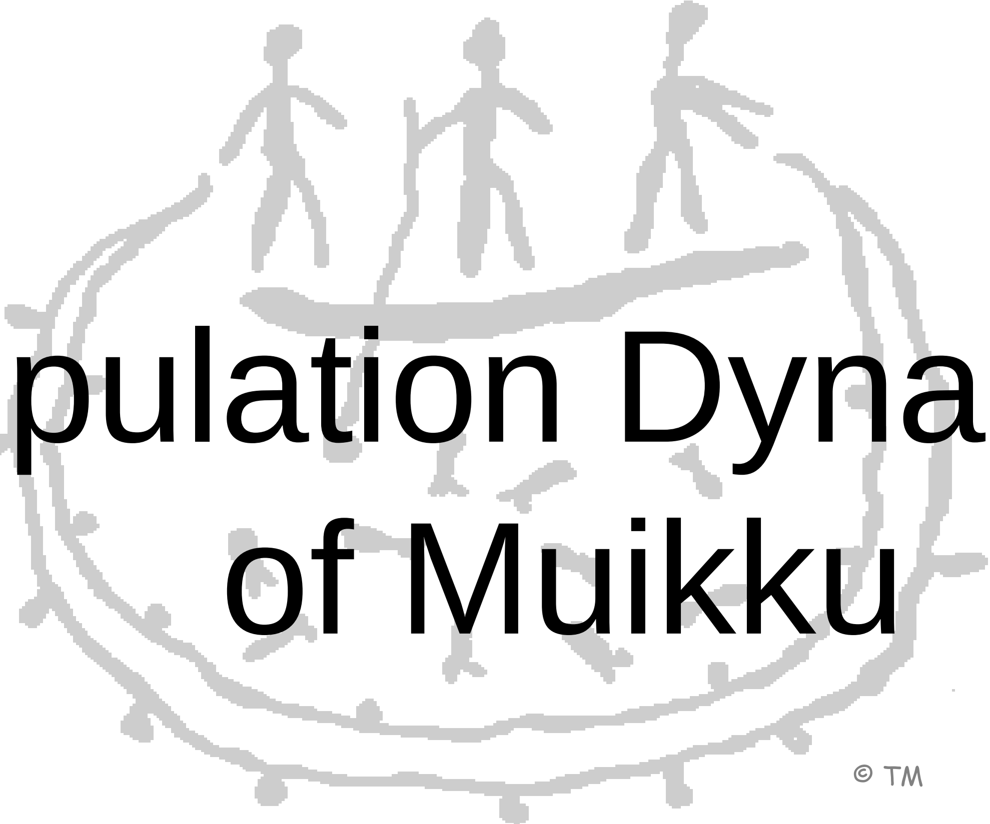

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Population Dynamics of Muikku

Timo J. Marjomäki

Aquatic Sciences

Fish resource biology & management

http://users.jyu.fi/~tmarjoma/opetus.htm

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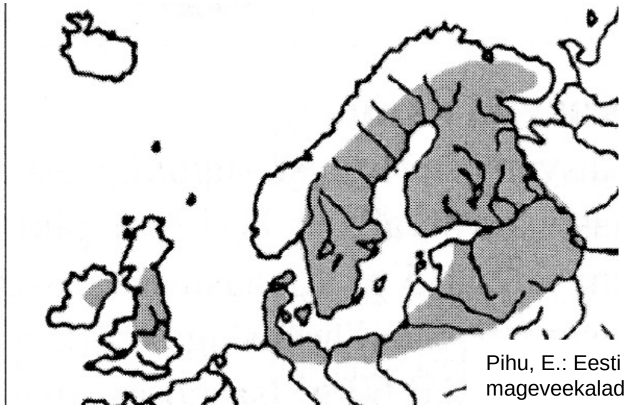
Muikku (*Coregonus albula* (L.))

Vendace, Siklöja, Lakesild, Heltling, Рябушка, Rääbis, Repsis, Seliawa, Sielawa, Kleine Maräne



Pihu, E.: Eesti mageveekalad

- Key pelagic planktivore
- Short-lived (<5 a)
- small (<20 cm, <30 g)
- mature after 2 summers
- Spawning October –> hatching May
- Key prey for longer-lived generalist predators

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Muikku (*Coregonus albula* (L.))

- Main target for commercial inland fishing
  - About 70 lakes, 15 000 km^2
  - Annual yield 2 500 tn/a
  - Value 5 milj. €
  - About 300 fishers
- Recreational gill netting
  - Annual yield 1 600 tn/a

Muikku research in Finland

- Population studies since 1908 by T. H. Järvi
- 26 doctoral dissertations
- Over 40 populations
- Longest time series 40 years
- >>150 scientific publications

Abb. 1. Zugnetzfischerei bei der Zugnetzstelle Koratinniemi in den Wassern von Taimonniemi. Phot. im Juli 1913 T. H. J—i.

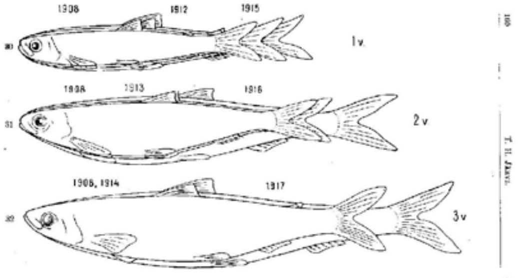

Abb. 30—32. **Mittlere Länge (und Grösse) der ein-, zwei- und dreijährigen kleinen Maräne.** Natürl. Grösse. Die Jahreszahlen bezeichnen die Fangjahre. 1 v.—3 v. = 1—3-jährige. Die Grösse mit den Jahren gewachsen.

Järvi T. H. 1919: Muikku ja muikkukannat 1. Keitele. Suomen Kalatalous 5.

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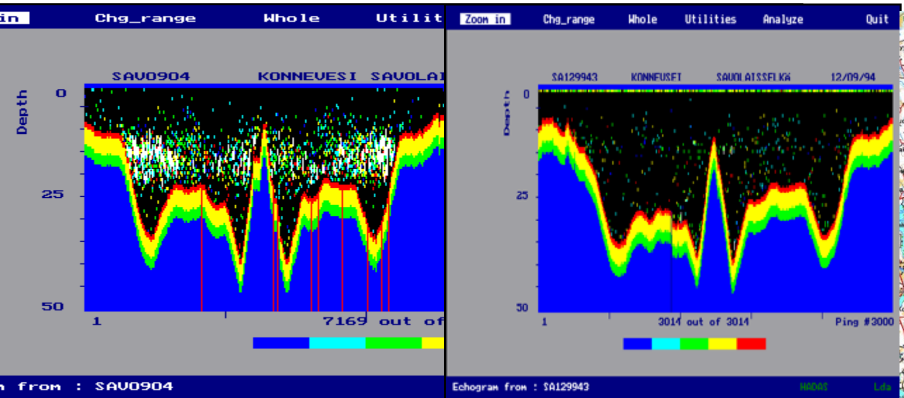
Why studied

- Resource use
  - Sustainable harvesting
  - Optimal harvesting
- Ecology
  - Understanding
    - Population regulation
    - Sources of variability

Royama: ”Why do populations fluctuate as they do?”

Population monitoring

- Fishing log books + catch samples
  - Catch Per Unit Effort = abundance index (B, D)
  - Age distribution
  - Size, growth
- Echo sounding
  - Absolute density estimate (D)
  - CPUE calibration
- Larval Density estimation



Population monitoring

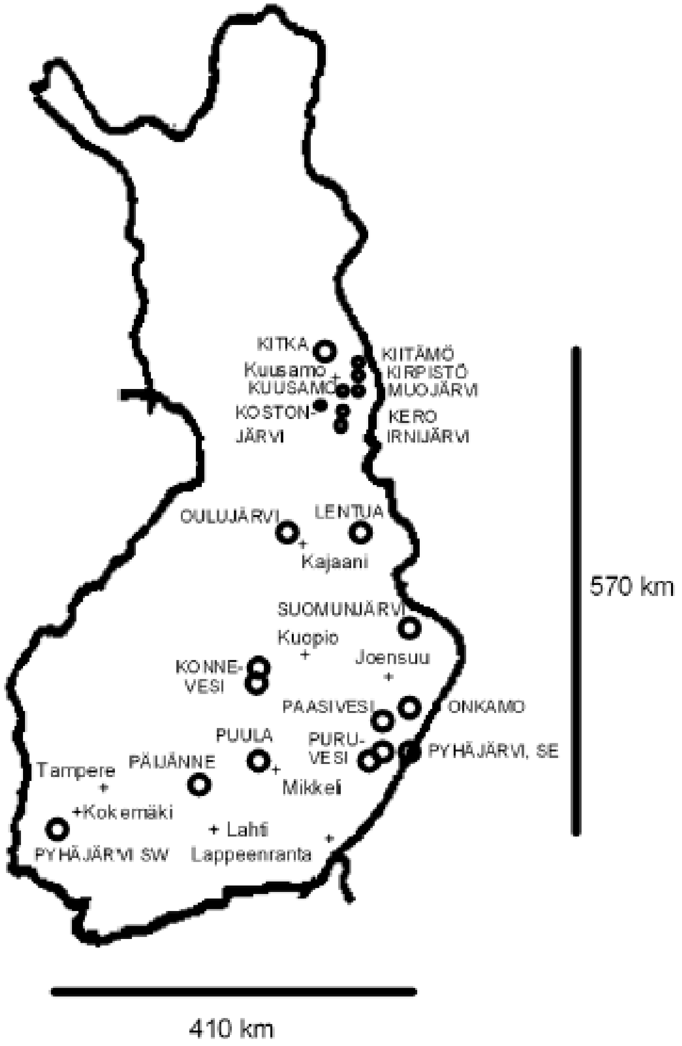


Fig. 1. Locations of the vendace populations (circles) and weather stations (crosses) used in the analysis.

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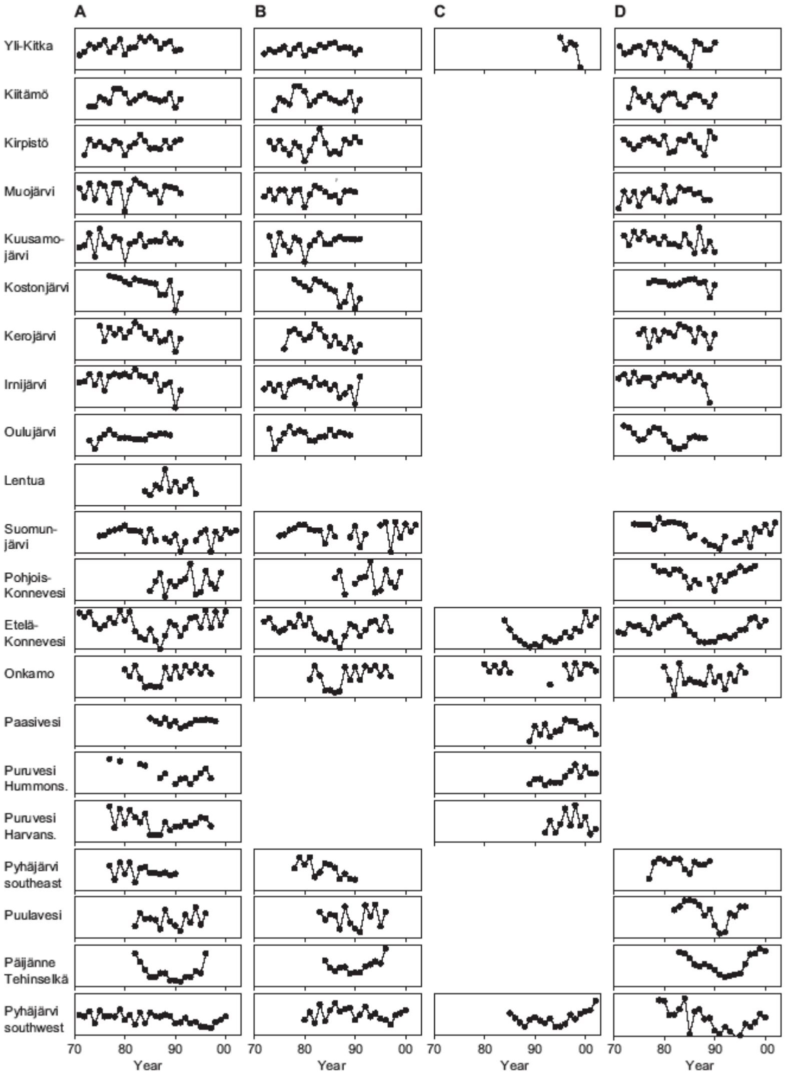

Fig. 2. Time-series of (**A**) ln(recruitment), (**B**) residuals of the density dependence model, (**C**) ln(newly hatched larvae) and (**D**) ln(spawning stock biomass or fecundity estimate) used in the analysis; *y*-axis scale arbitrary.

Typical variability

Typical variability

- Already T. H. Järvi, over 70 years ago listed:
  - Strong interannual variability in year-class strength
  - Tendency for 2-y cyclicity
  - Occacional longer recession periods
  - Spatial syncrony in year-class strength variability
- Examples:

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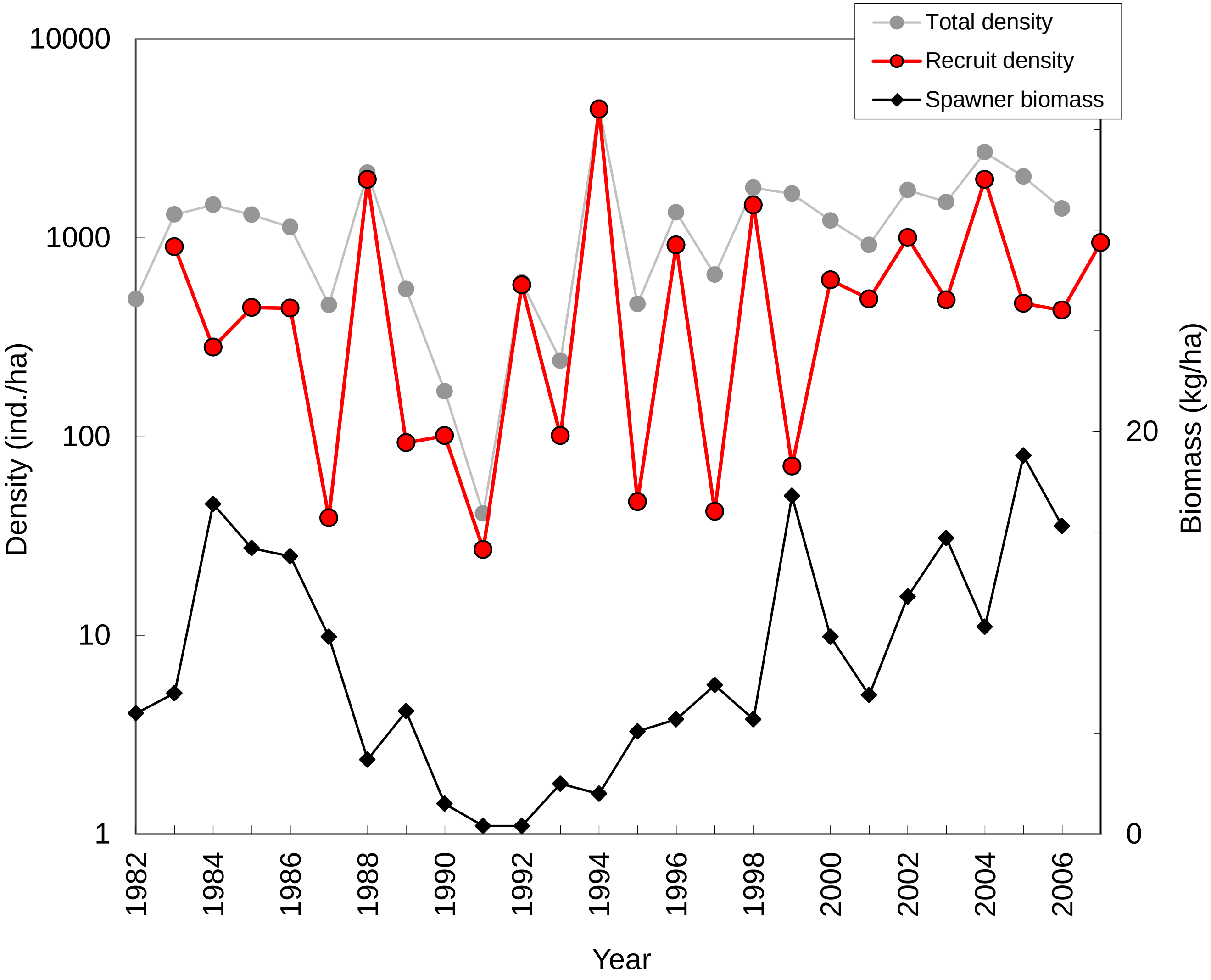
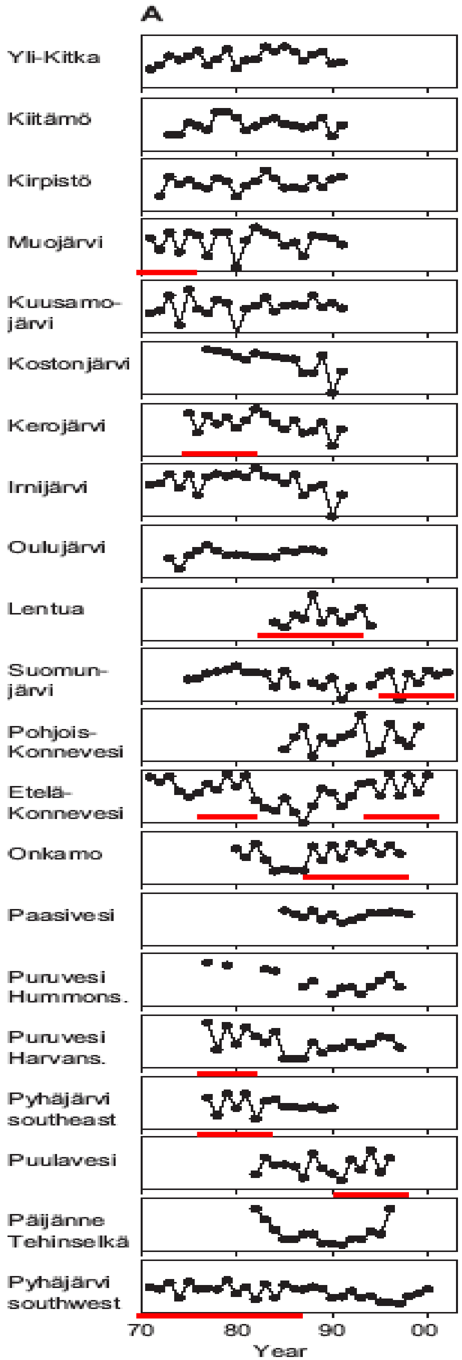
Typical variability: Year-class

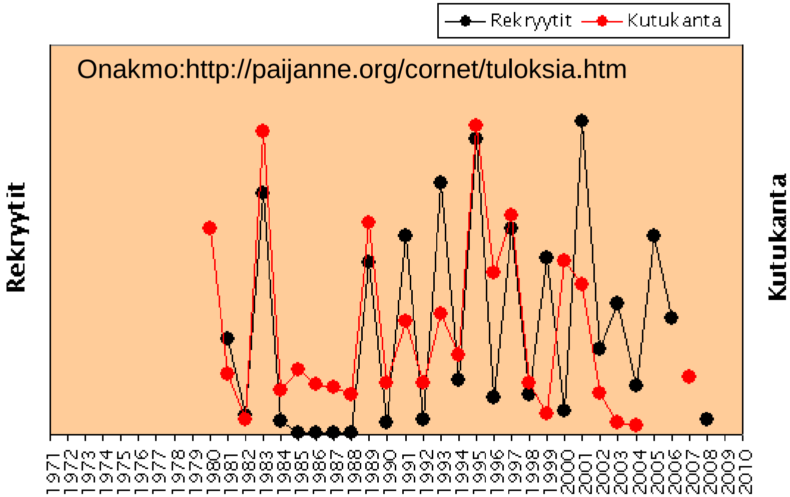


Lake Puula (Marjomäki et al. 2014)



Typical variability: 2-y cycle

- Several lake specific case studies, e.g. Marjomäki et al. 2014
- meta-analysis (Marjomäki et al. unpublished):
  - 24 time series, 8-36 years
  - Significant 2-y c in recruitment



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Typical variability: Recessions

KONNEVESI

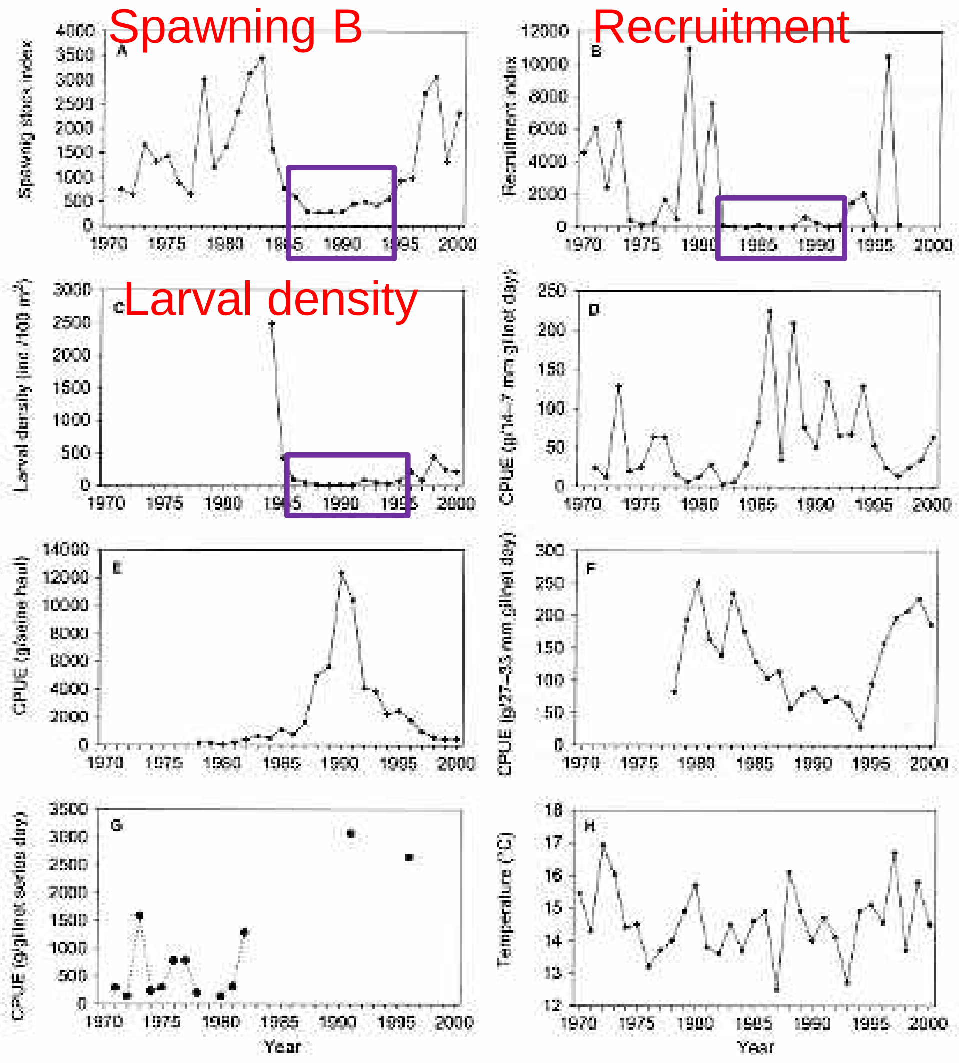
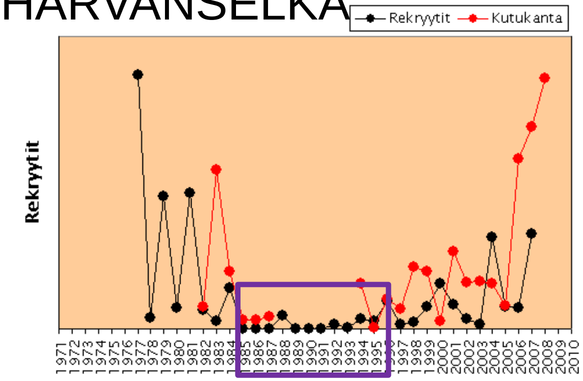
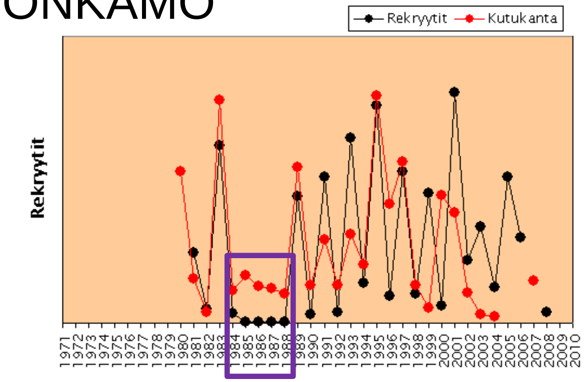


Fig. 1. The most important time series analyzed from 1971 to 2000. — A: index of vendace spawning stock. — B: index of vendace recruits. — C: vendace larval density one week after ice-off. — D: index of small perch (CPUE (g) of perch in 14–17 mm gill nets from knot to knot. — E: CPUE (g) of perch in seine. — F: index of big perch (CPUE (g) of perch in 27–33 mm gill nets). — G: CPUE of perch in test fishing (g per gill net series day) (Puttonen & Valkeajärvi 2000). — H: mean temperature from June to August.

HARVANSELKÄ



ONKAMO



Valkeajärvi &
Marjomäki2004

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Typical variability: Spatial syncrony

- Marjomäki et al. 2004

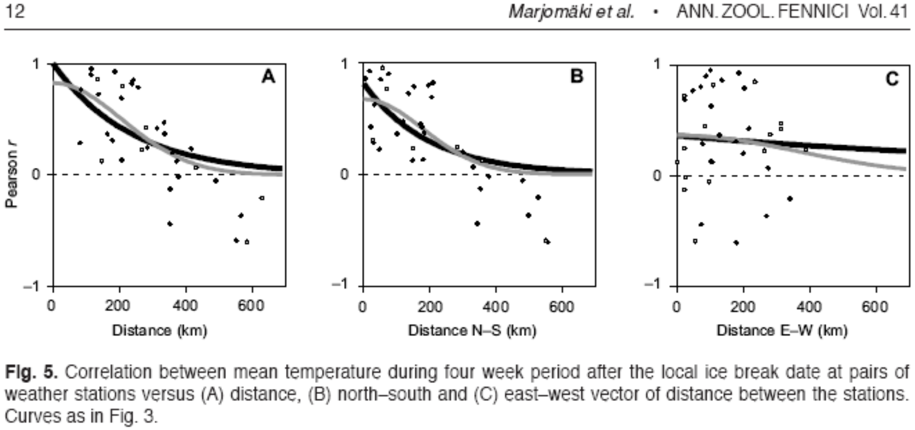

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Fig. 5. Correlation between mean temperature during four week period after the local ice break date at pairs of weather stations versus (A) distance, (B) north–south and (C) east–west vector of distance between the stations. Curves as in Fig. 3.

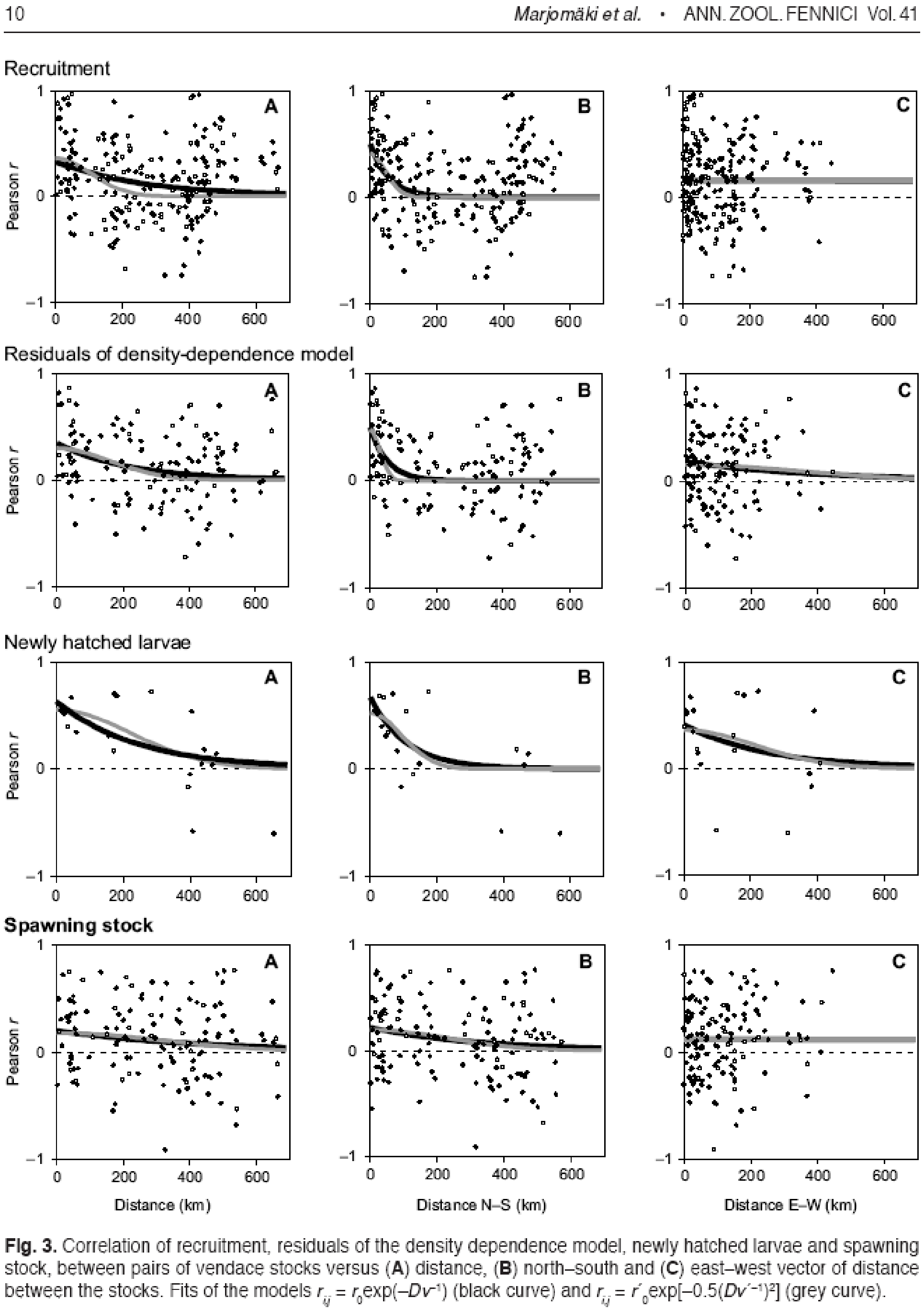

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Fig. 3. Correlation of recruitment, residuals of the density dependence model, newly hatched larvae and spawning stock, between pairs of vendace stocks versus (**A**) distance, (**B**) north–south and (**C**) east–west vector of distance between the stocks. Fits of the models $r_{ij} = r_0\exp(-Dv^{-1})$ (black curve) and $r_{ij} = r'_0\exp[-0.5(Dv'^{-1})^2]$ (grey curve).

But Why?

Analysis, hypotheses and speculation

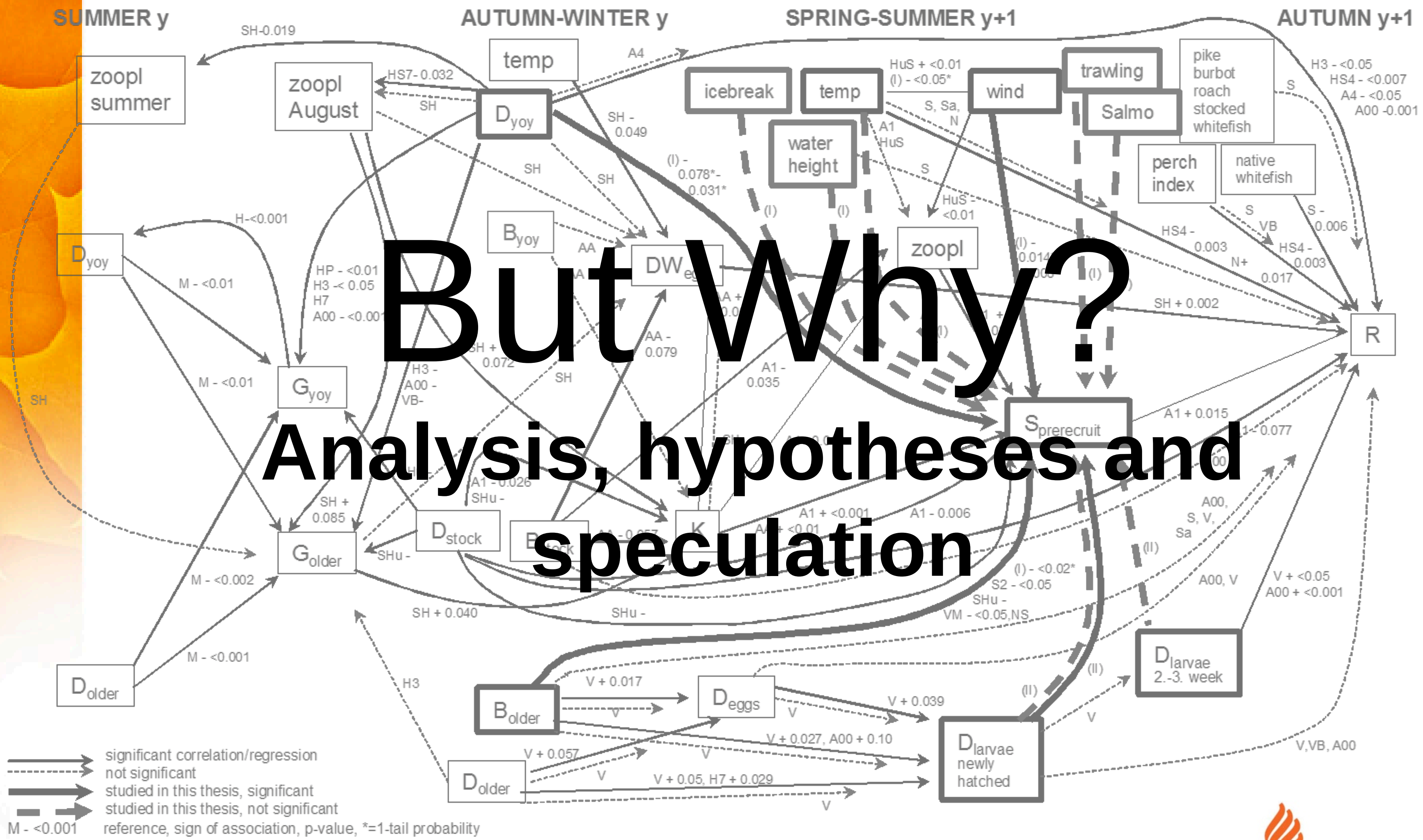


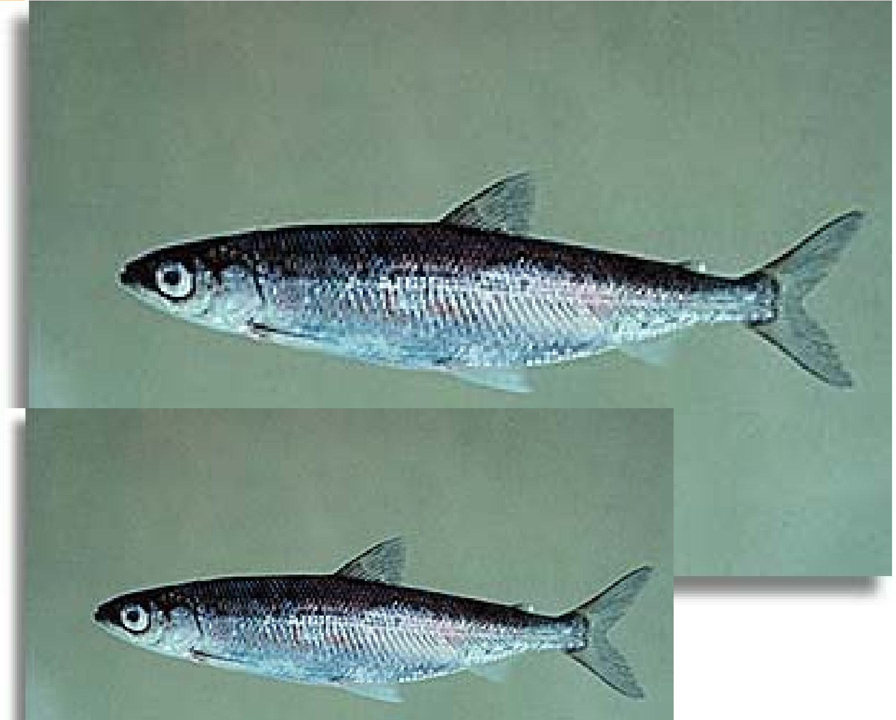
FIGURE 3 A selection of analysed associations between factors potentially linked to recruitment of vendace in field data. In boxes: B=biomass, D=density, DW=dry weight, G=growth, K=condition, $S_{prerecruit}$=survival, temp=temperature, zoopl=zooplankton. References: A1= Auvinen 1988, A4= Auvinen 1994, AA=Auvinen & Auvinen 1994, A00=Auvinen et al. 2000, H3=Helminen et al. 1993a H7=Helminen et al. (1997) HP=Hamrin & Persson 1986, HS4=Helminen & Sarvala 1994, HS7= Helminen & Sarvala 1997, HuS= Huusko & Sutela 1998b, M=Marjomäki & Kirjasniemi 1995, N=Nyberg et al. 2001, S=Salojärvi 1991a, S2=Salojärvi 1991b, Sa=Salonen (1998), SHu=Salmi & Huusko 1995a & b, SH=Sarvala & Helminen 1995, V= Viljanen 1988b, VB=Valkeajärvi & Bagge 1995, VM= Valtonen & Marjomäki 1988.

Marjomäki, T. J. 2003: Recruitment variability in vendace, (Coregonus albula (L.)), and its consequences for vendace harvesting. Jyväskylä Studies in Biological and Environmental Science 127: 1-66.

Density dependent compensatory regulation

Density dependent compensatory regulation: Growth

- Strong negative relationship between D and G
  - E.g. Lake Puula age 1+ (first spawners)
    - Sparse stock (<100 ind./ha): 150 mm, 25 g
    - Dense stock (>1000 ind./ha): 115 mm, 11 g



Density dependent compensatory regulation: Growth

Consequences for **population fecundity**

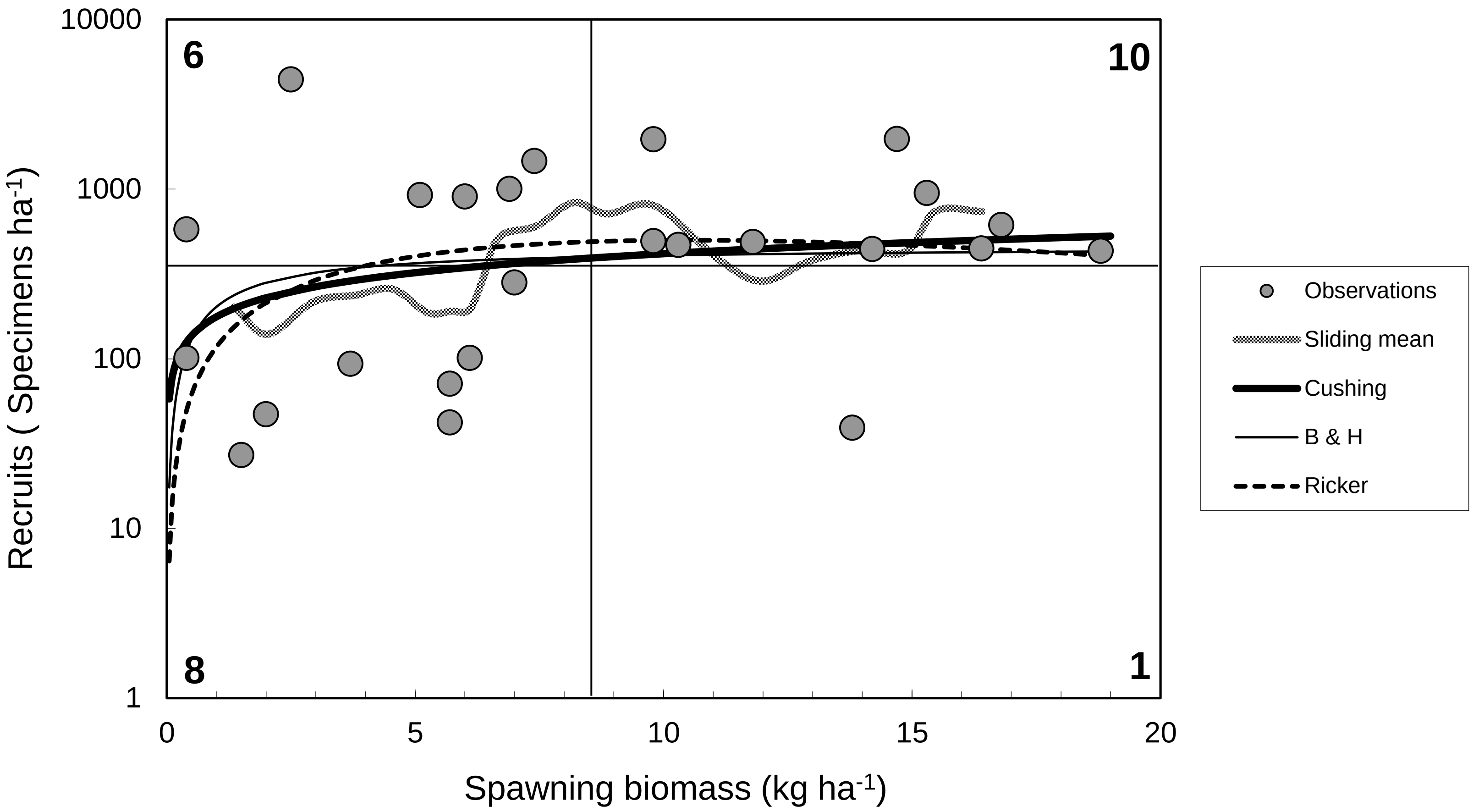
- Egg number practically proportional to weight
  - Relative fecundity (eggs/g) marginally density dependent
- Egg wet weight rather constant

Consequences of **natural mortality**

- Predation mortality size dependent

Density dependent compensatory regulation: SB->R

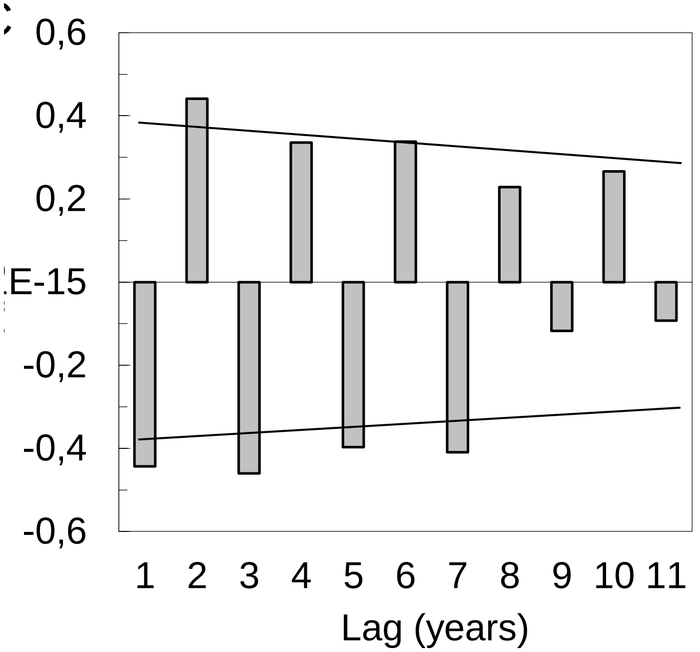
- Strong compensation



Lake Puula (Marjomäki et al. 2014)

Density dependent compensatory regulation: Previous R->R

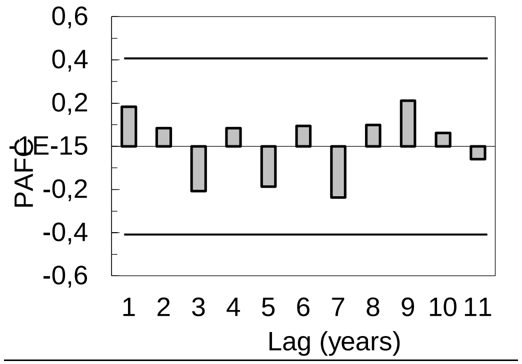
- Strong compensation?
- Serial correlation in residuals -> 2-y damped oscillation, phase-forgetting quasi-cycles



Lake Puula (Marjomäki et al. 2014)

Density dependent compensatory regulation:

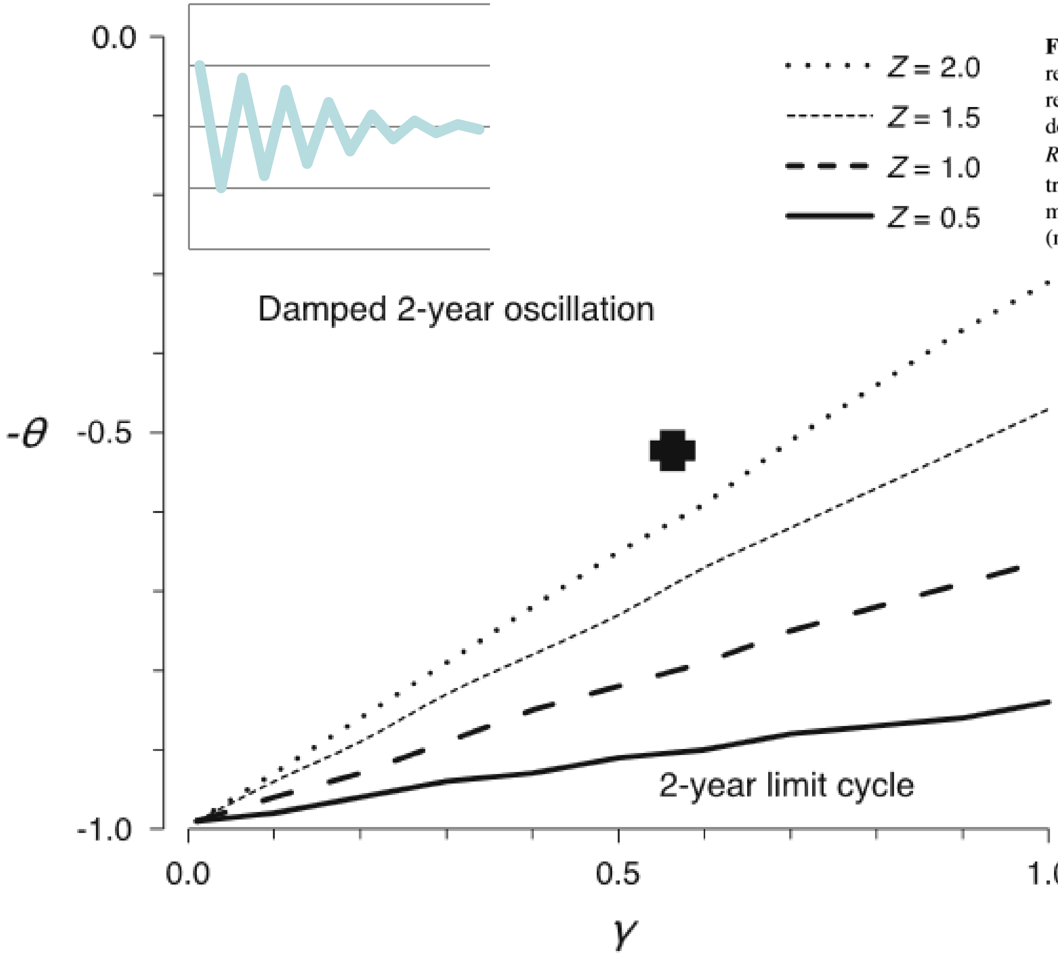
- Combining the compensatory effects of SB and prev. R -> no serial correlation in residual



- Simulations with the artificially perturbed deterministic skeleton of the model produce two year *Phase-forgetting quasi-cycles* (*sensu* Nisbet & Gurney 1982)

Density dependent compensatory regulation:

Popul Ecol (2014) 56:513–526



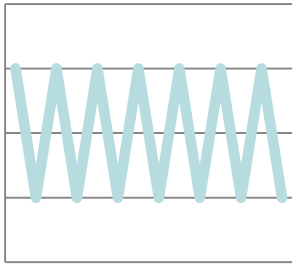


Fig. 7 The transition lines in parameter space (γ, $-\theta$) between the regimes of damped 2-year oscillations and 2-year limit cycles for the recruitment time series simulated with the artificially perturbed deterministic population model incorporating recruitment function $R_y = \alpha SB_{y-1}^{\gamma} \times R_{y-1}^{-\theta}$ ($\alpha = 2000$). The *different lines* represent the transition lines for different levels of constant instantaneous total mortality Z. The *cross* indicates the parameter estimates for γ and $-\theta$ (model 12 in Table 1)

<- More previous R-R compensation

Less adult survival ->

Less SB-R compensation ->

Depensatory density dependence

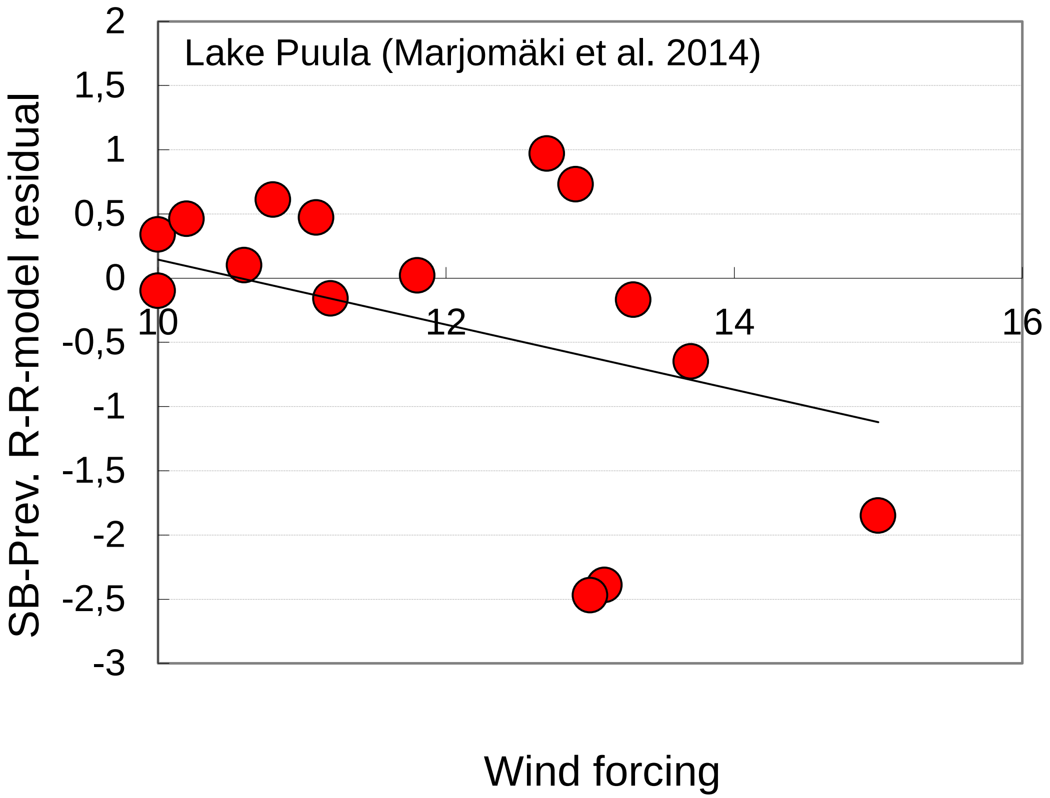
- At least in theory
  - predation mortality if predator saturation possible
- In practice
  - commercial fishing aiming at constant catch (Marjomäki et al. 1996, 2005)

http://www.comicvine.com/forums/battles-7/the-joker-vs-punisher-and-or-cyclops-1547721/

Density independent factors

Density independent factors

- Remember the spatial synchrony
- E.g. Wind forcing during larval period



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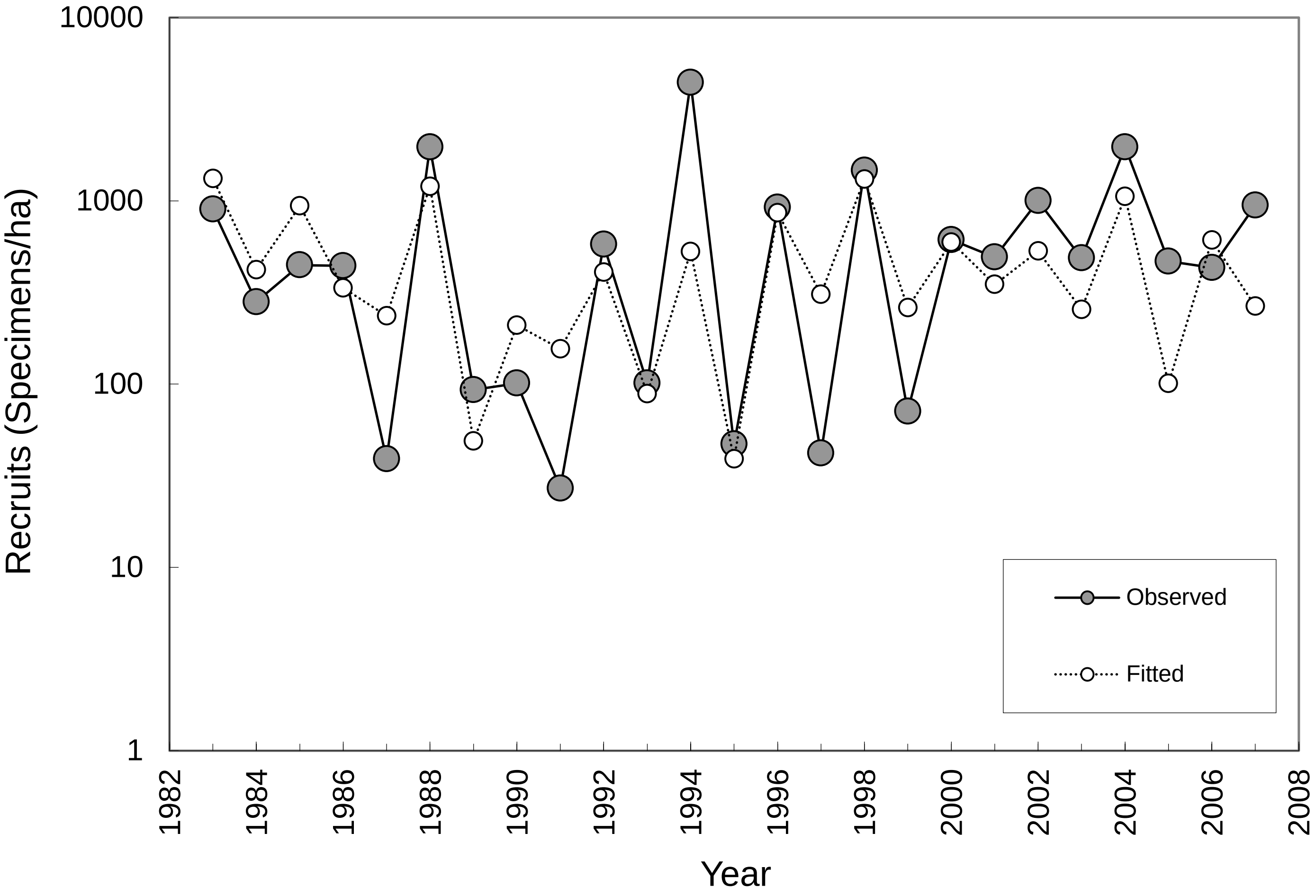
Final model fit



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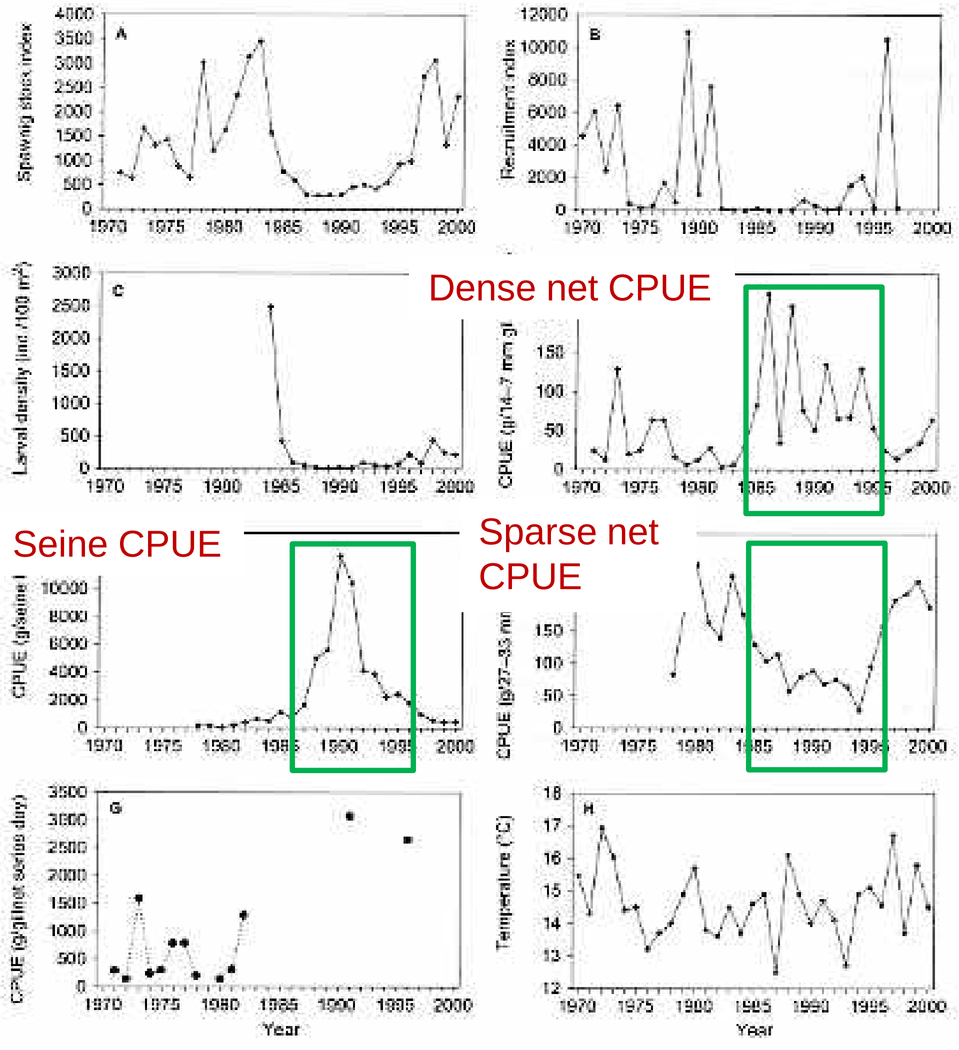
Density independent factors

- Predators?
  - E.g. perch + Temperature



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Valkeajärvi & Marjomäki 2004

Analysis summary

Compensation

- Growth
- Natural mortality?
- Reproductive success

Depensation

Unpredictable environmental factors

- E.g. Wind
- E.g. Perch (mostly temperature related)
  - Recessions?

BUT WHY?

Facts and fiction about 2-y cycles

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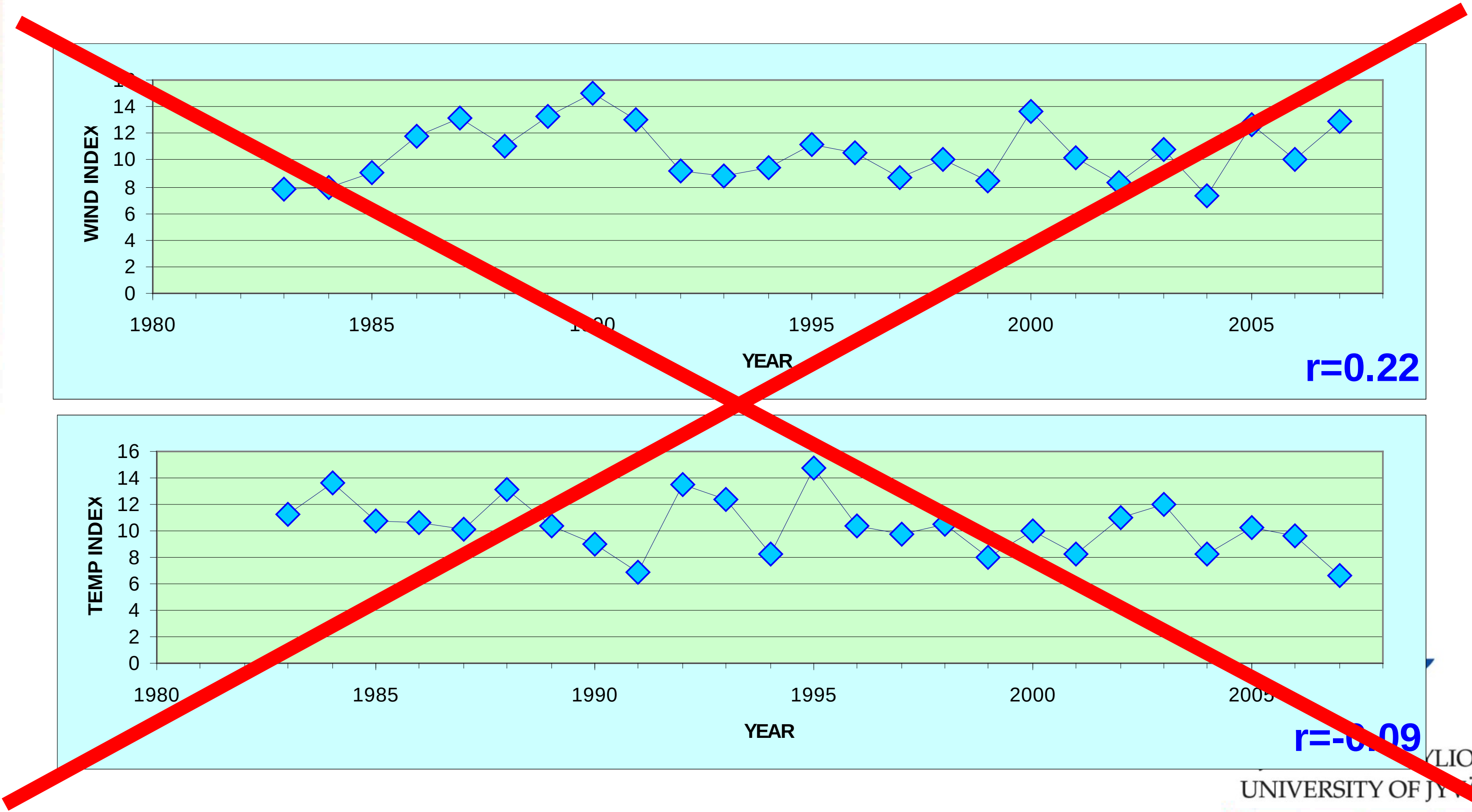
Why 2-y cycles

- NOT Independent external force (Elton 1924)

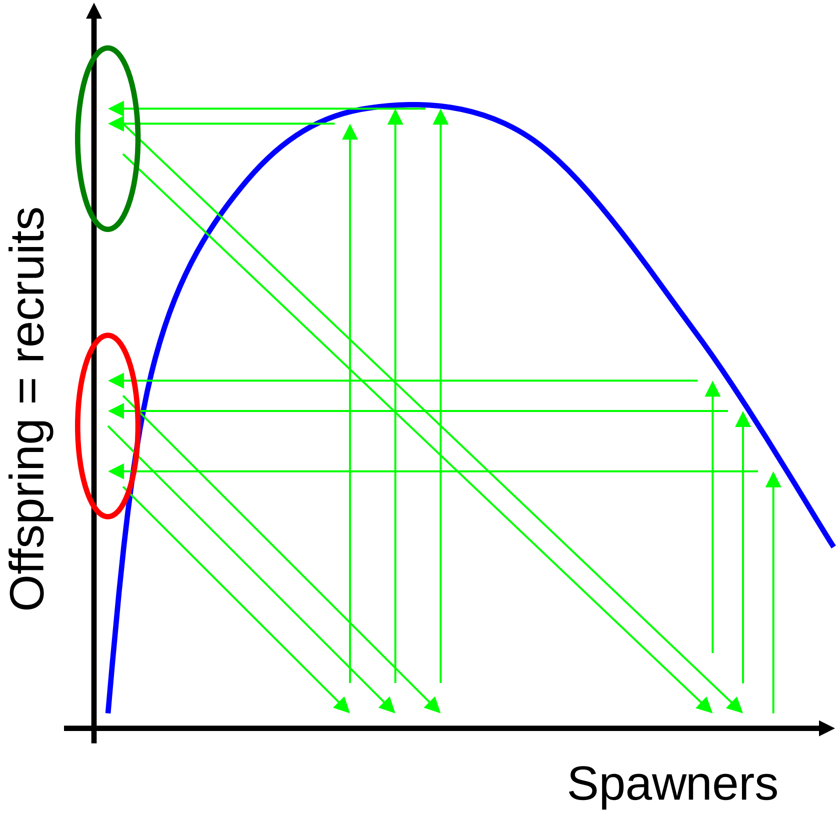


Why 2-y cycles

- NOT induced by strong SB-R relationship
  - Over-compensation (Ricker 1954)
  - Generation cycle (Townsend 1990)

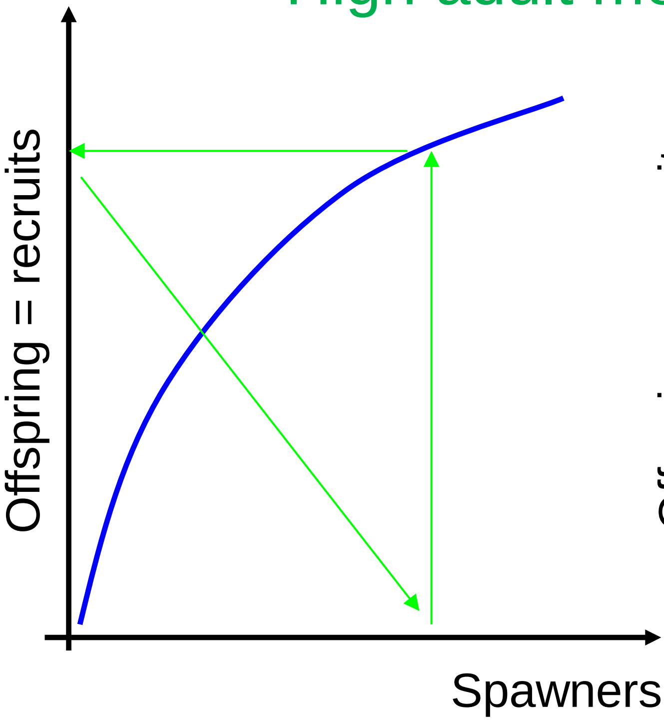
Why 2-y cycles

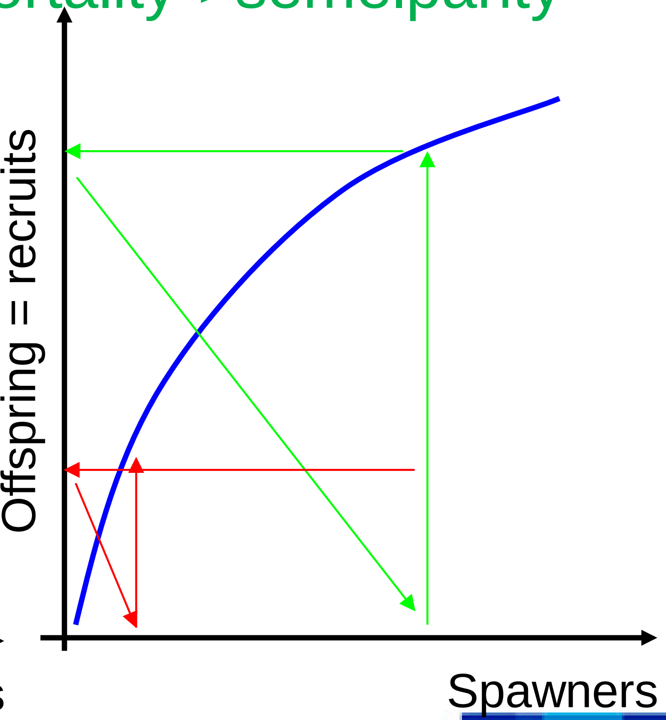
- NOT generation cycle



Why 2-y cycles

- NOT TYPICALLY Generation cycle
  - BUT POSSIBLE IF e.g. high fishing mortality
    - Low spawning stock
    - High adult mortality->semelparity





Why 2-y cycles

- **Instant** density dependent inter-life stage effect

- In muikku: How could the previous year-class inhibit the next?
  - Egg and larval cannibalism (Nordqvist 1944) ?
    - NOT LIKELY, yet possible, common in lab (Urpanen et al. 2012)
  - Older fish outcompete younger (0+) (Sandlund et al. 1991)?
    - NOT LIKELY (yet possible)

Why 2-y cycles

- ***Delayed*** density dependent effect (Ward & Larkin 1964) =the regulatory process manifests itself with a delay
  - A. ***Exogenous*** mechanism involving species interactions
    - Typically trophic interactions e.g.
      - the suppressing effect of this years cropping on the food resources in the following year (Auvinen 1988)
        - » NOT LIKELY, yet possible, some association found
      - predator-prey cycles
        - » NO SHORT LIFE CYCLE SPECIALIST PREDATOR FOUND
        - » But remember perch and tendency for recessions with long cycle length

Why 2-y cycles

- ***Delayed*** density dependent effect (Ward & Larkin 1964) =the regulatory process manifests itself with a delay
  - B. ***Endogenous*** dd parental effect e.g.
    - earlier experienced competition induces a cohort (generally sub-population) effect regulating
      - population fecundity and offspring number

      or/and

      - offspring mortality

Why 2-y cycles

- ***Delayed*** density dependent effect (Ward & Larkin 1964) =the regulatory process manifests itself with delay
  - B. ***Endogenous*** dd <u>parental effect</u>
  - Hypothesis for muikku (Hamrin & Persson 1986):
  - Asymmetric inter-cohort competition in summer: an abundant year-class (0+) induces a <u>sub-population effect</u> on becoming spawners (1+->) regulating
    - population fecundity and offspring number
      - YES, slightly, but compensated for in the models by using biomass in S-R-relationship
    - offspring mortality (Experiments: Karjalainen et al. unpublished)
      - fertilisation
      - Egg mortality in winter
      - larval mortality

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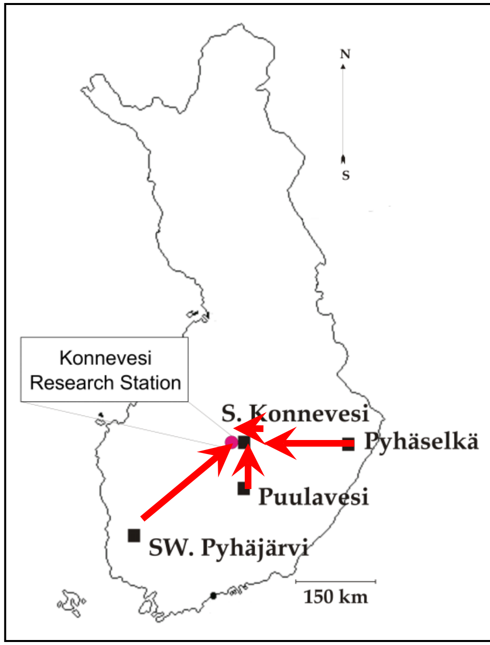
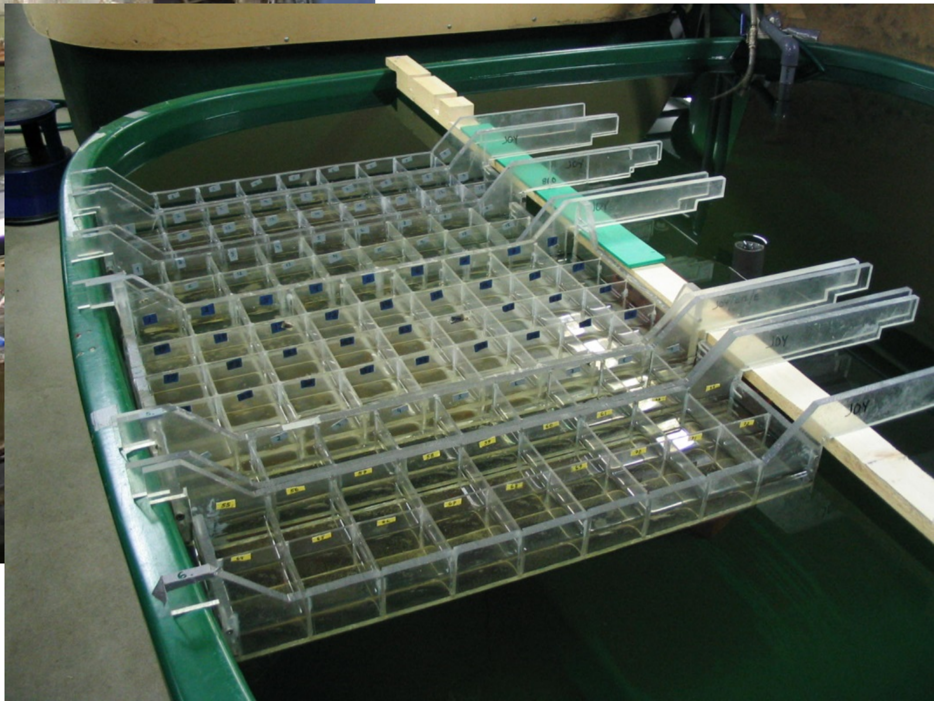
”Experiments”

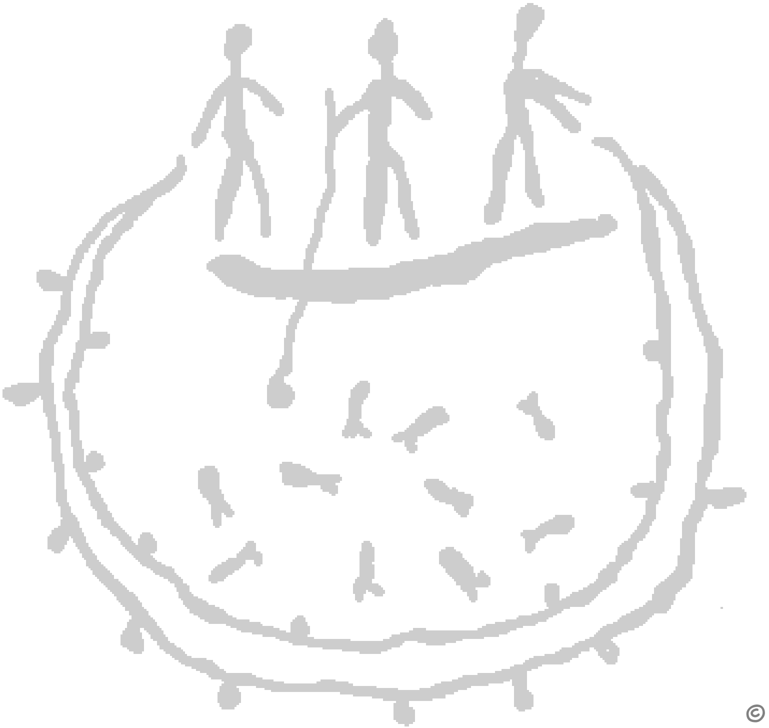




Why 2-y cycles

- Conclusion:
  - Several potential parallel forces
    - Cannibalism
    - Future food resources
    - Competition->Sub-population effect->egg/larval quality
    - Generation cycling in special cases
- What next:
  - Critical period
    - Preliminary analysis: 2-y c already in larval density???->What happens in winter
  - More experiments on parental effect
  - Field observations on cannibalism

QUESTIONS? ANSWERS? COMMENTS?



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References

- Auvinen, H. 1988. Factors affecting the year-class strength of vendace (Coregonus albula (L.)) in Lake Pyhäjärvi (Karelia, SE Finland). Finnish Fish. Res. 9: 235-243. Helsinki.
- Marjomäki, T. J. 2003: Recruitment variability in vendace, (Coregonus albula (L.)), and its consequences for vendace harvesting. Jyväskylä Studies in Biological and Environmental Science 127: 1-66.
- Elton, C. S. 1924. Periodic fluctuations in the numbers of animals: Their causes and effects. J Exp Biol 2: 119-163.
- Hamrin, S. F. & Persson, L. 1986. Asymmetrical competition between age classes as a factor causing population oscillations in an obligate planktivorous fish species. Oikos 47: 223-232.
- Marjomäki, T. J., Kirjasniemi, J. & Huolila, M. 1995: The response of fisheries to decline in the vendace (Coregonus albula (L.)) stock of Lake Puulavesi, Finland. -Arch. Hydrobiol. Spec. Issues Advanc. Limnol. 46: 421-428.
- Marjomäki, T. J. 2004: Analysis of the spawning stock - recruitment relationship of vendace (Coregonus albula (L.)) with evaluation of alternative models, additional variables, biases and errors. -Ecol. Freshw. Fish 13: 46-60.
- Marjomäki, T. J., Auvinen, H., Helminen, H., Huusko, A., Sarvala, J., Valkeajärvi, P., Viljanen, M. & Karjalainen, J. 2004: Spatial synchrony in the inter-annual population variation of vendaec (Coregonus albula (L.)) in Finnish inland waters. -Ann. Zool. Fennici 41: 225-240.
- Marjomäki, T. J. 2005: Evaluation of different harvest strategies for a vendace population with highly variable recruitment: a simulation approach. –Boreal Env. Res. 10: 255-279.
- Marjomäki, T. J., Urpanen, O. & Karjalainen, J. 2014: Two-year cycliciy in recruitment of a fish populaiton is driven by an inter-stage effect. –Popul. Ecol. 56: 513-526.
- Nisbet, R. M. and Gurney, W. S. C. 1976. Population dynamics in a periodically varying environment. Journal of Theoretical Biology 56: 459-475.
- Nordqvist, H. 1944. Några synpunkter på fiskevården i sydsvenska sjöar. Skrifter utgivna av södra Sveriges Fiskeriförening. 21 p.
- Ricker, W.E. 1954. Stock and recruitment. J. Fish. Res. Bd Can. 11: 559-623.
- Sandlund, O. T. , Jonsson, B., Naesje, T. F. & Aass P. 1991: Year-class fluctuations in vendace, Coregonus albula (Linnaeus): Who's got the upper hand in intraspecific competition? J. Fish Biol. 38: 873–885.
- Townsend, C. R., Sutherland, W. J. & Perrow, M. R. 1990. A modelling investigation of population cycles in the fish Rutilus rutilus. J. Anim. Ecol. 59: 469-485.
- Olli Urpanen, O., Marjomäki, T. J., Keskinen, T. & Karjalainen, J. 2012. Features of intercohort cannibalism of Vendace (Coregonus albula L.) under laboratory conditions. Marinen and Freshwater Biology and Physiology (in press.)
- Valkeajärvi, P. & Marjomäki, T. J. 2004: Perch (Perca fluviatilis) as a factor in recruitment variations of vendeace (Coregonus albula) in Lake Konnevesi, Finland. -Ann. Zool. Fennici 41: 329-338.
- Ward, F. J. & Larkin, P. A. 1964. Cyclic dominance in Adams River sockeye salmon. Fish. Comm. Prog. Rep. 11: 1-116.