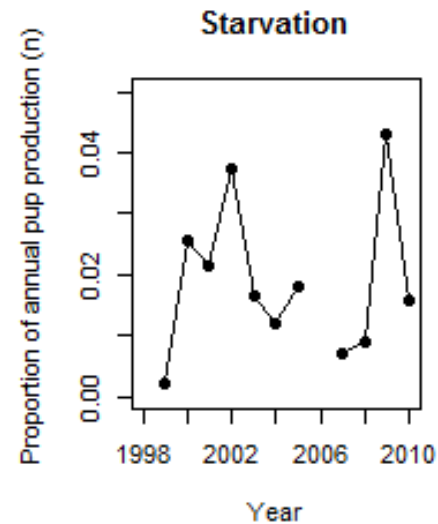
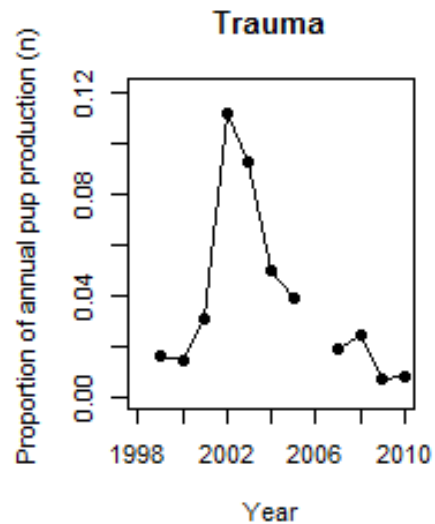
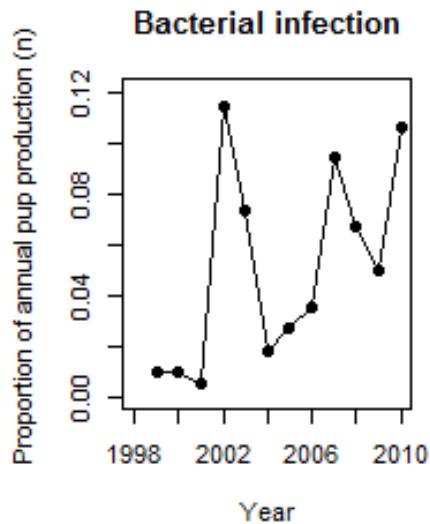
Survival pups and yearlings



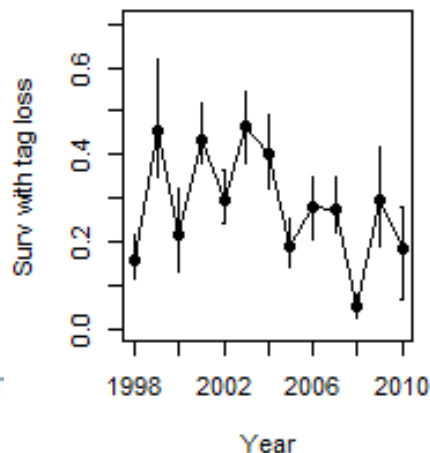
2a. Early pup mortality & pup/yearling survival



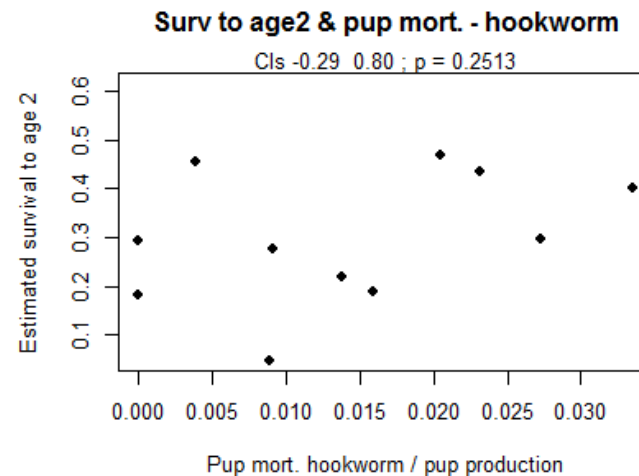
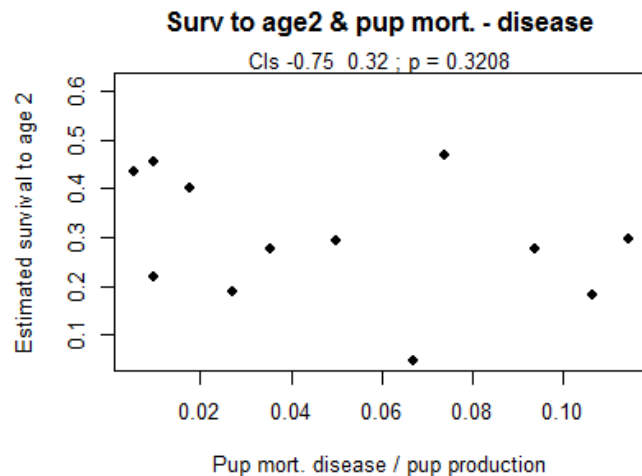
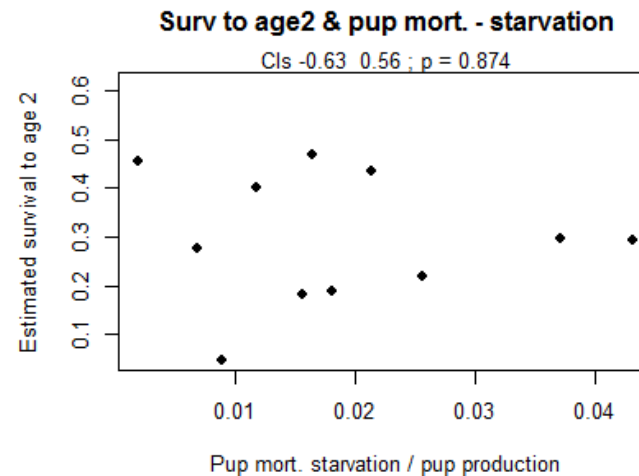
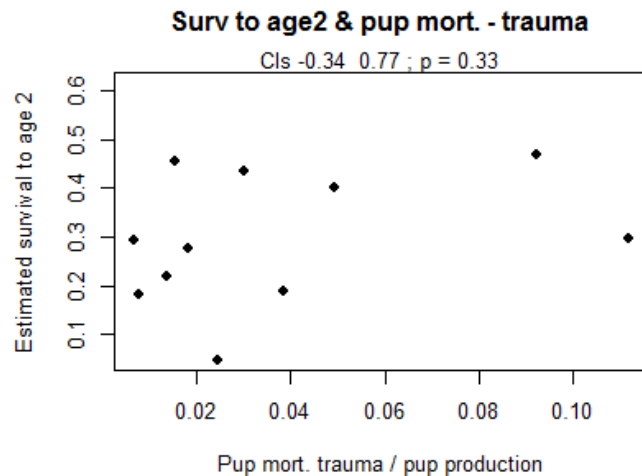
2b. Pup mortality cause & pup/yearling survival



Survival pups and yearlings

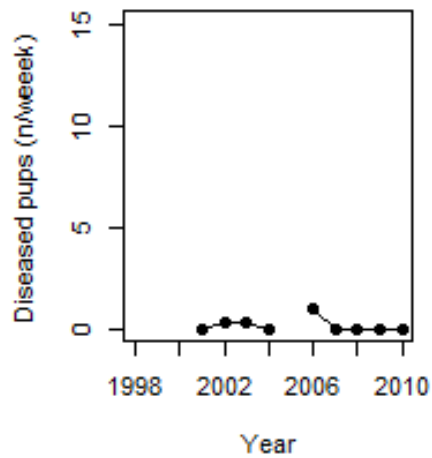


2b. Pup mortality cause & pup/yearling survival

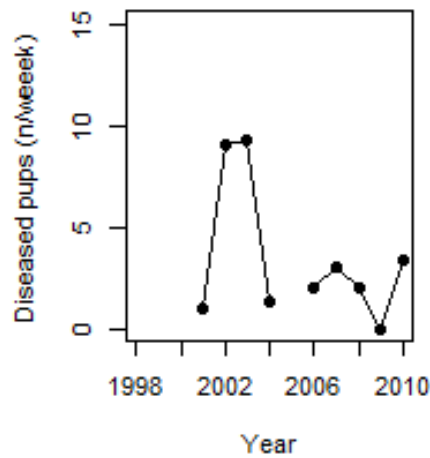


2c. Timing of disease mortality & pup/yearling survival

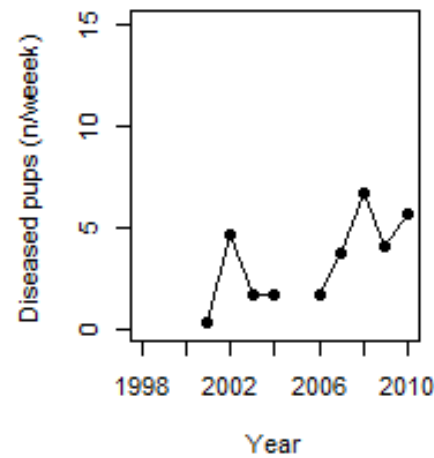
Disease mortality (2-4 weeks)



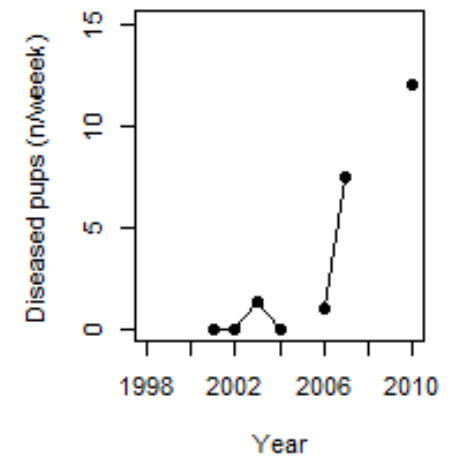
Disease mortality (5-7 wks)



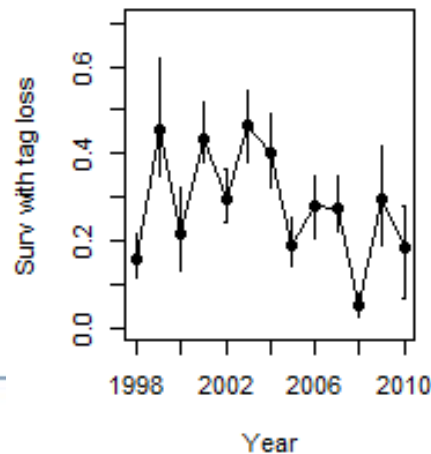
Disease mortality 8-10 wks



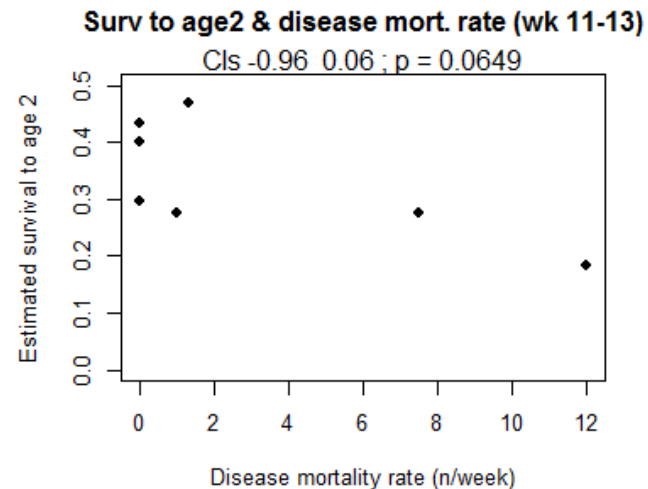
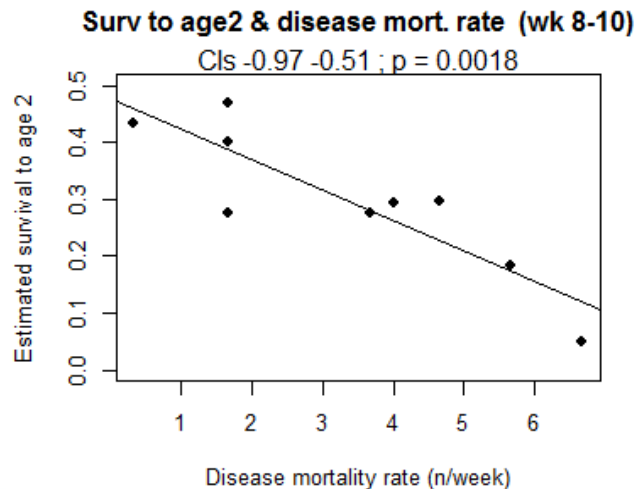
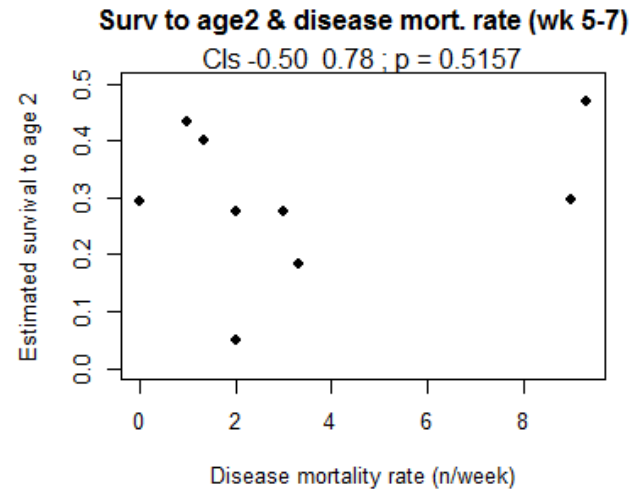
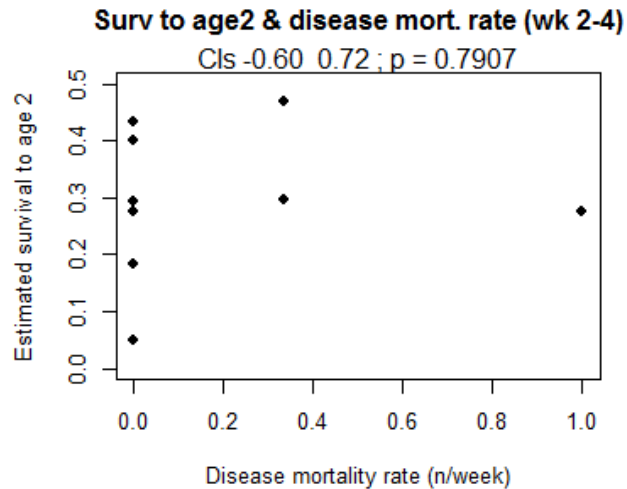
Disease mortality 11-13 wks



Survival pups and yearlings



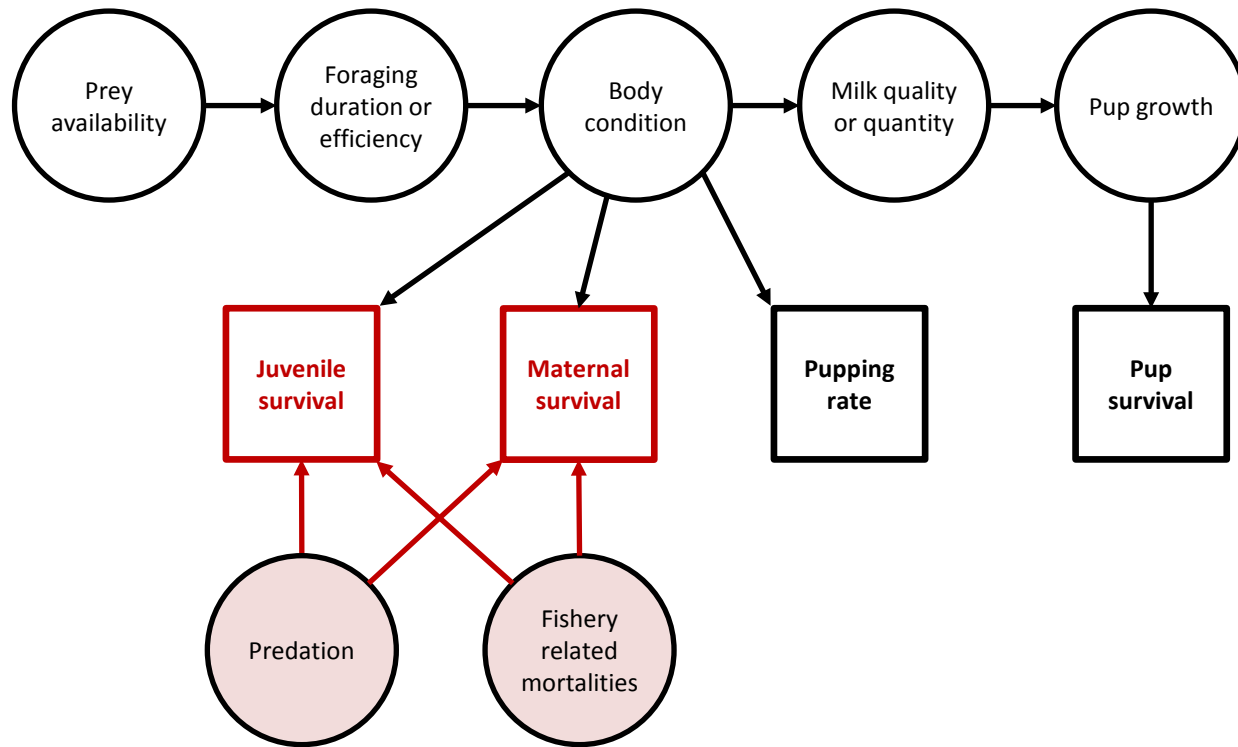
2c. Timing of disease mortality & pup/yearling survival



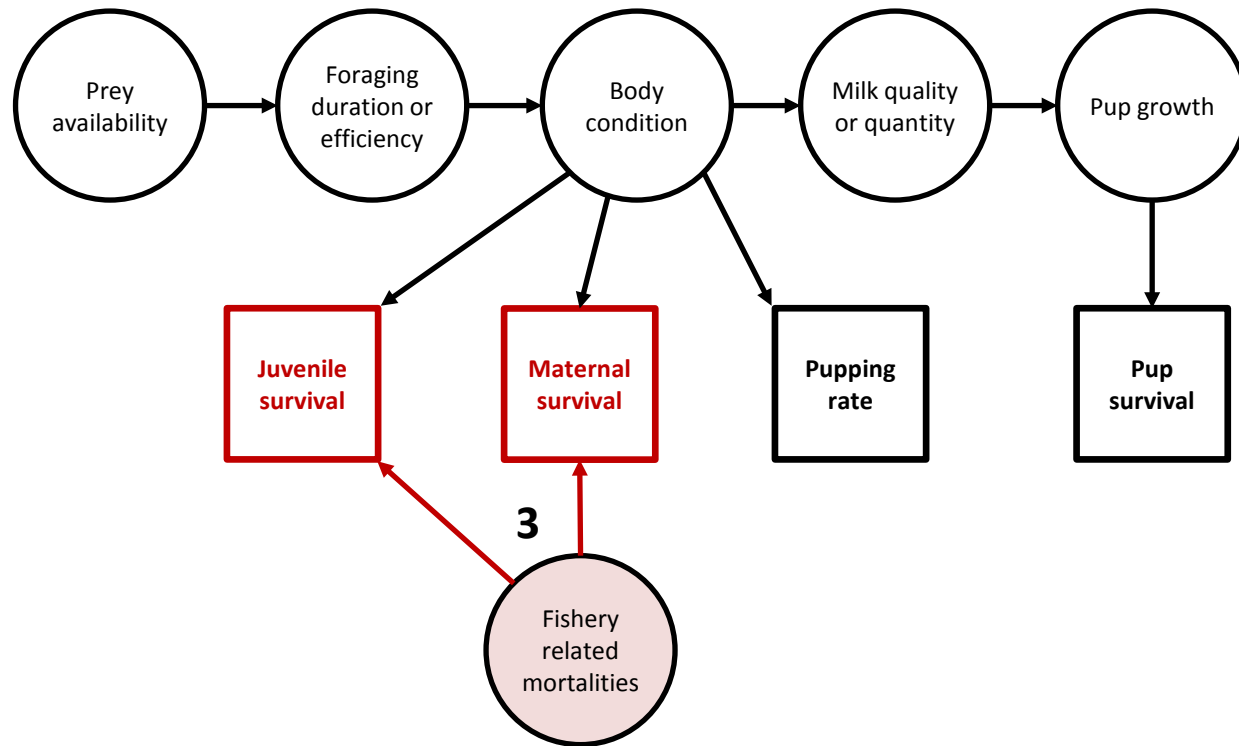
Summary of correlative assessment – disease-related pup mortality

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)

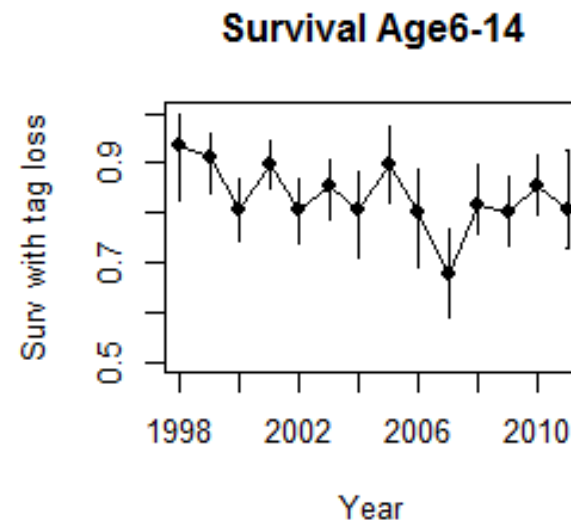
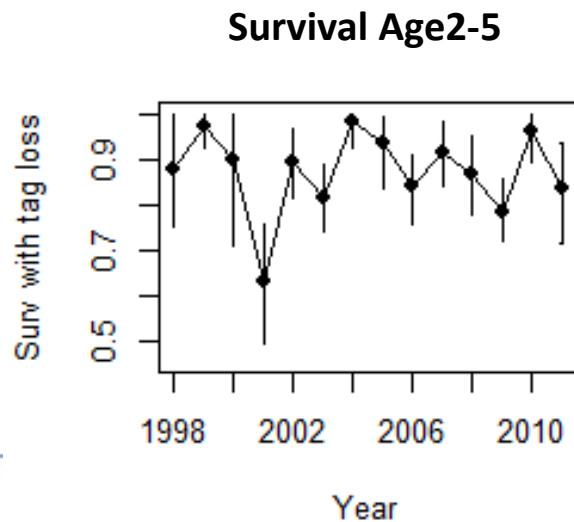
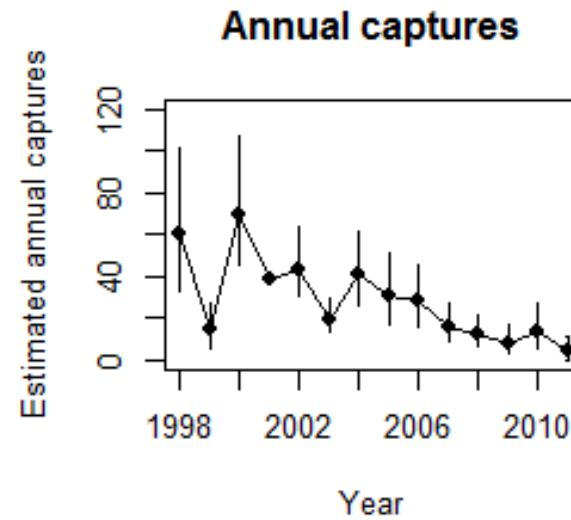
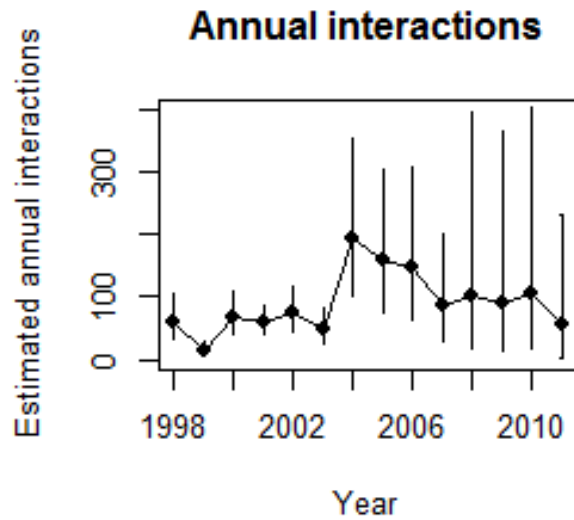
3. Predation or fishery-related mortalities & juvenile/adult survival



3. Fishery-related mortalities & juvenile/adult survival

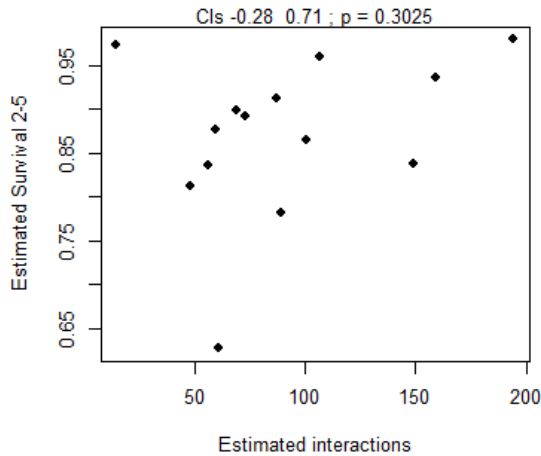


3. Fishery-related mortalities & juvenile/adult survival

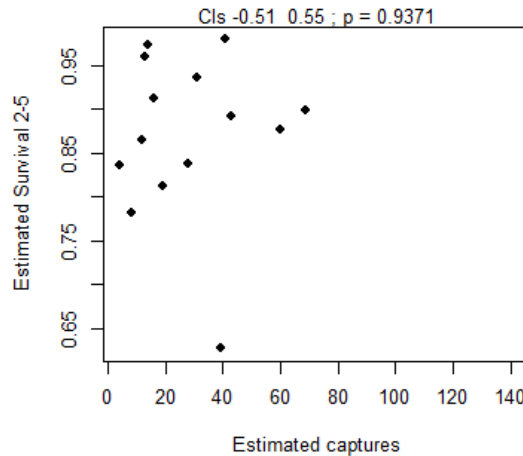


3. Fishery-related mortalities & juvenile/adult survival

Fishery interactions & Juvenile survival

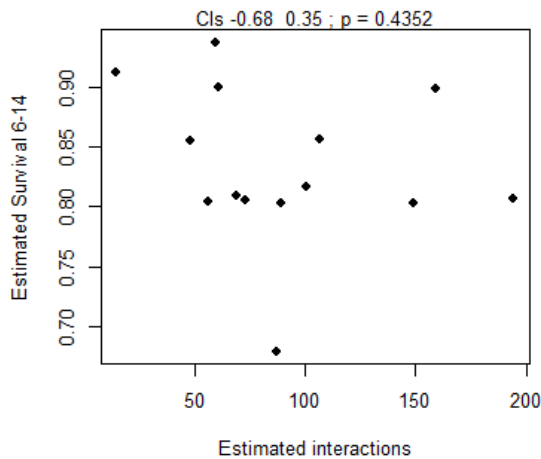


Fishery captures & Juvenile survival

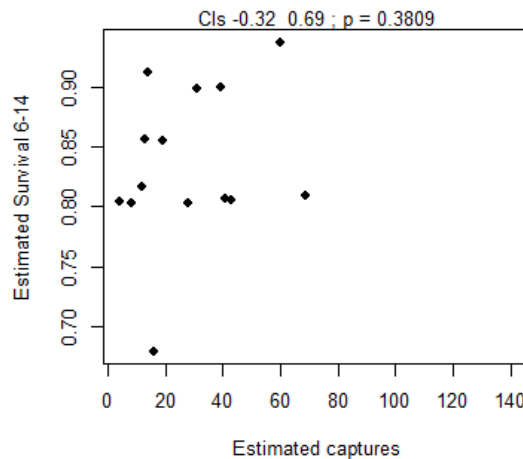


Simple test of correlation between **estimated captures/interactions** and survival estimates for ages 2-5 and 6-14 (confounded with tag loss)

Fishery interactions & Adult survival



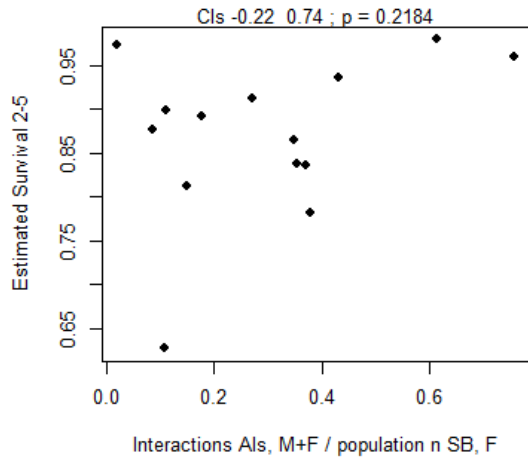
Fishery captures & Adult survival



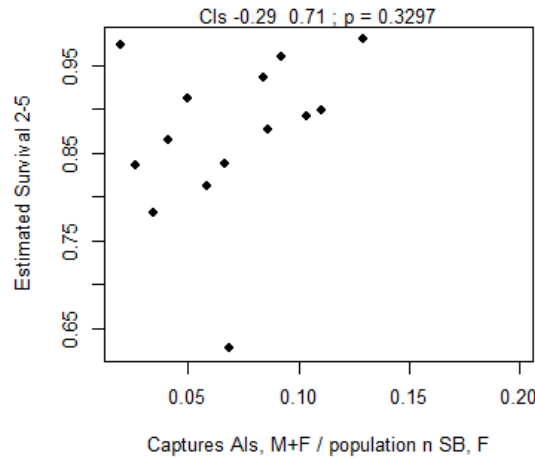
None significantly correlated

3. Fishery-related mortalities & juvenile/adult survival

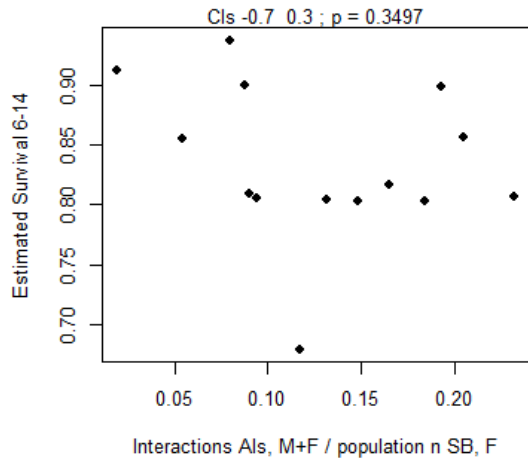
Interactions/pop n & Juvenile survival 2-5



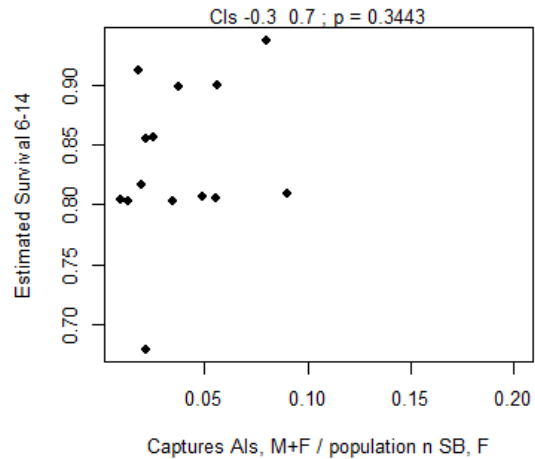
Captures/pop n & Juvenile survival 2-5



Interactions/pop n & Adult survival 6-14



Captures/pop n & Adult survival 6-14



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

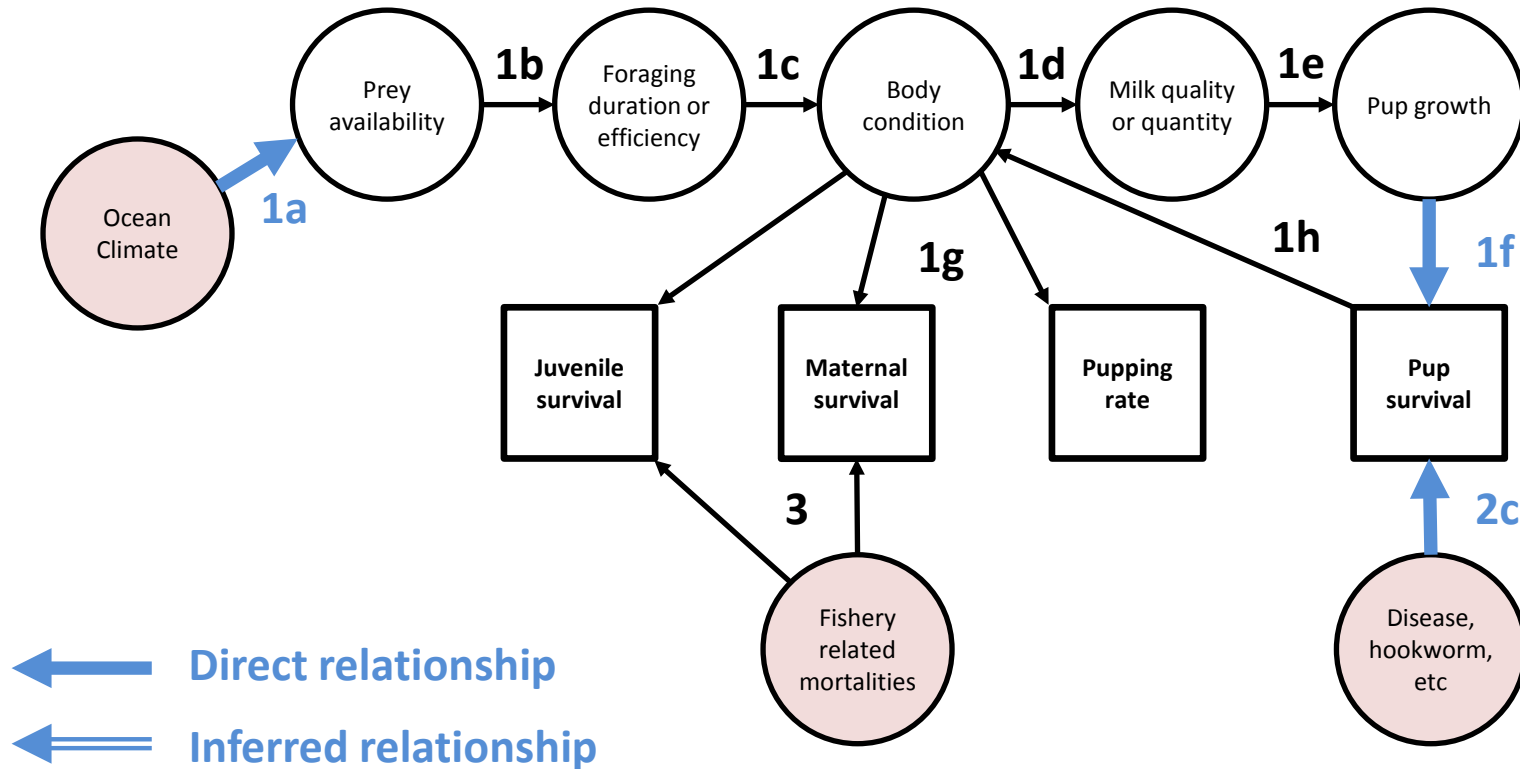
Summary of correlative assessment

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?

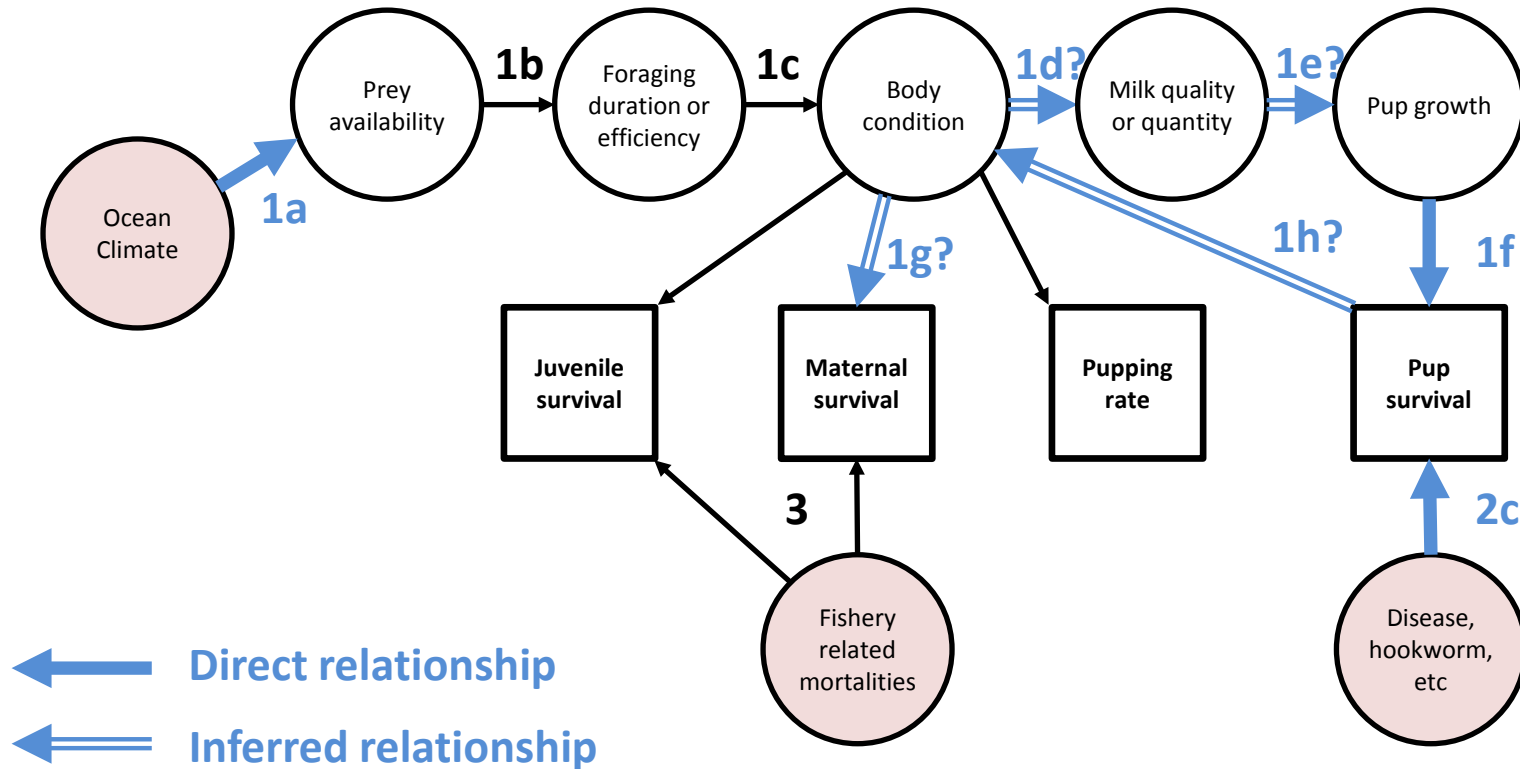
- Only three direct effects upheld by correlative assessment



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

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Response variable	Predation or fishery captures	Nutritional stress (climate or fishery driven)	Pup disease (but non-nutritional stress driven)
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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
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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-Saprizza
 - Wendi Roe
 - Martin Cawthorn
 - Simon Childerhouse

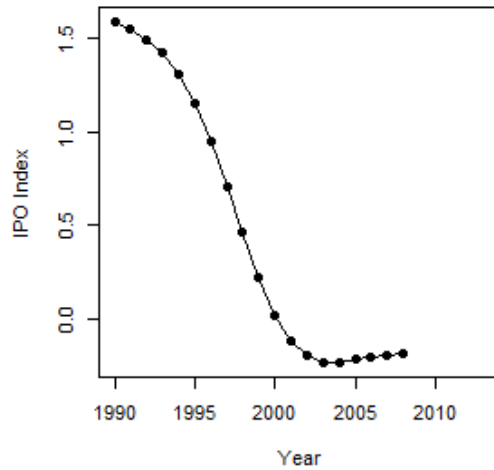
End of talk 3

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

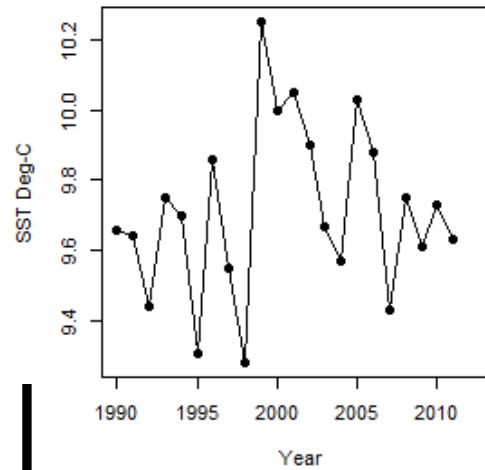
Supplementary analyses

1a (i) Climate & prey abundance

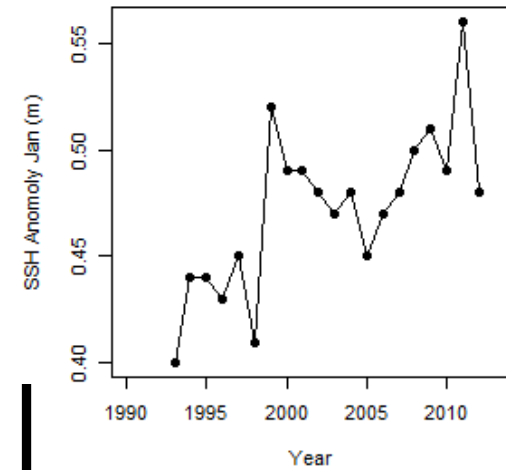
IPO Index



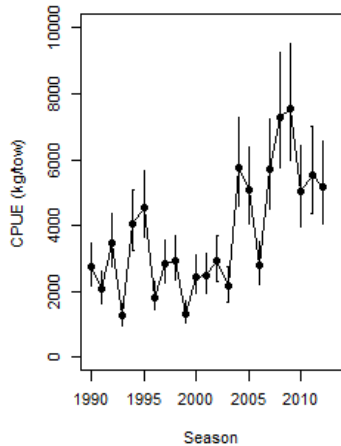
Sea surface temperature



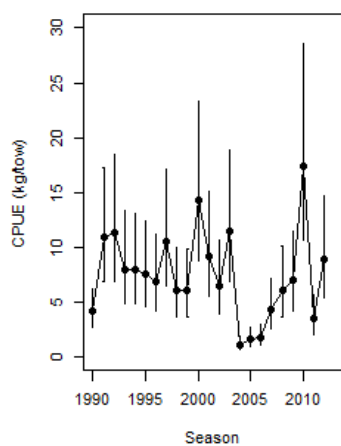
Sea surface height



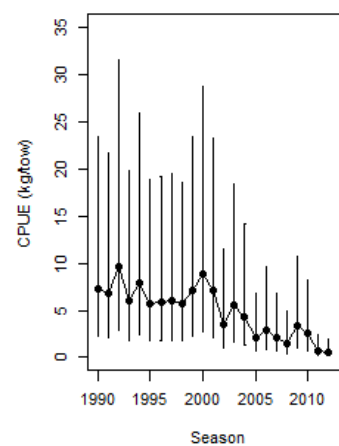
CPUE Arrow squid



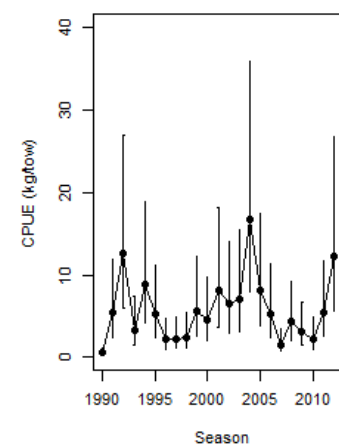
CPUE Hoki



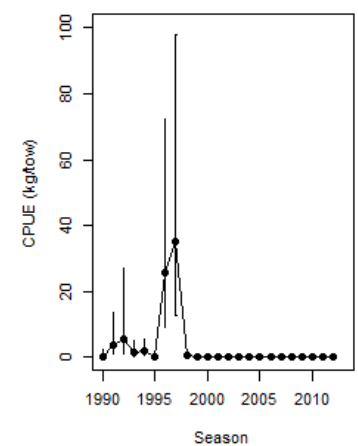
CPUE Ling



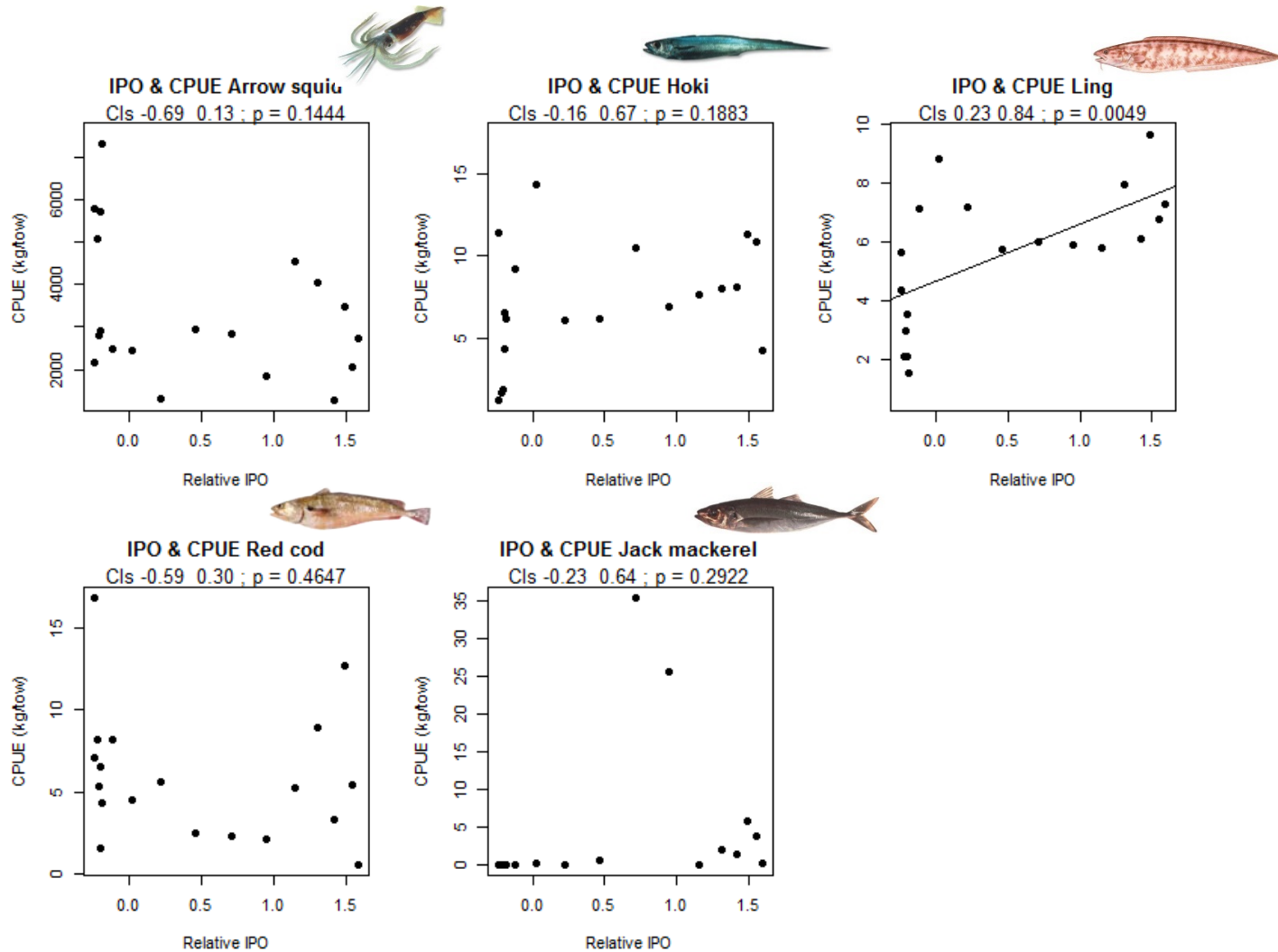
CPUE Red cod



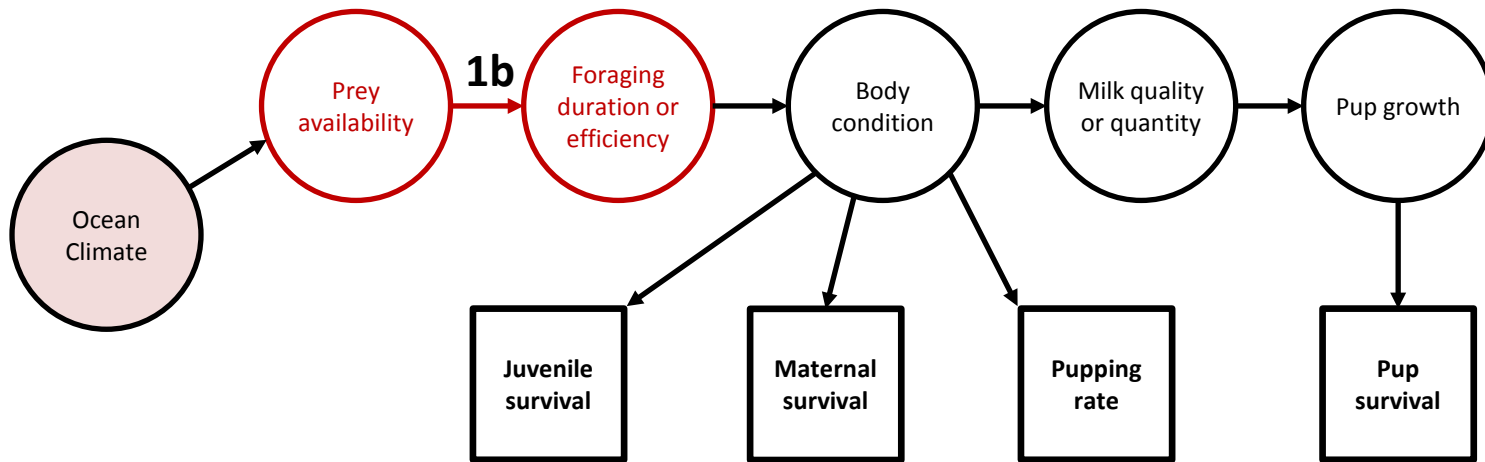
CPUE Jack mackerel



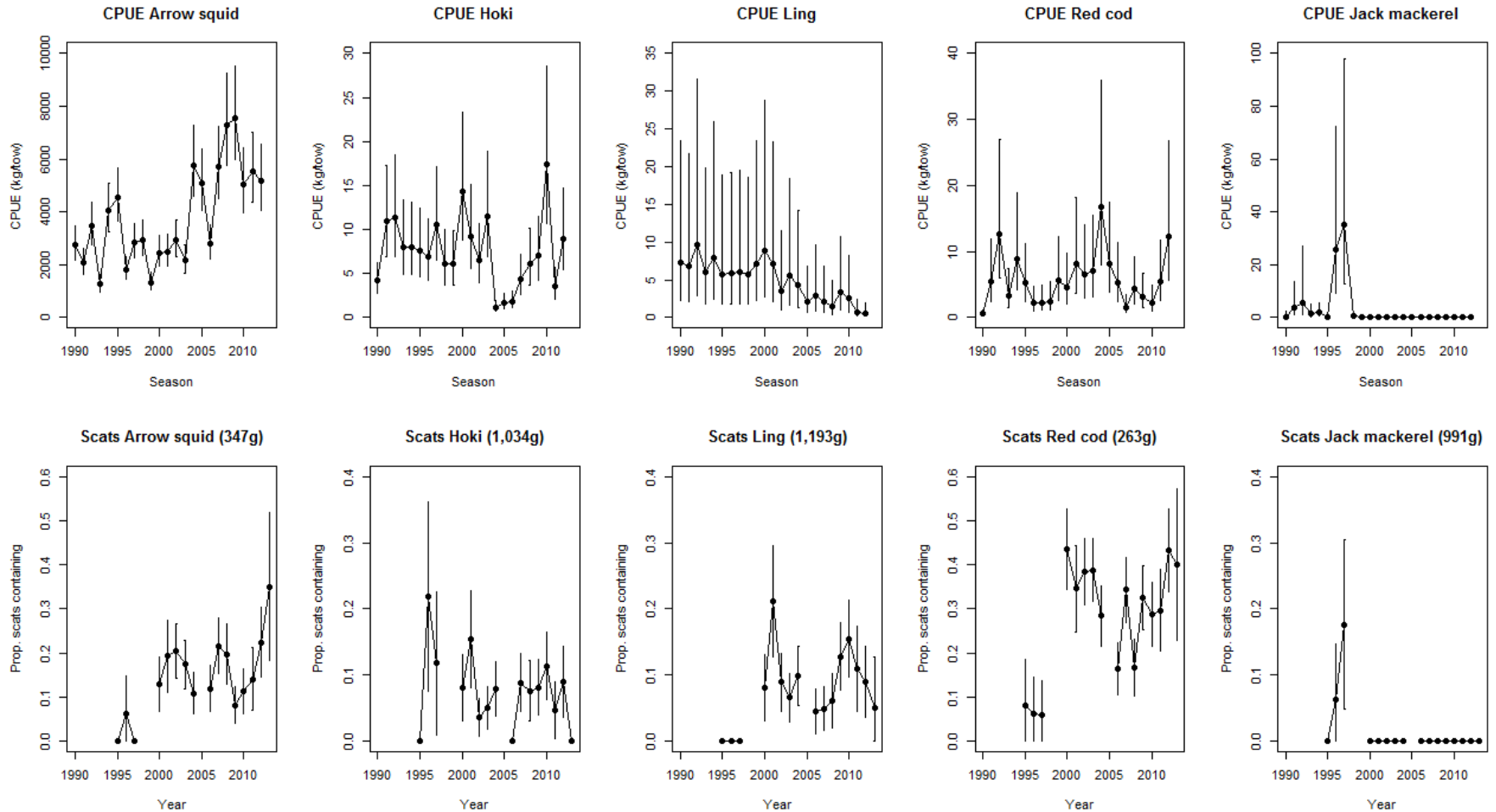
1a (i) Climate & prey CPUE – Inter-decadal Pacific Oscillation



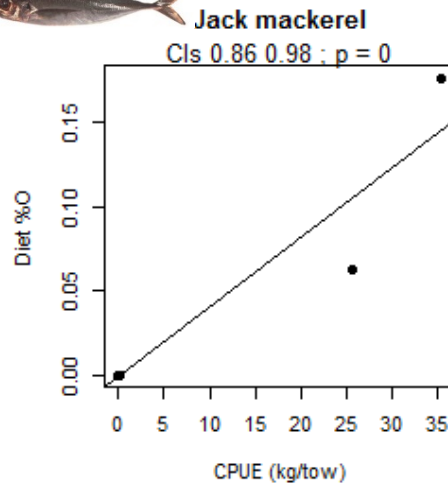
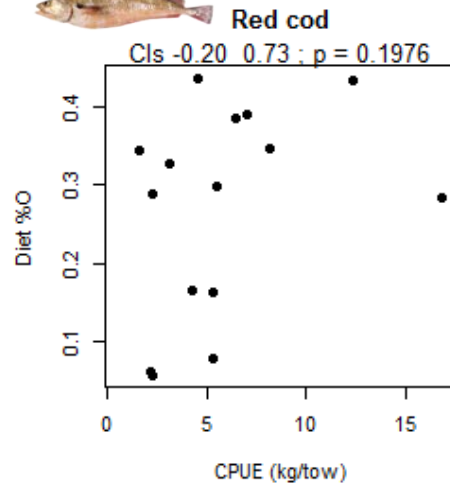
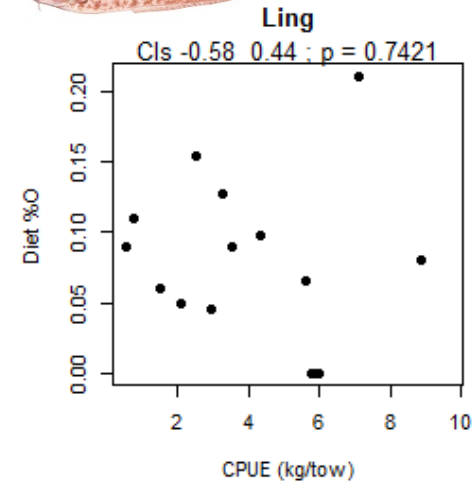
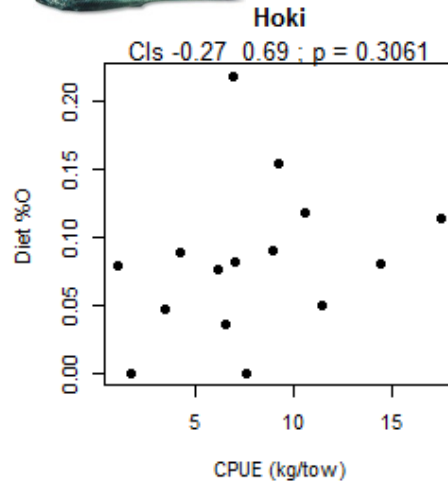
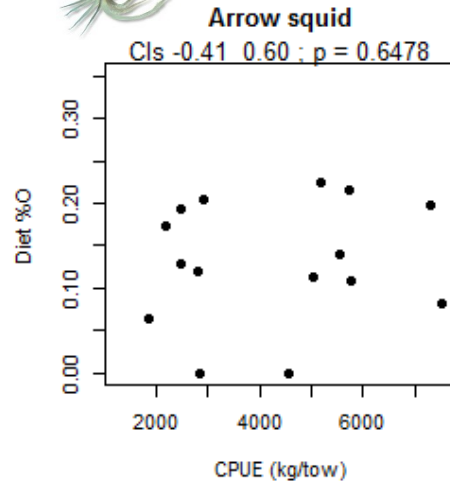
1b. prey abundance/availability and **diet**



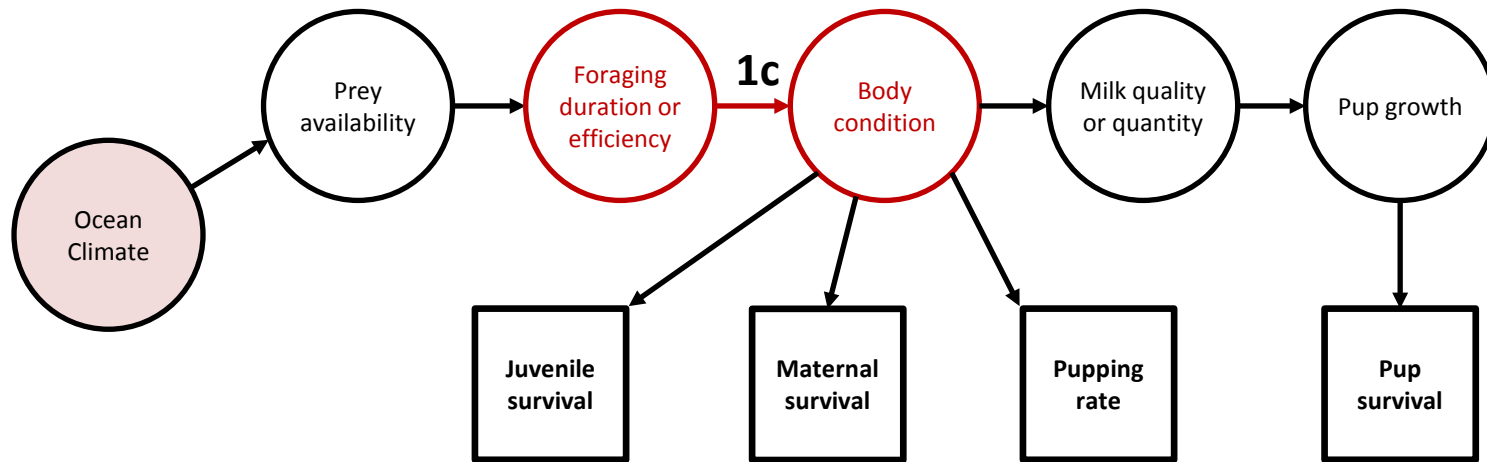
1b. prey abundance/availability and diet



1b. prey abundance/availability and diet

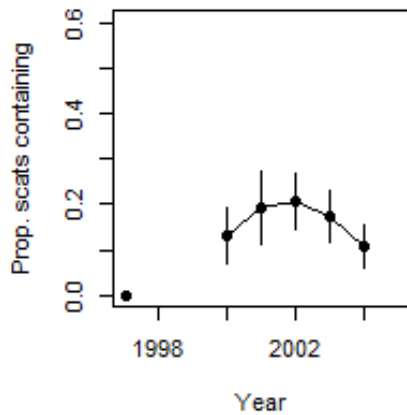


1c. Diet & maternal condition

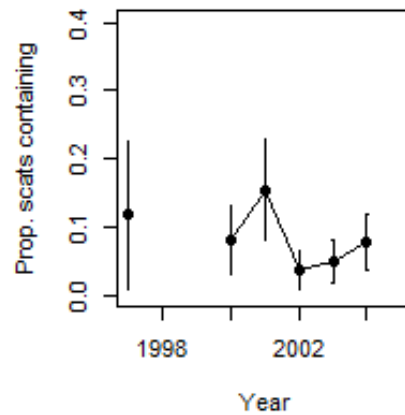


1c. Diet & maternal condition

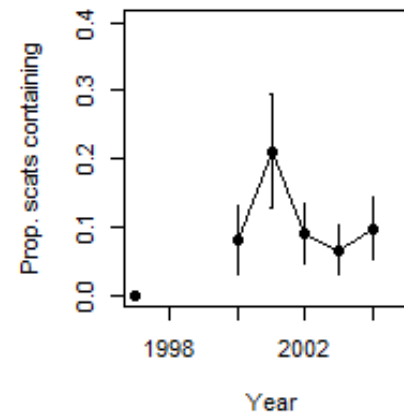
Scats Arrow squid (347g)



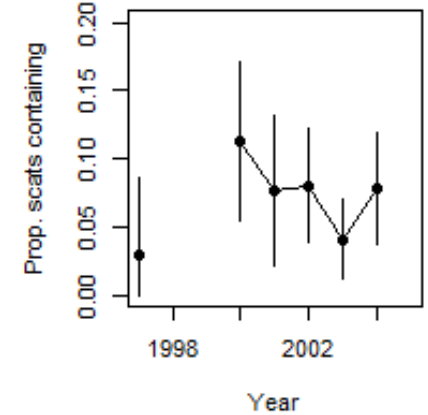
Scats Hoki (1,034g)



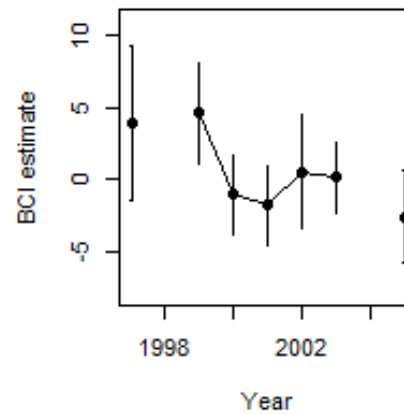
Scats Ling (1,193g)



Scats Giant octopus (1,788g)



BCI Jan & Feb

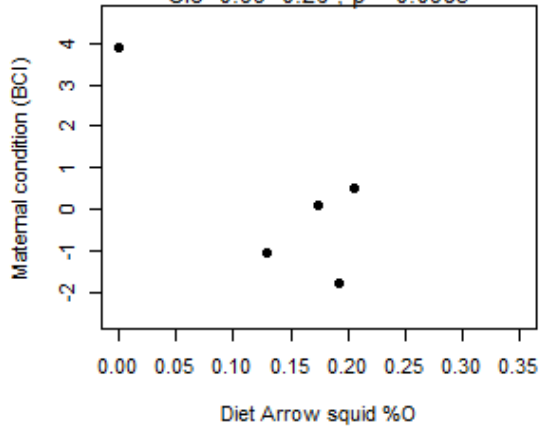


1c. Diet & maternal condition



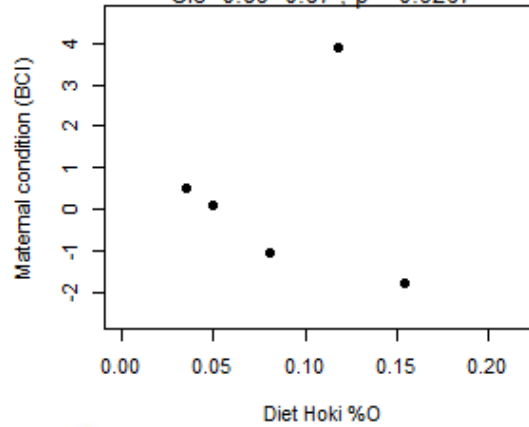
Maternal condition & diet - Arrow squid

CI's -0.99 0.26 ; p = 0.0983



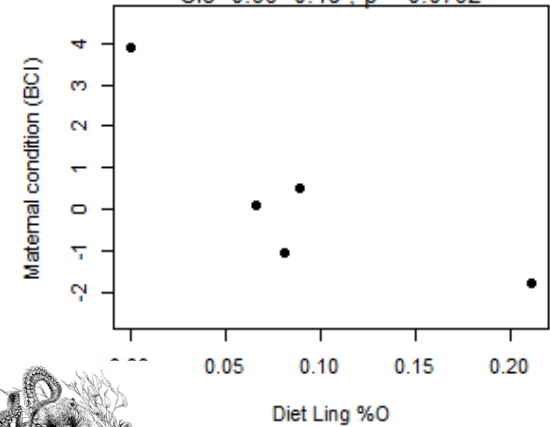
Maternal condition & diet - Hoki

CI's -0.89 0.87 ; p = 0.9267



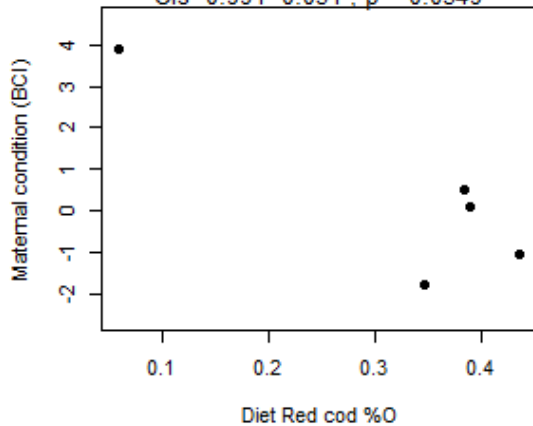
Maternal condition & diet - Ling

CI's -0.99 0.18 ; p = 0.0792



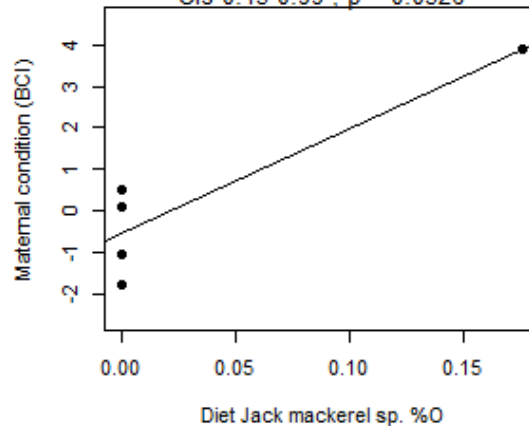
Maternal condition & diet - Red cod

CI's -0.991 0.051 ; p = 0.0549



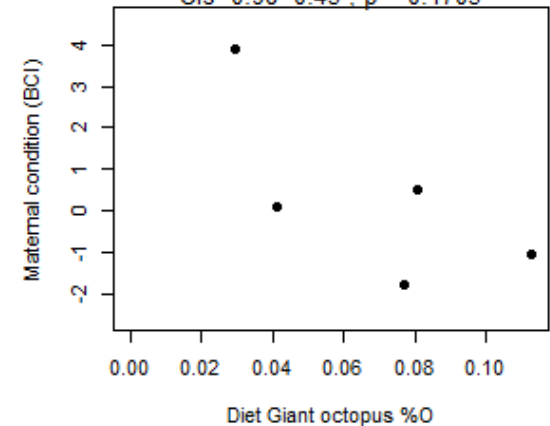
Maternal condition & diet - Jack mackerel sp.

CI's 0.13 0.99 ; p = 0.0326

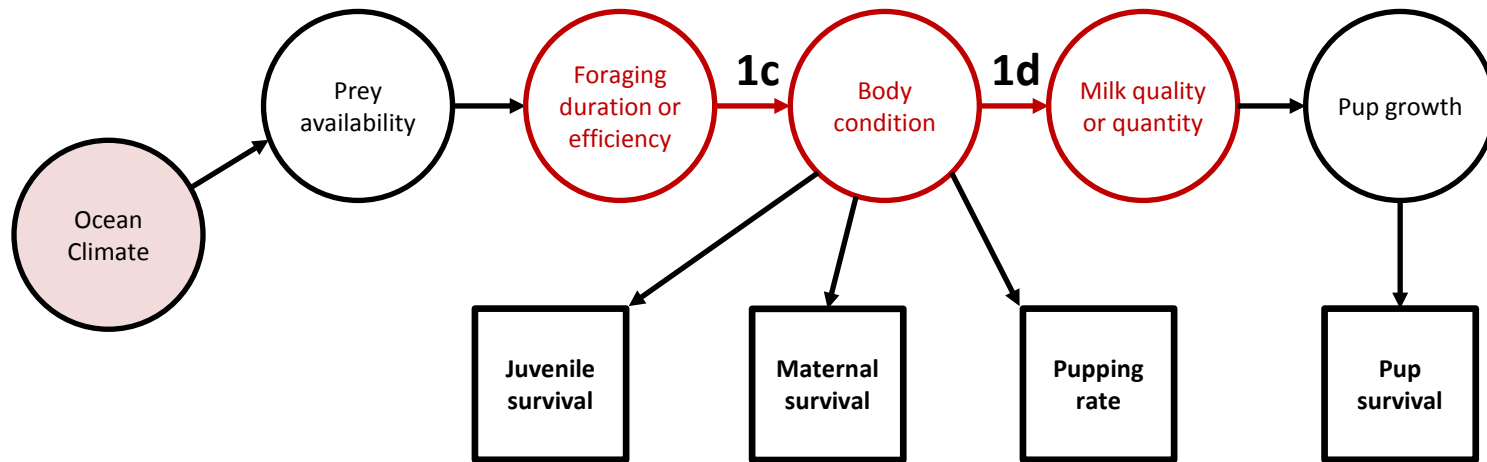


Maternal condition & diet - Giant octopus

CI's -0.98 0.45 ; p = 0.1705

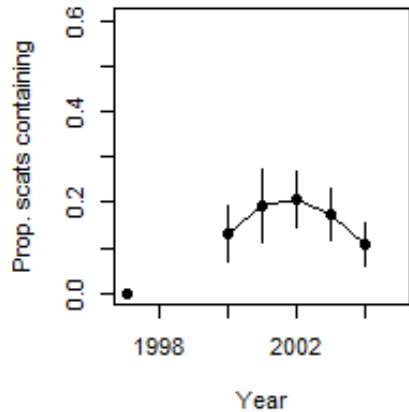


1d. Diet & milk quality

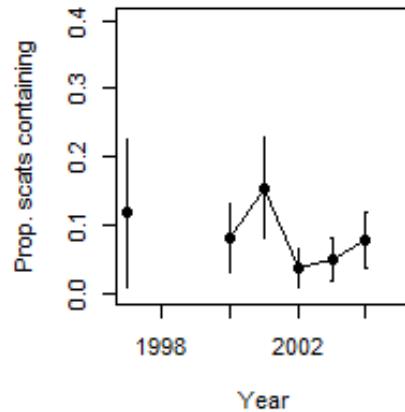


1d. Diet & milk quality

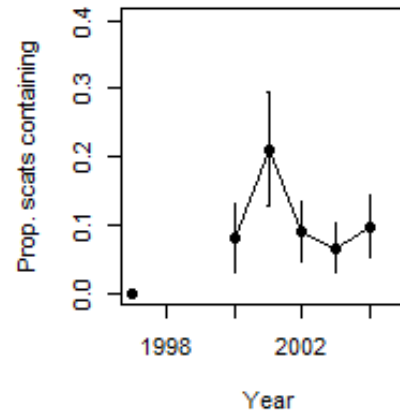
Scats Arrow squid (347g)



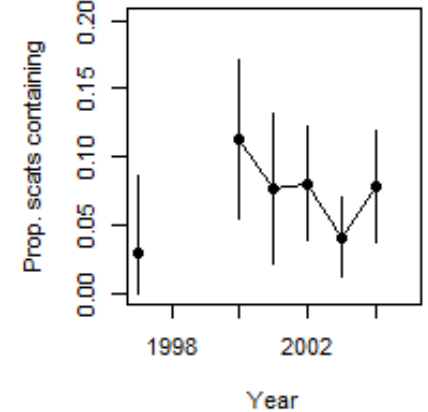
Scats Hoki (1,034g)



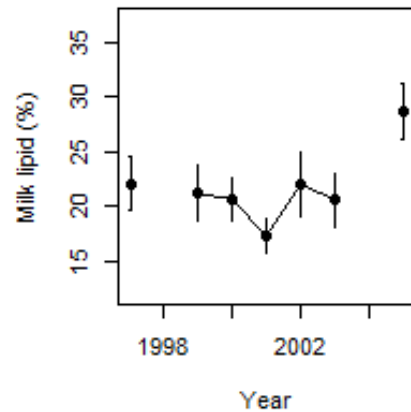
Scats Ling (1,193g)



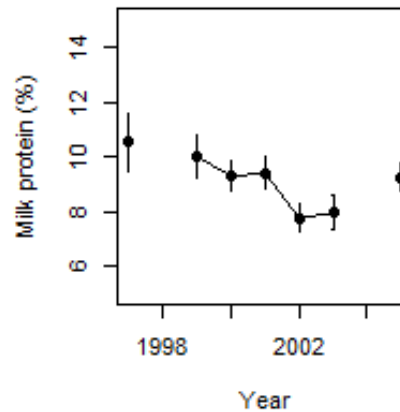
Scats Giant octopus (1,788g)



Milk lipid content Jan & Feb



Milk protein content Jan & Feb

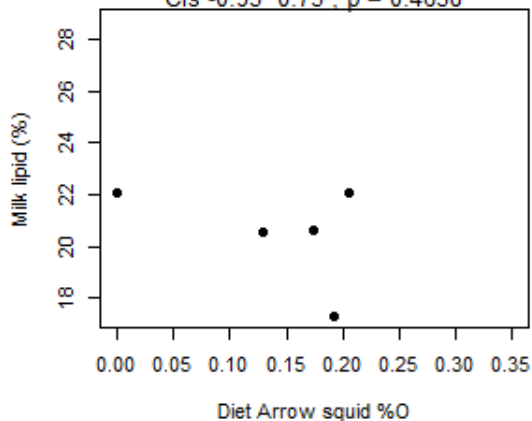


1d. Diet & milk quality – lipid %



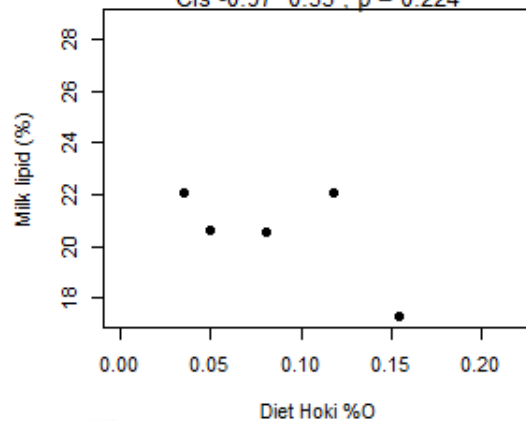
Milk lipid & diet - Arrow squid

CIs -0.95 0.73 ; p = 0.4658



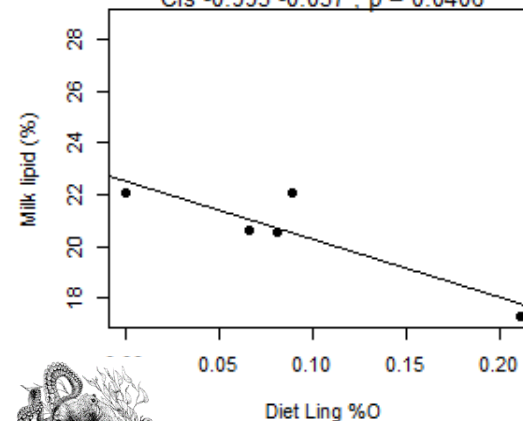
Milk lipid & diet - Hoki

CIs -0.97 0.53 ; p = 0.224



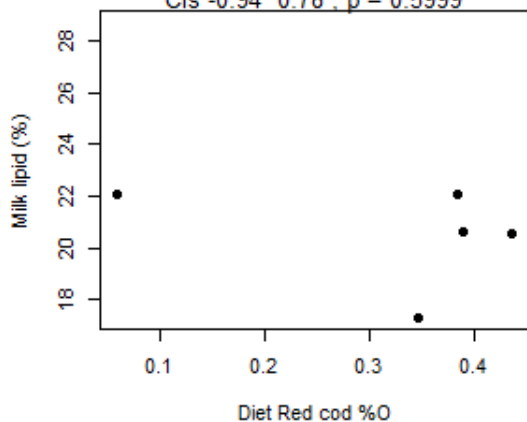
Milk lipid & diet - Ling

CIs -0.993 -0.057 ; p = 0.0406



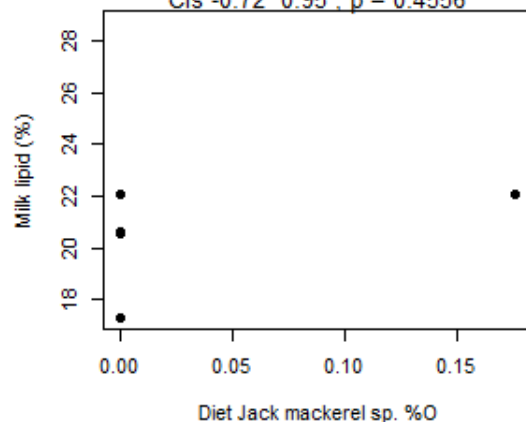
Milk lipid & diet - Red cod

CIs -0.94 0.78 ; p = 0.5999



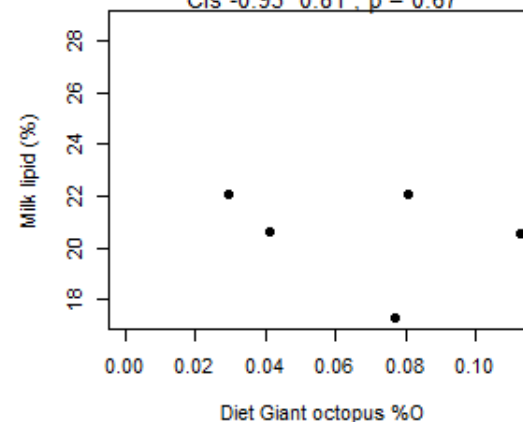
Milk lipid & diet - Jack mackerel sp.

CIs -0.72 0.95 ; p = 0.4556



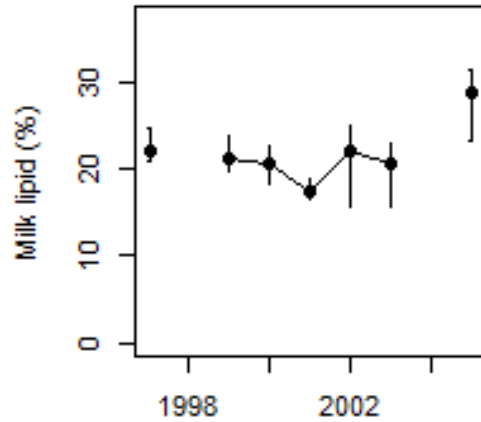
Milk lipid & diet - Giant octopus

CIs -0.93 0.81 ; p = 0.67

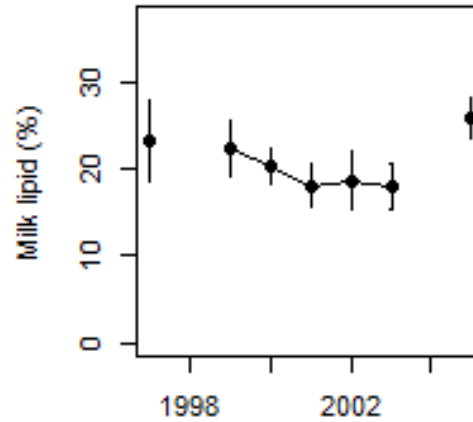


Month effect on milk quality

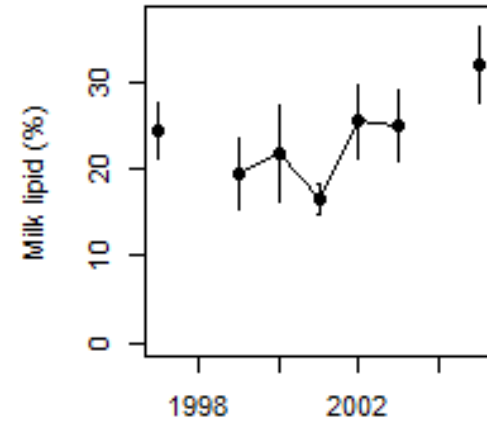
Milk lipid content Jan & Feb



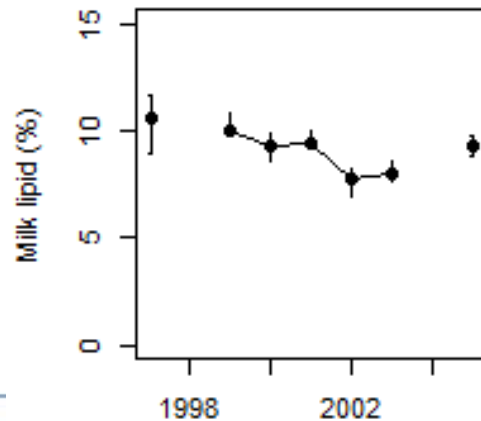
Milk lipid content Jan



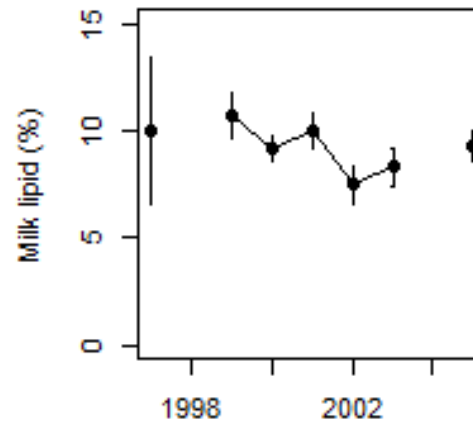
Milk lipid content Feb



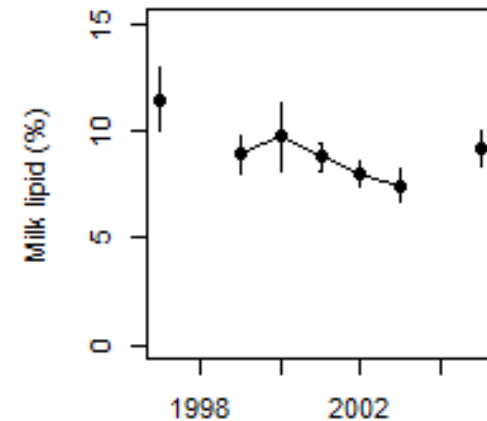
Milk protein content Jan & Feb



Milk protein content Jan



Milk protein content Feb



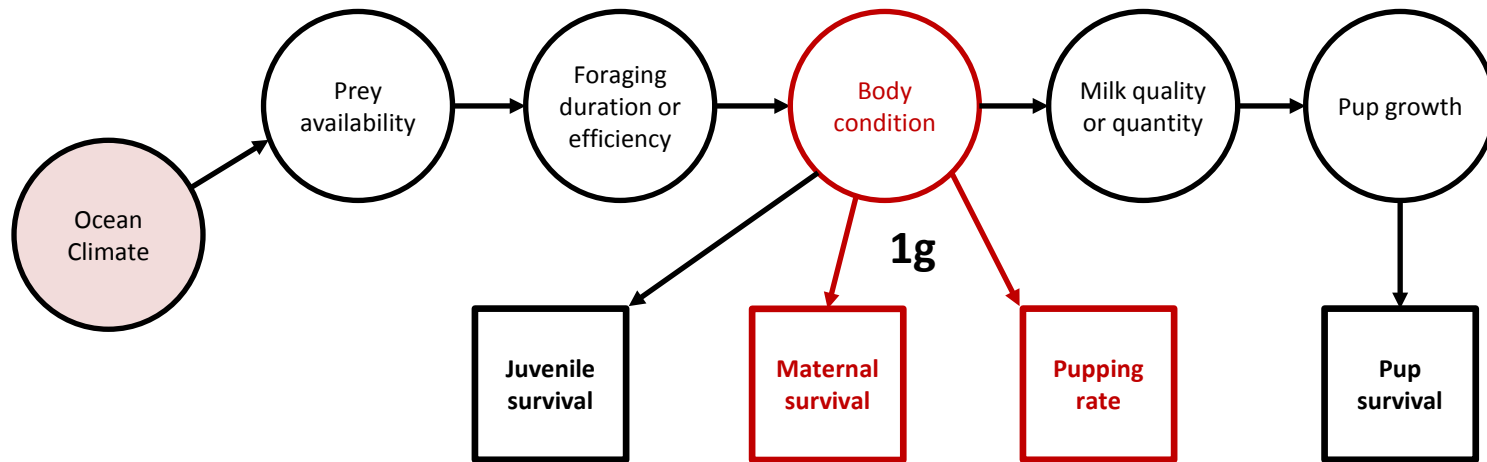
Year

Year

Year

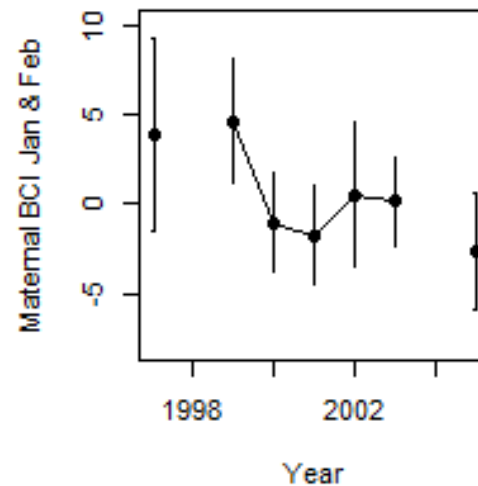


1g. Maternal condition and pupping rate/maternal survival

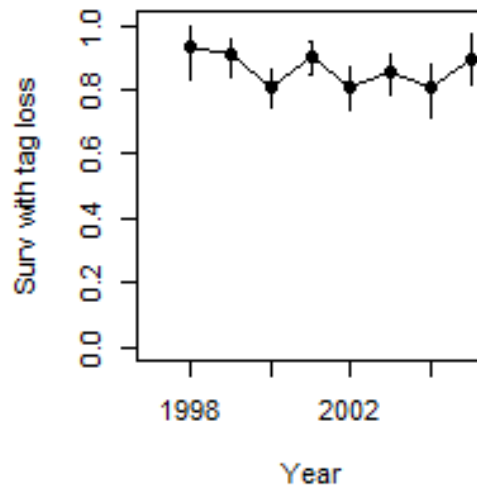


1g. Maternal condition and **pupping rate/maternal survival**

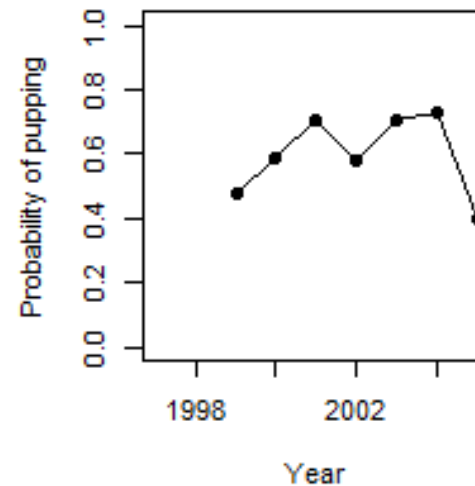
Maternal BCI Jan & Feb



Survival Age6-14

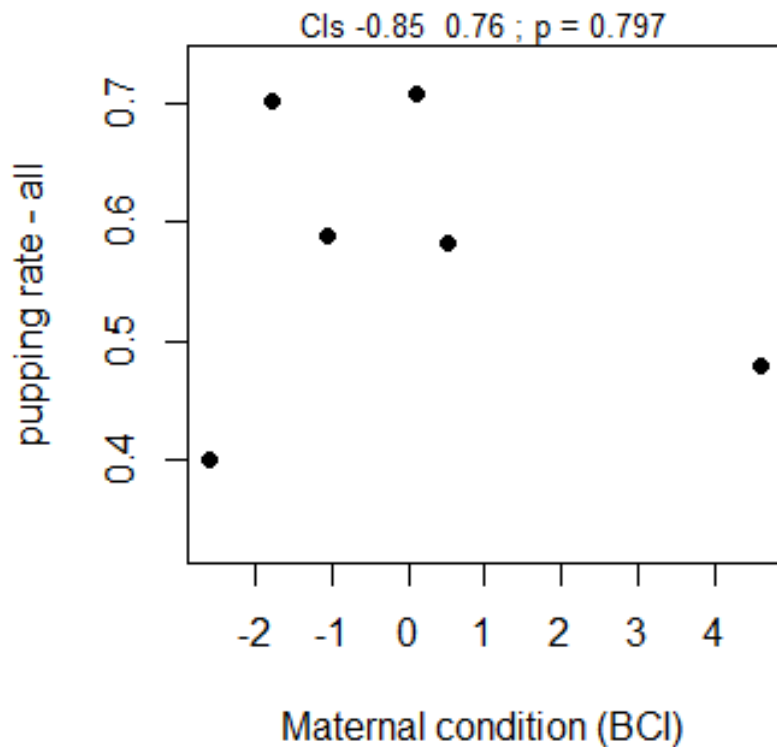


Prob. pupping in yr (all)

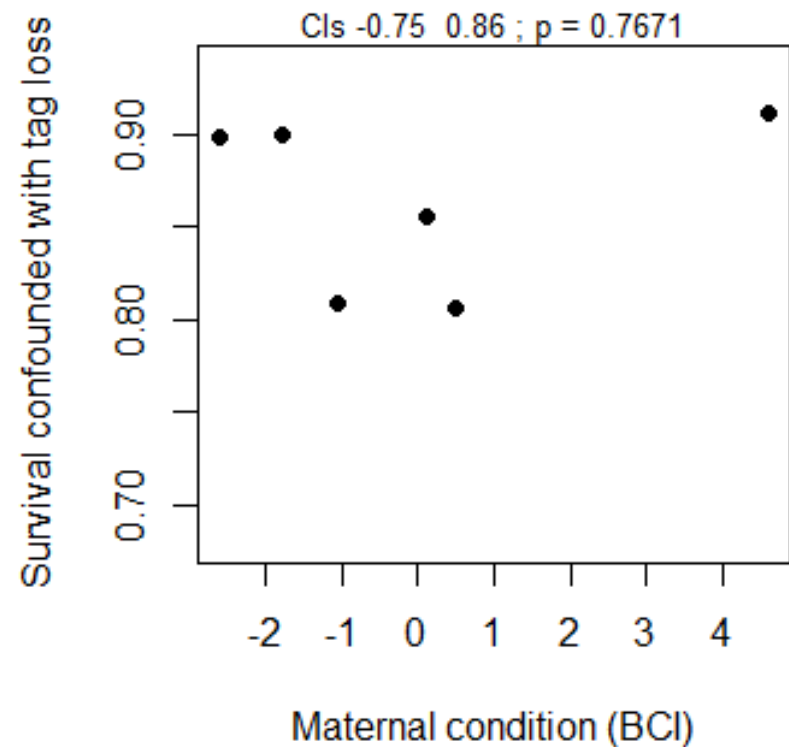


1g. Maternal condition and pupping rate/maternal survival

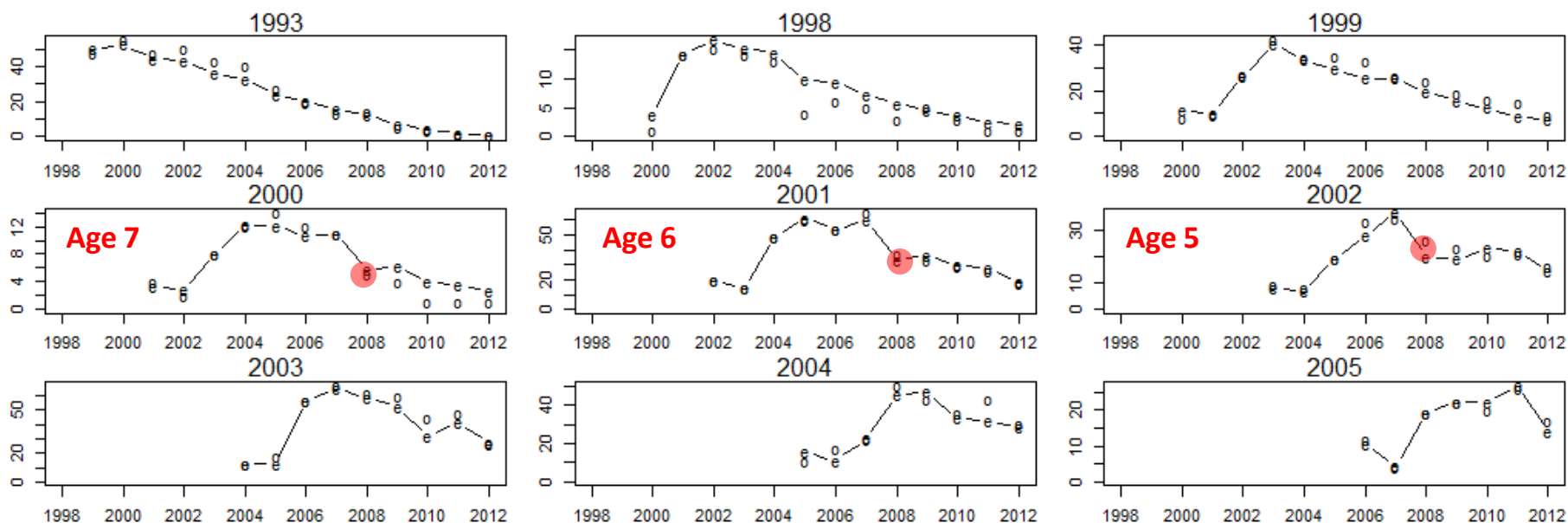
Maternal condition & pupping rate



Maternal condition & adult survival



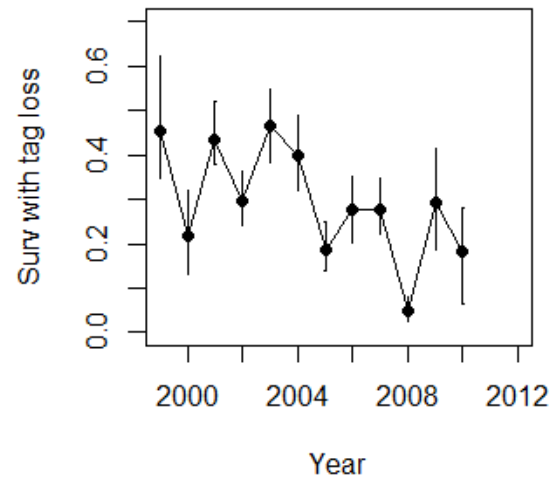
Low survival in 2007 – first-time puppers?



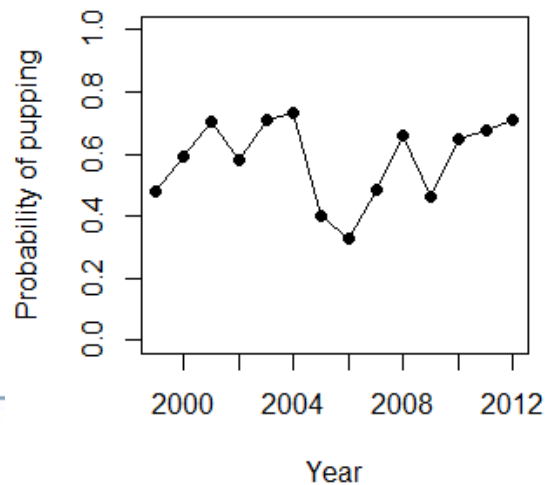
- Low survival in 2007 driven by three cohorts (born 2000-2002)
- Potentially first-time breeders in that year (aged 5-7).

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

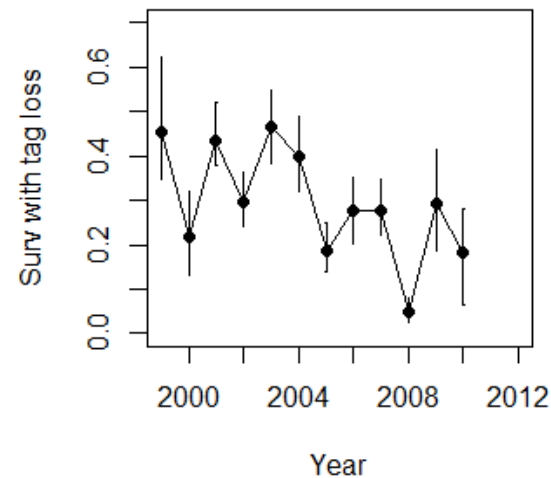
Survival pups and yearlings



Prob. pupping in yr (all)

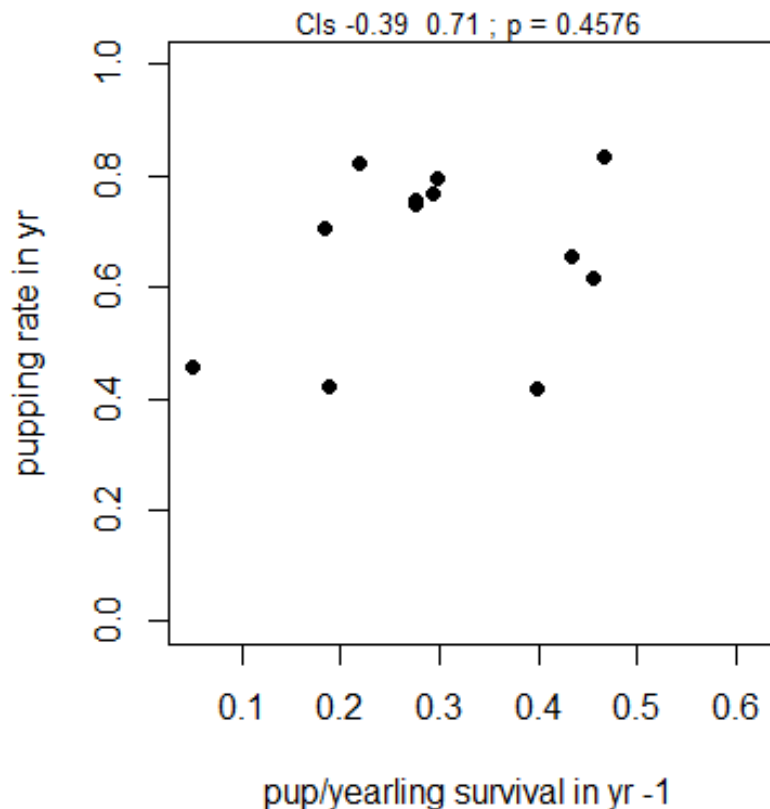


Survival pups and yearlings



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

Surv01 in yr-1 and Pupping rate in yr



Surv01 in yr-1 and Surv01 in yr

