BEST-BSIERP Bering Sea Project

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Long-term forecasts of walleye pollock dynamics in the eastern Bering Sea based on estimated responses of recruitment and growth to climate variability

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Goals

- Quantify impacts of climate variability on recruitment and growth of walleye pollock on the eastern Bering Sea shelf
- Project future recruitment, biomass, and catches under possible warming scenarios & fishing scenarios

Distribution of walleye pollock stages on the southeastern Bering Sea shelf

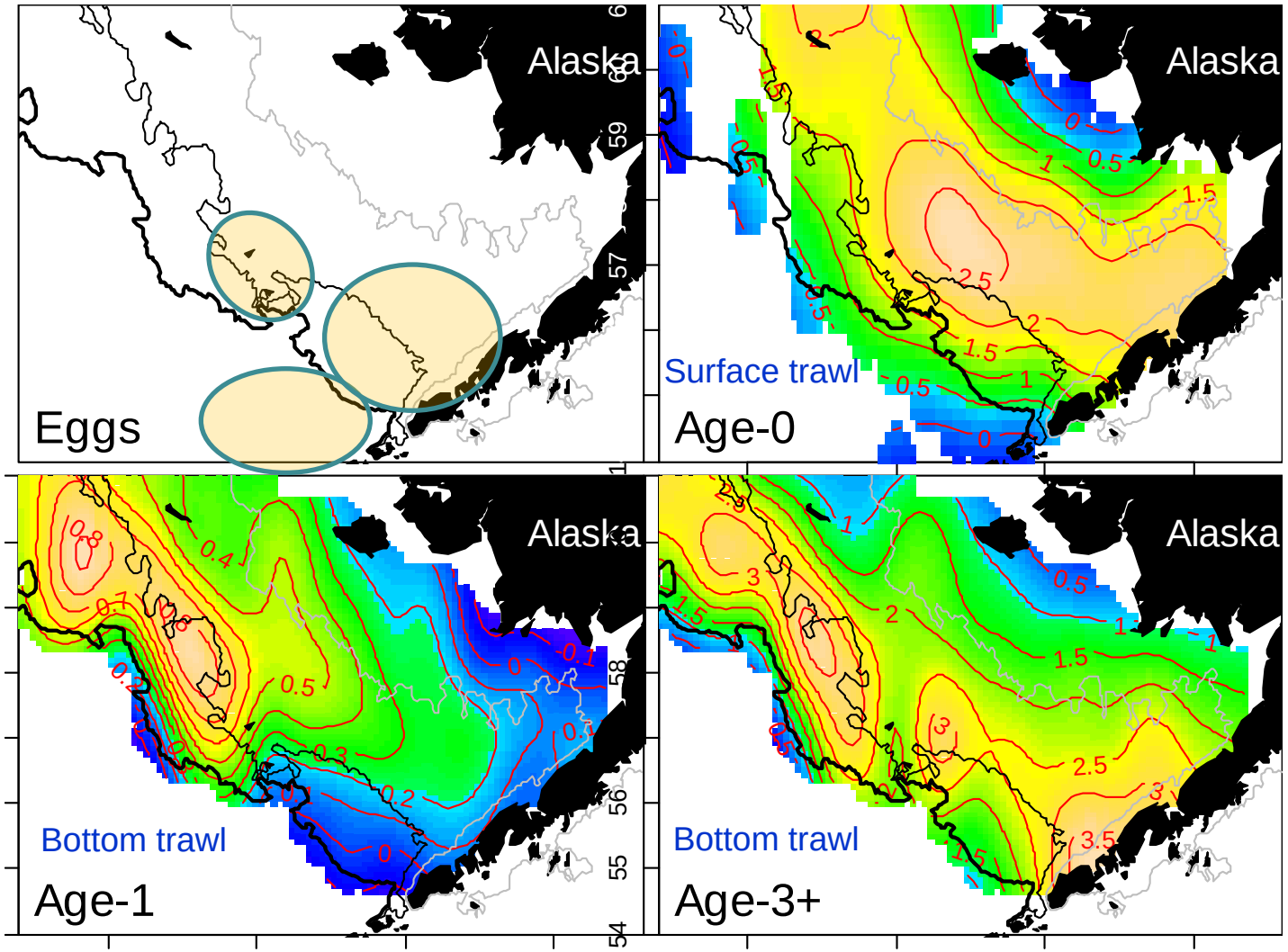
(Scaled catch-per-unit effort)

Based on:

Eggs: Bacheler et al. (2010)

Age-0: BASIS (Ed Farley, AFSC)

Age-1 & 3+: Average distribution from bottom trawl surveys 1982 - 2009 Data from Bob Lauth, AFSC

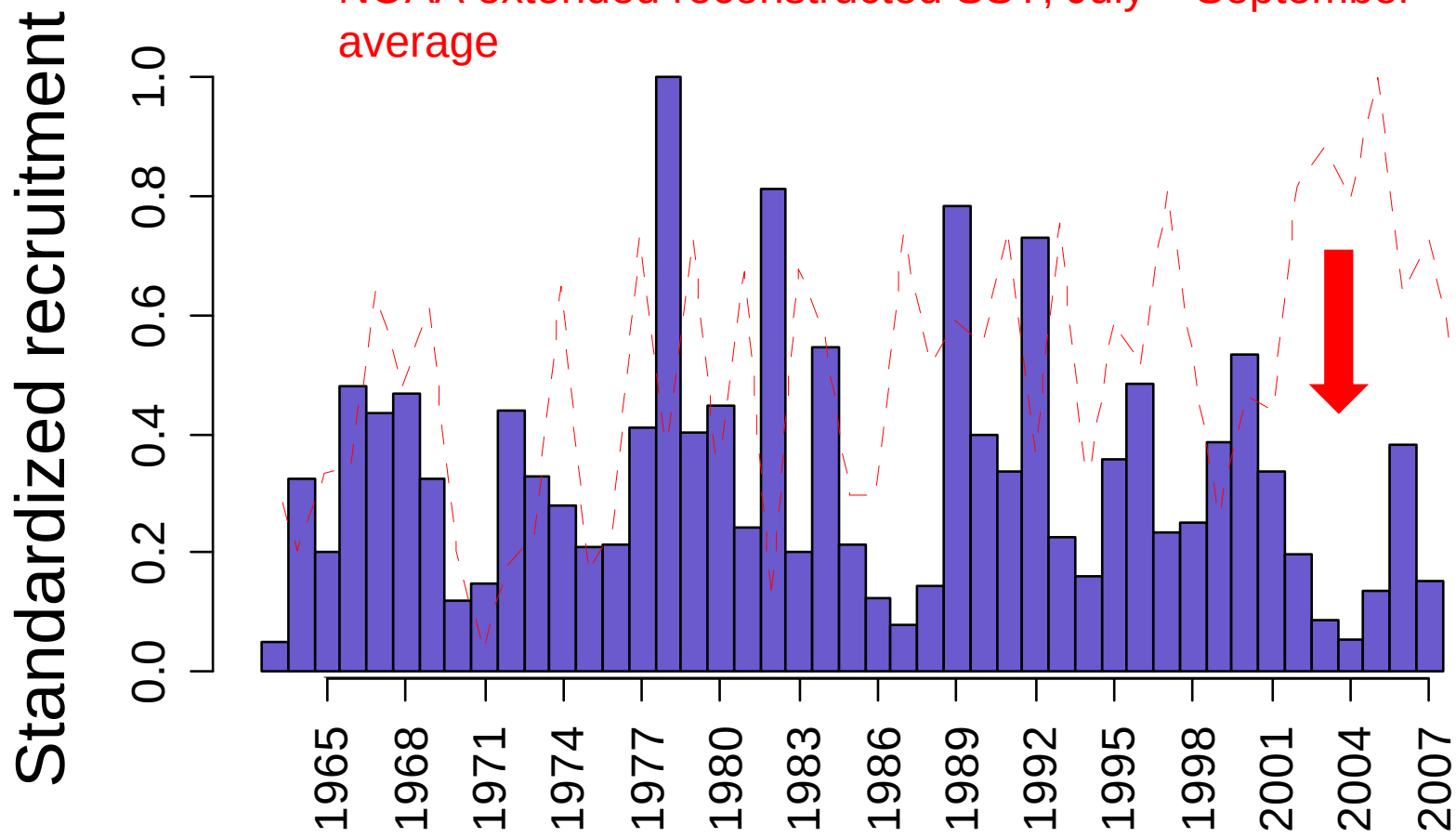


General approach

1. Identify likely mechanisms driving recruitment
2. Develop robust empirical relationships
   - Recruitment as function of temperature and predation (cannibalism, other groundfish)
   - Growth (weight-at-age) as function of temperature and age-class abundance
3. Generate future temperature scenarios from IPCC model projections (downscaling)
4. Simulate possible population trajectories of pollock under various climate scenarios and different harvest control rules

Walleye pollock recruitment

NOAA extended reconstructed SST, July – September average



Recruitment estimates from Ianelli et al (2009)

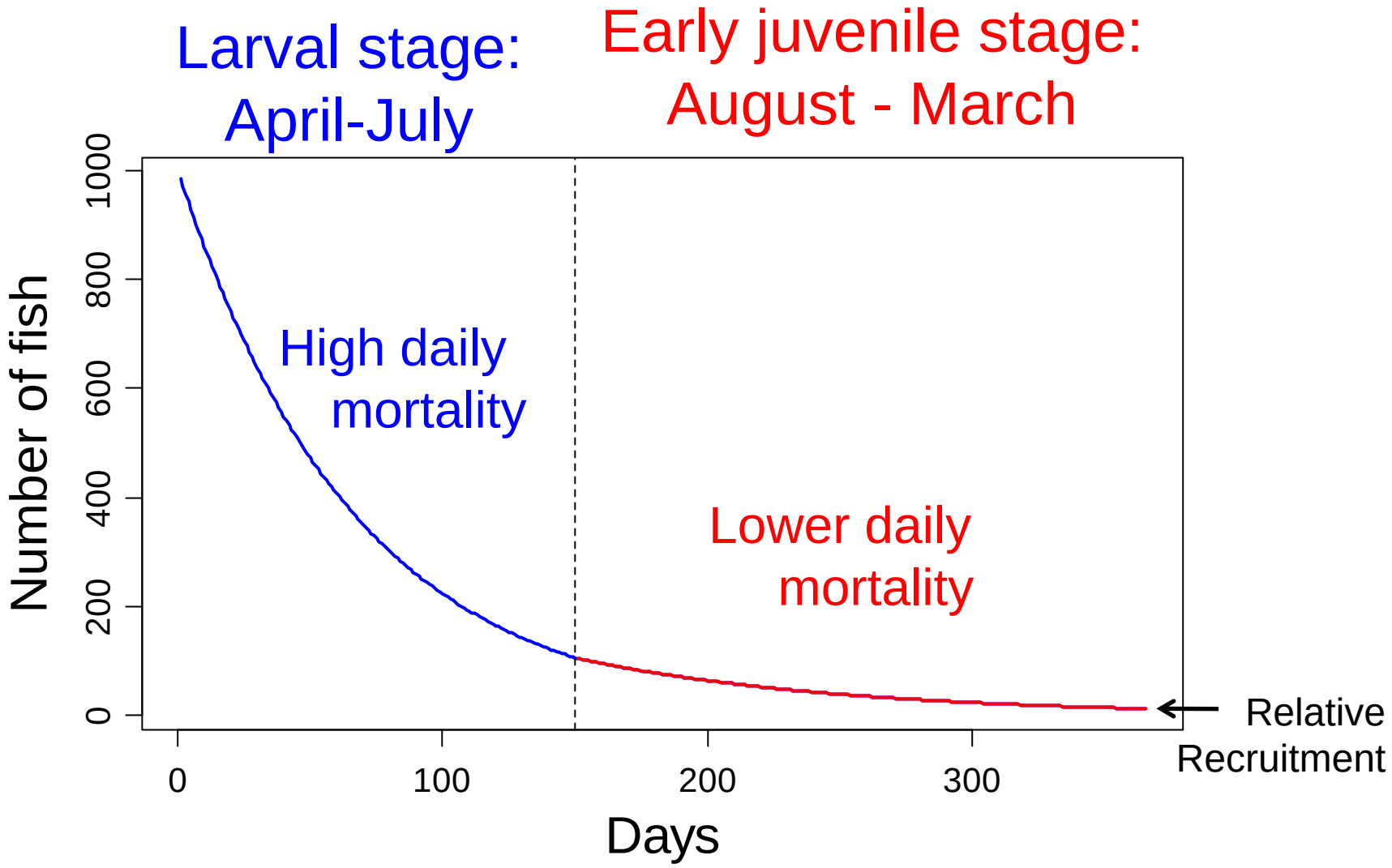
Drivers of pollock recruitment

- **Ice and temperature conditions** on the shelf are consistently associated with pollock recruitment
- Effects of spring ice conditions and summer temperature conditions cannot be separated statistically due to strong confounding
  - Warm spring temperatures / early ice breakup associated with small zooplankton, good feeding conditions for pollock, and abundant age-0 pollock
  - However, warm temperatures (in particular in late summer) are associated with reduced abundances of large zooplankton and poor overwinter survival of pollock
  - Suggests opposite effects of temperature conditions during spring & summer on survival

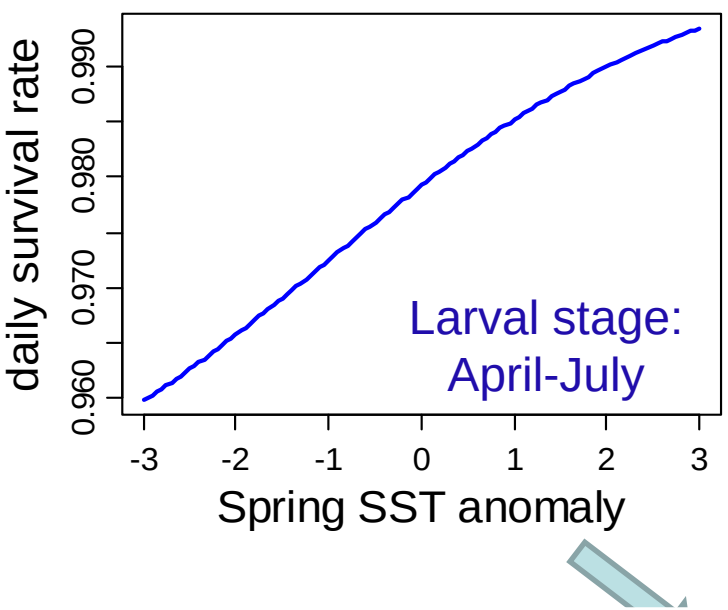
⇒ Simulate possible functional relationships

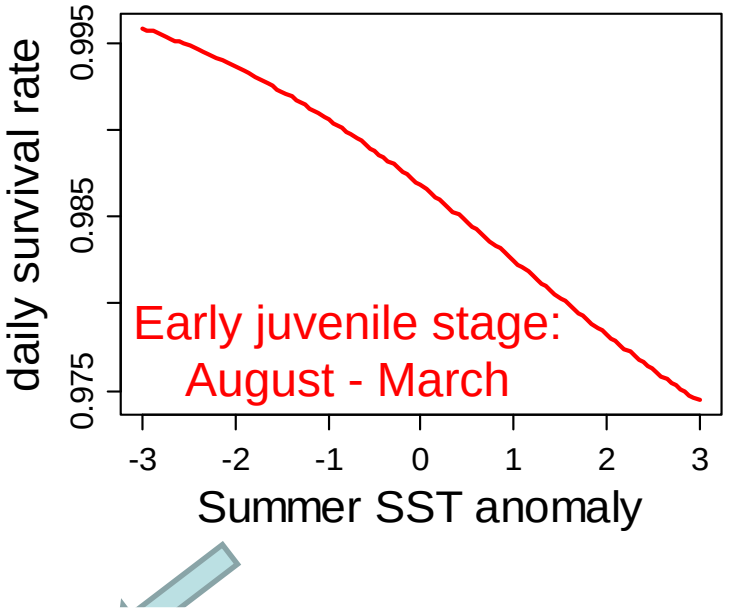
⇒ Estimate empirical relationships

2-stage survival simulation

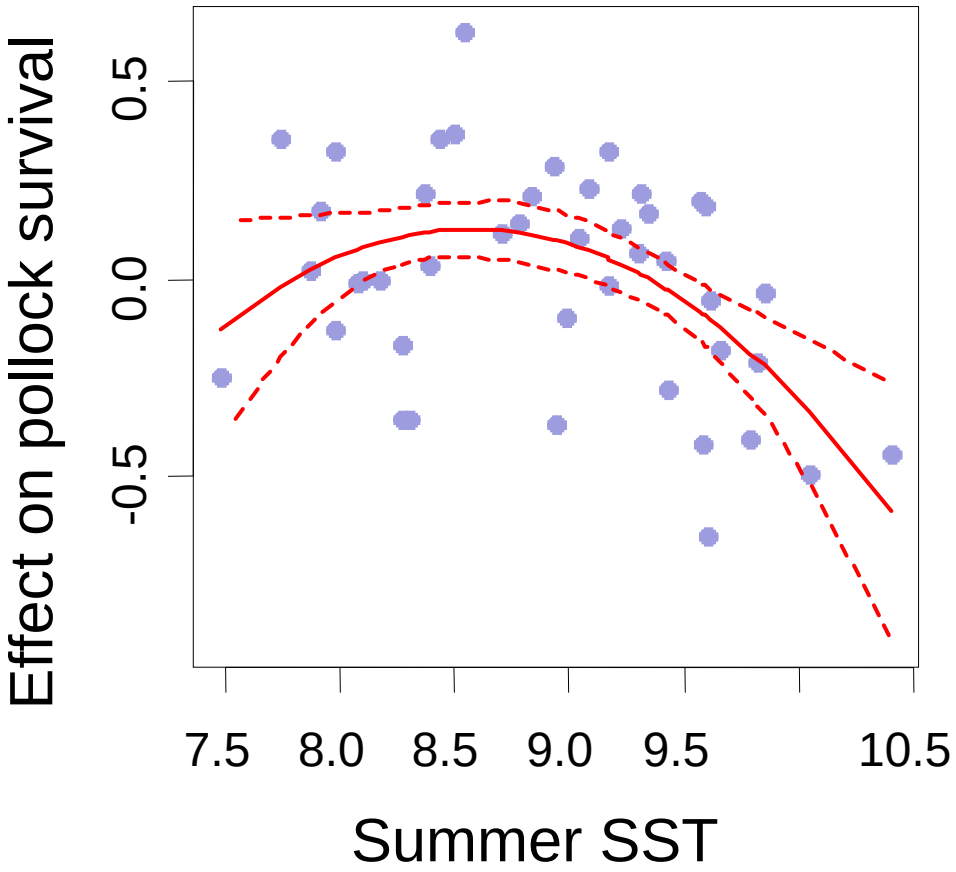


2-stage survival simulation

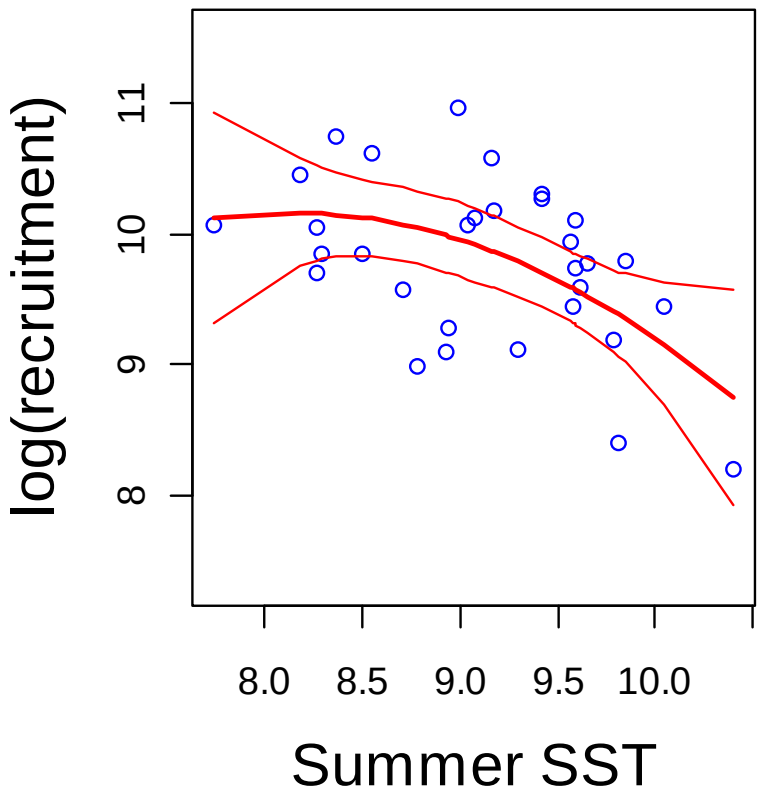




Empirical relationship: Survival anomaly vs. SST



Estimated effects of SST and predation on recruitment



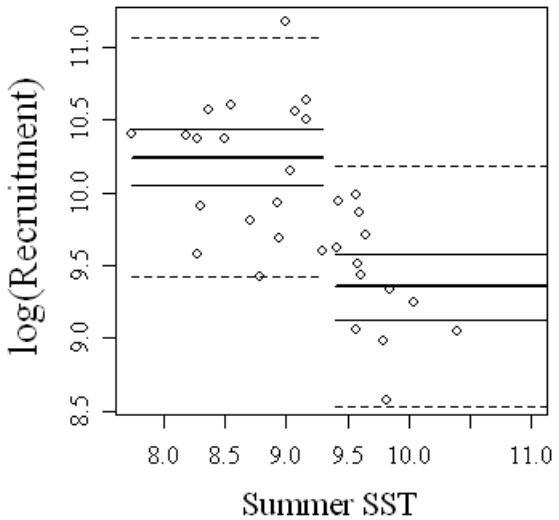
R^2 =0.44
P = 0.001

pollock

Arrowtooth flounder
(Atheresthes stomias)

- Robust relationship for projecting future recruitment under different SST scenarios
  - Account for uncertainty!

- Examined two alternative SST-recruitment relationships:
  - Dome-shaped (quadratic) model
  - Threshold model: reduced survival if SST > 9.4ºC



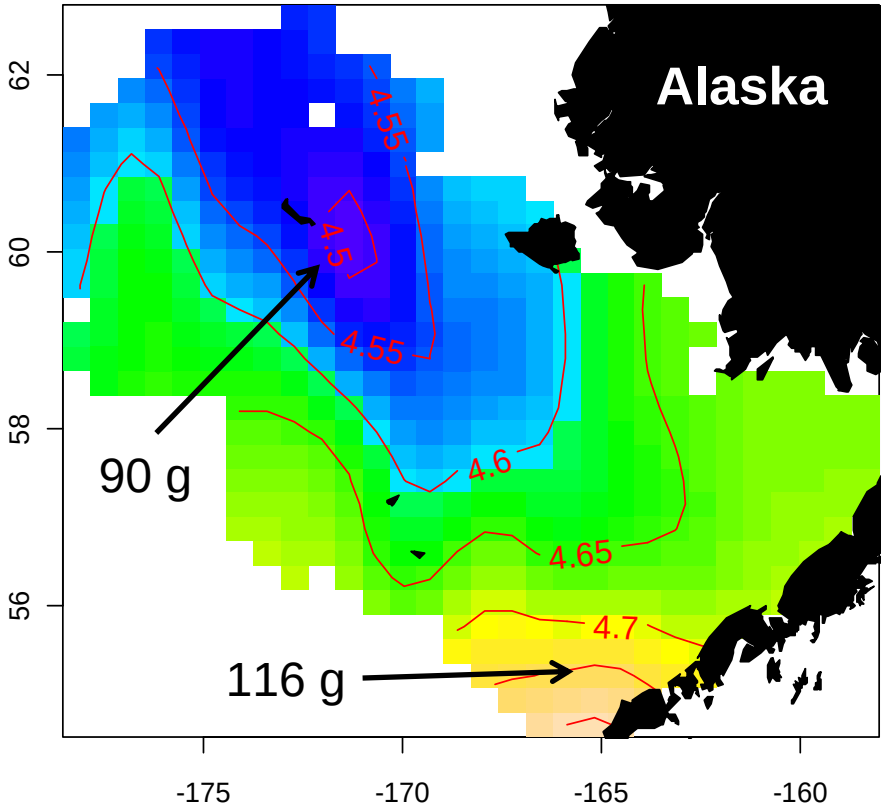
Effects of temperature and density on growth and condition of walleye pollock

- Examine weight-at-length (condition index) in summer trawl survey

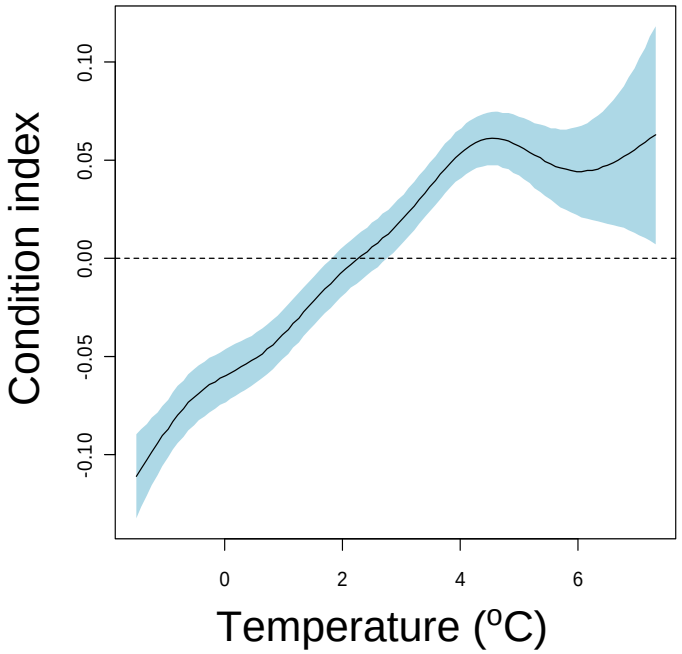
- Model weight-at-age at time of spawning (for projections using age-structured model)

Temperature effects on pollock condition (weight-at-size in summer trawl survey)

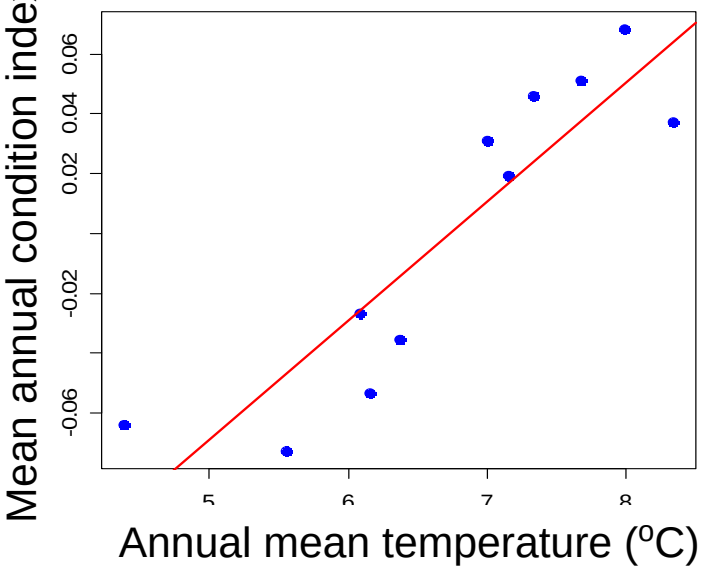
Spatial pattern: mean log(weight) at 250mm



Local temperature effect



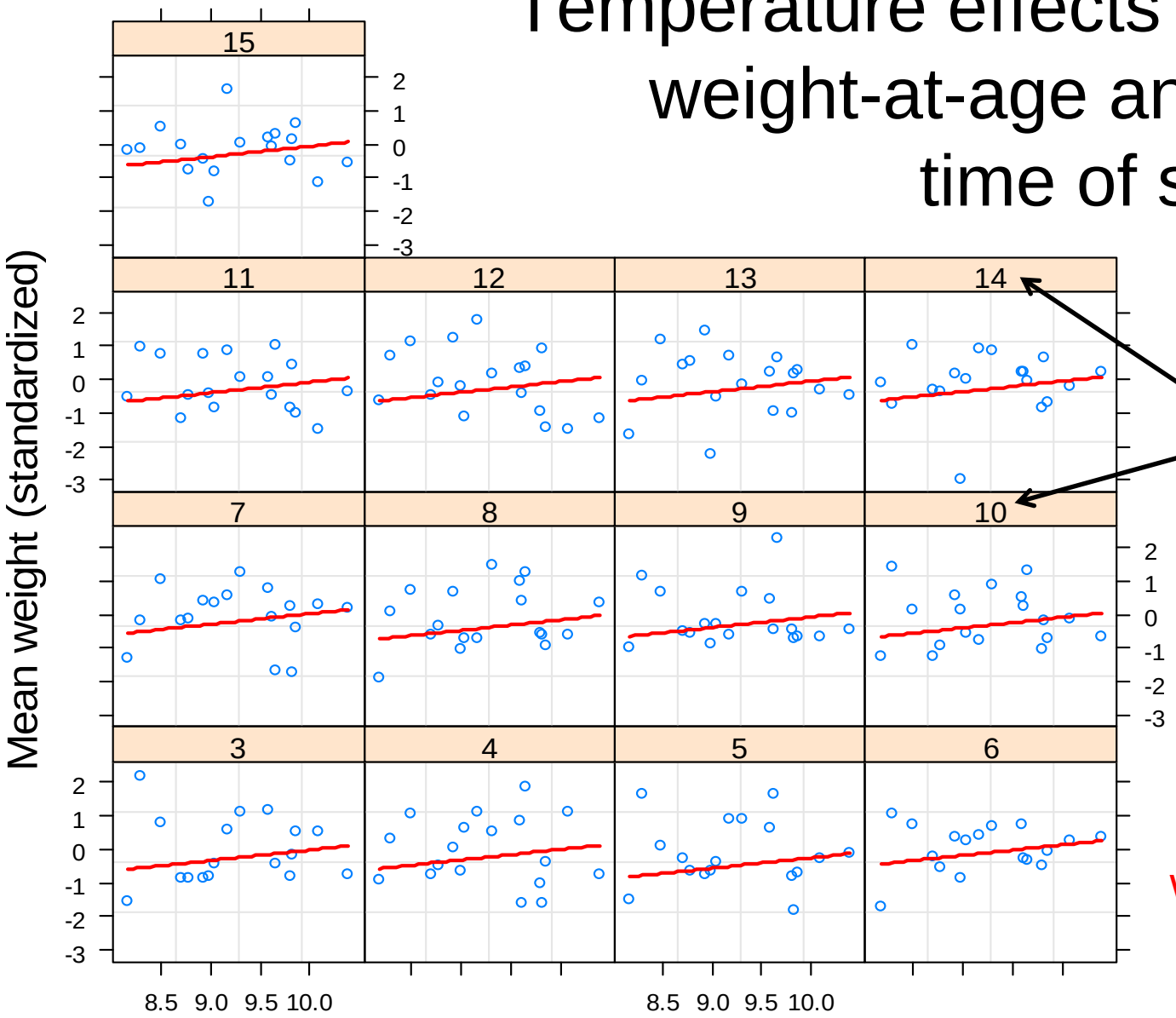
Annual means



Effects of temperature on weight-at-age at time of spawning

- Fishery observer data: 1991-2009
- Modeling weight-at-age as function of:
  - Previous year temperature (SST as proxy)
  - Numbers-at-age (same cohort)
- Both temperature effect and density-dependent effect may vary by age (ages 3 - 15+)

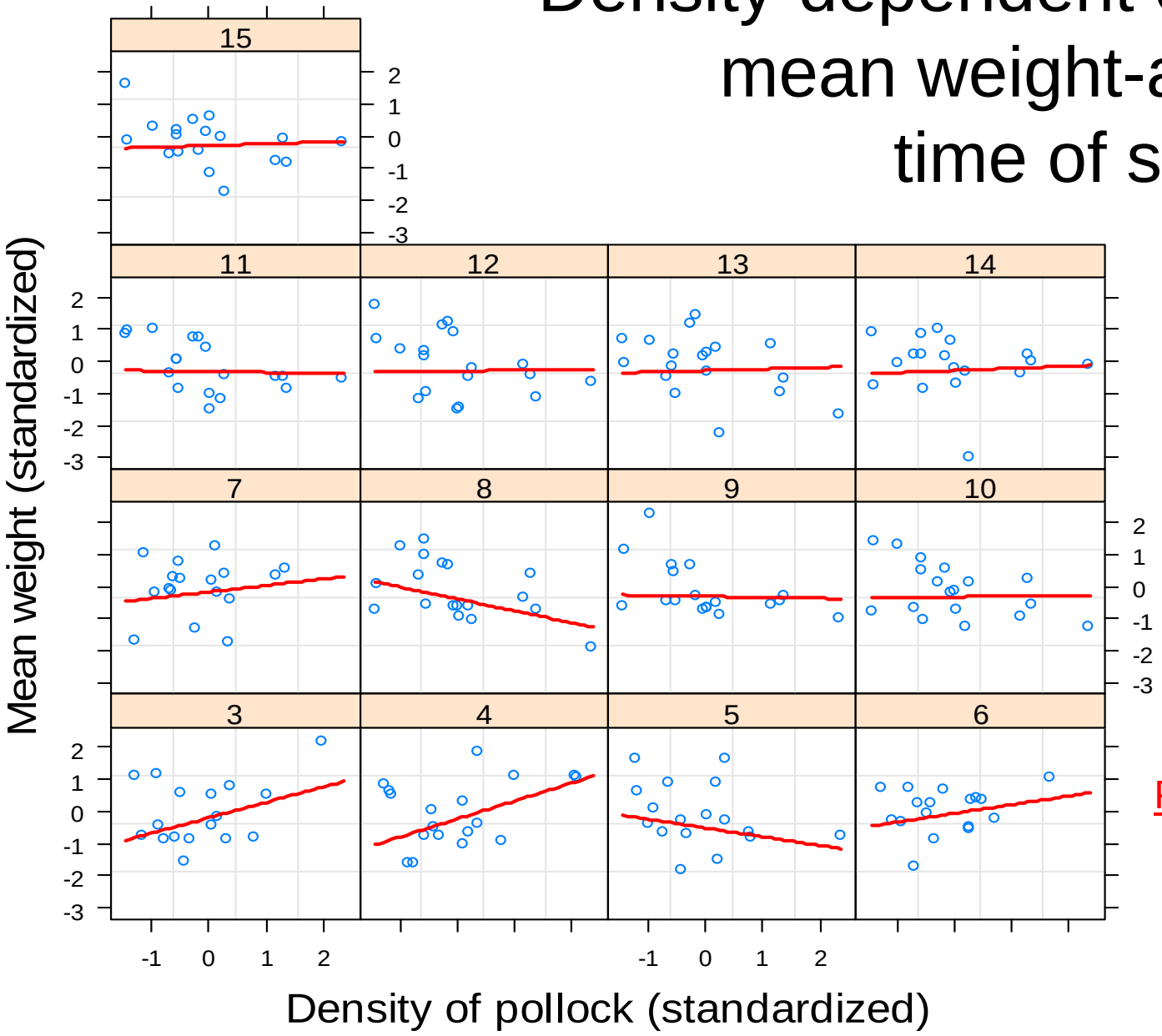
Temperature effects on mean weight-at-age anomaly at time of spawning



(Best fit from linear mixed-effects model)

Weak SST effect ($P < 0.001$)

Density-dependent effect on mean weight-at-age at time of spawning

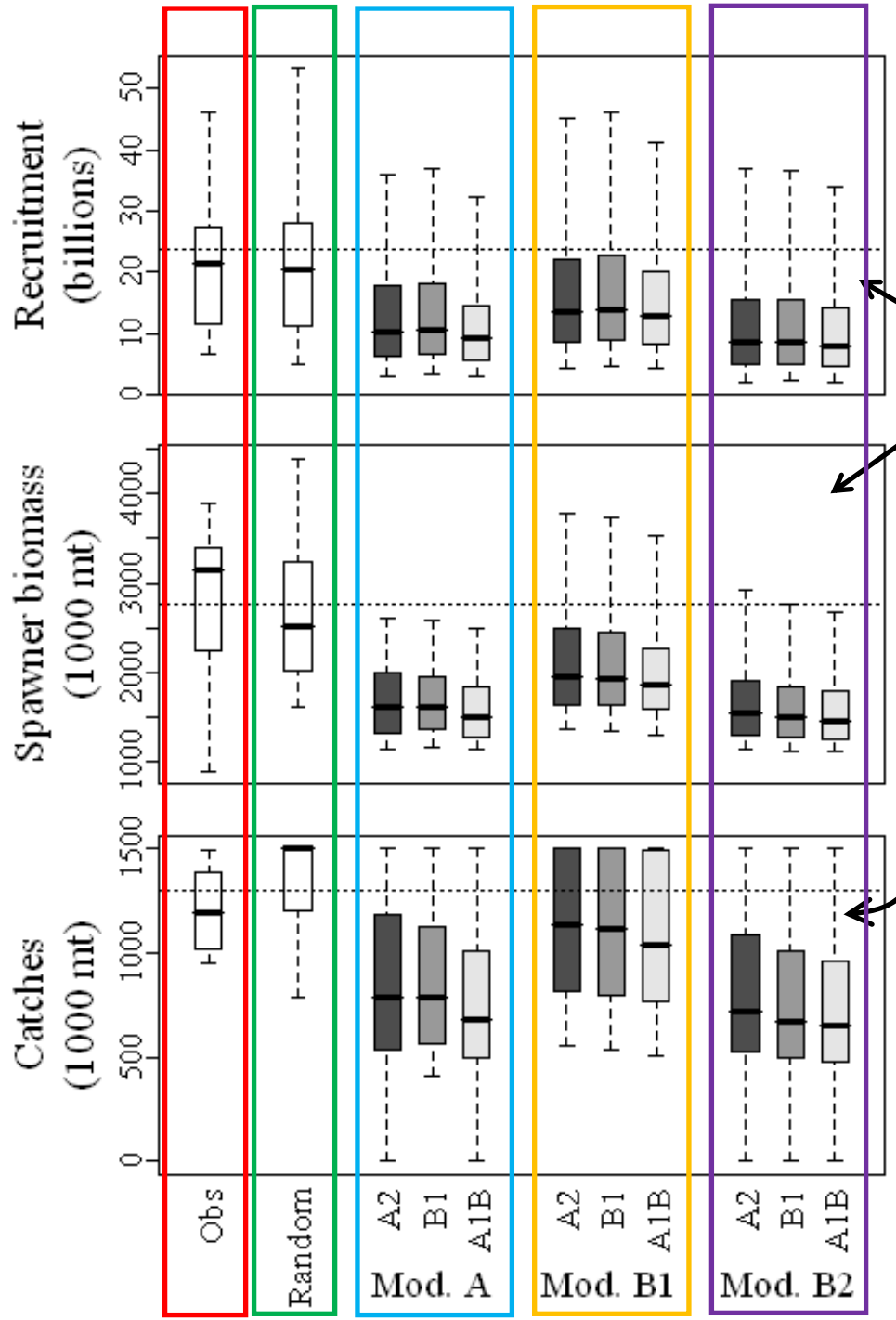


No (or negative) effect at older ages

Positive effect at youngest ages

Projections

- Project population forward through 2050 starting with numbers-at-age and parameters from 2009 assessment
- Fishing under current harvest control rule
- Recruitment scenarios:
  - Draw random R from observed (1977-2008)
  - Predicted recruitment based on projected summer SSTs downscaled from 3 IPCC scenario
    - dome-shaped-recruitment relationship w/ predation
    - Threshold model w/ predation
    - Threshold model w/ predation & increasing arrowtooth
- Temperature-dependent weight-at-age
- (No density-dependent effect)



Distribution of projected values (2041-2050) with full uncertainty:

- Recruitment
- Spawning biomass
- Catch

1977-2009 observations

Random recruitment scenario

Model A:
Dome-shaped SST + predation

Model B1:
SST threshold + predation

Model B2:
SST threshold + predation w/ increasing arrowtooth flounder

Conclusions

- Robust empirical relationship, combined with SST projections estimated from IPCC model output, provide reasonable projections of future pollock dynamics
- Large uncertainties in future trajectories arise from uncertainty in SST projections & uncertainty in empirical relationships
- Future declines in pollock abundance and catches are likely under current harvest control rule, other fishing scenarios, and without fishing

Conclusions (cont'd)

- Effects of temperature and (cohort-specific) density on weight-at-age is relatively weak and highly uncertain
  - no effect on recruitment
  - minor effects on spawner biomass and catches
- No evidence of density-dependent growth at younger ages (Abundant cohorts tend to have higher weight-at-age)
- Low weight-at-age at low abundances could exacerbate negative effects of SST

Acknowledgements

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