Stage-specific effects of acute exposure to pesticides on the soft-shell clam, *Mya arenaria*

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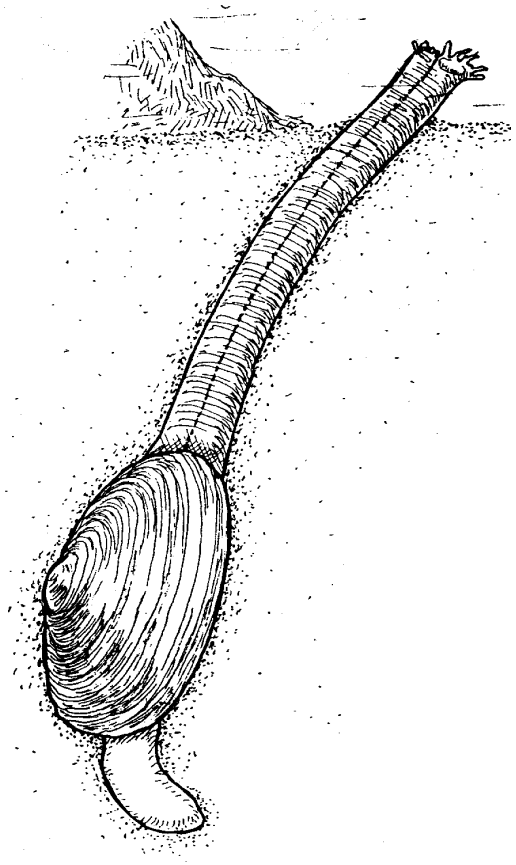
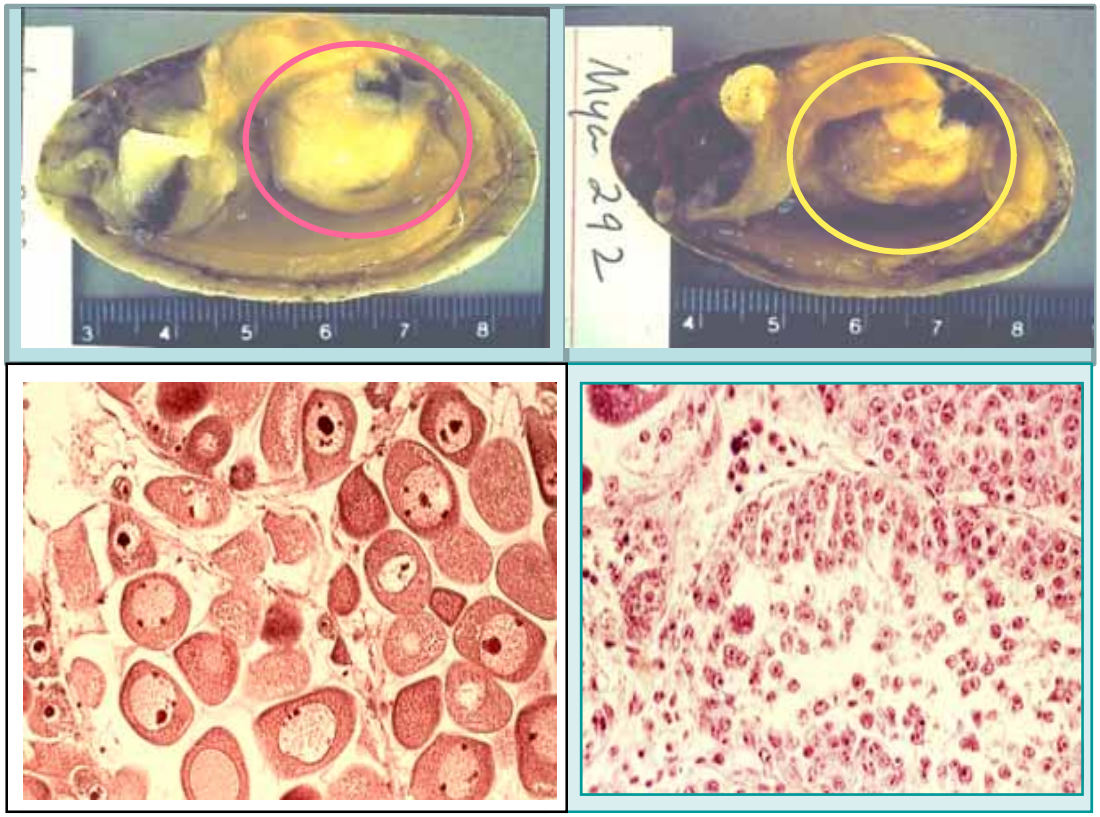
Mya arenaria, the soft-shell clam



- **Life history**
  - **Sessile**
  - **Filter feeders**
  - **Long lived**
- **Commercial importance**
  - **4th most valuable ME fishery**
  - **Population decline**
- **Sentinel species**
  - **Bioaccumulation**
  - **Model for human environmental exposures**

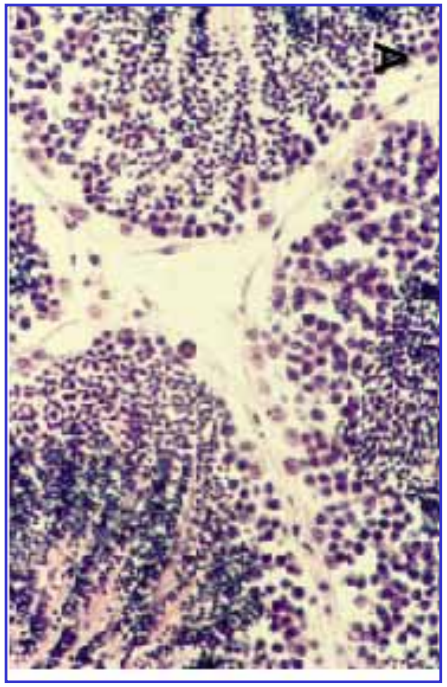
Clam Gonadal Neoplasia

- Germinomas
- Eastern Maine
- >20% prevalence
- Etiology unknown

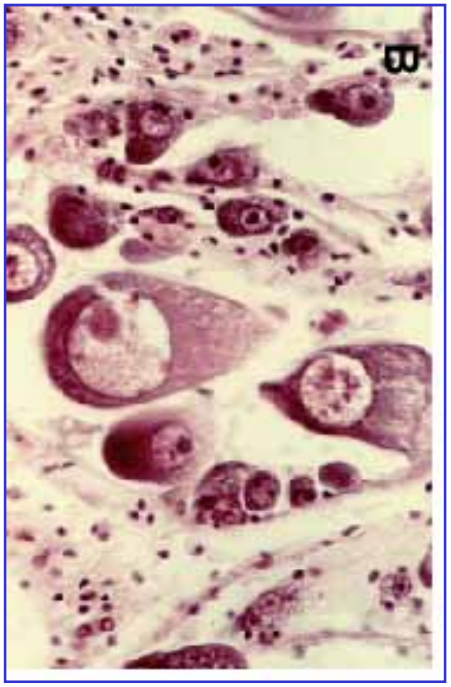


Normal female Gonadal neoplasm

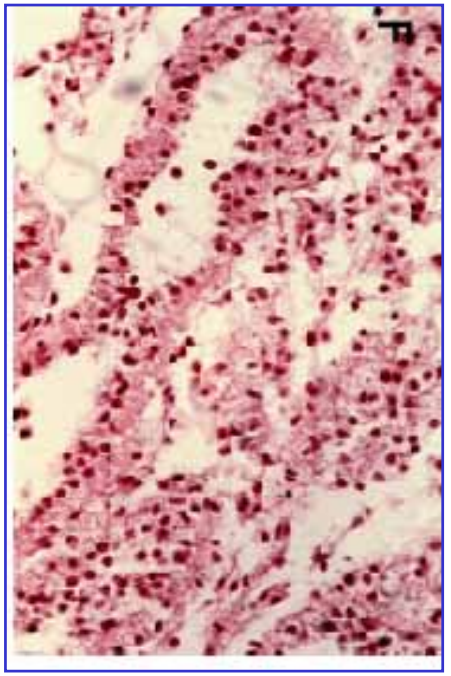
Exposure of Adults to 2,4-D inhibits Gamete Development



male

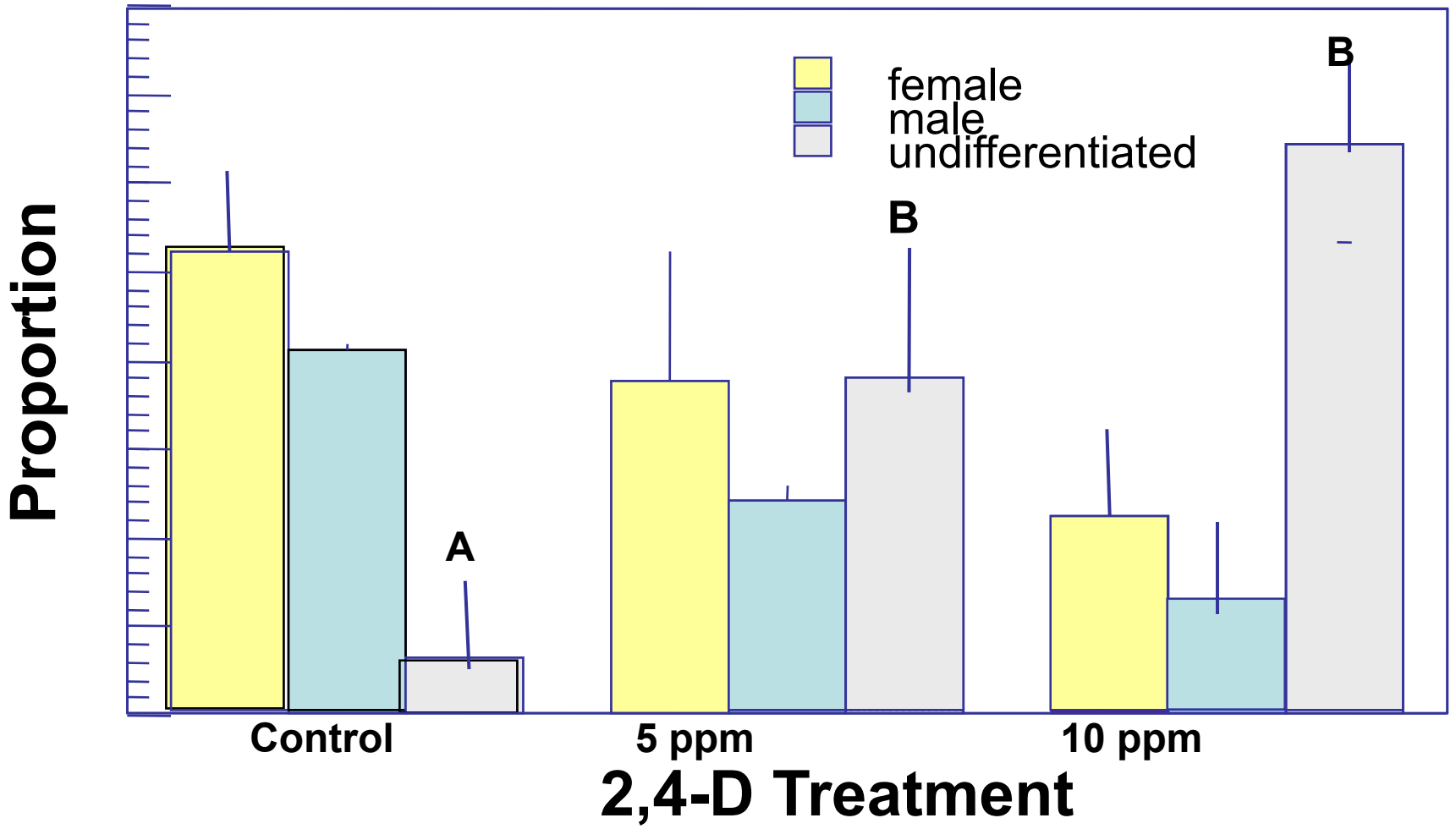


female



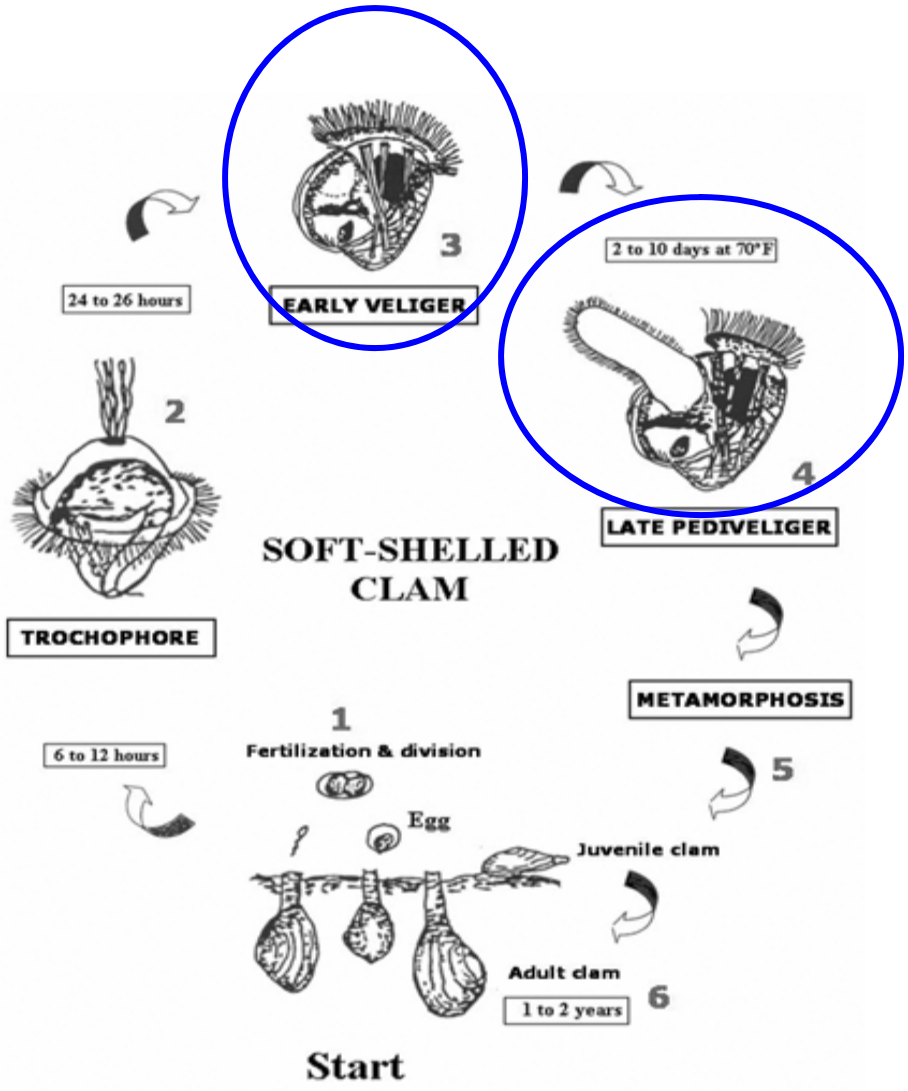
undifferentiated (10 ppm)

Gender distribution of treated/control animals at six-months post-exposure.



Different letters represent significant differences ($p<0.05$)

Background & Questions

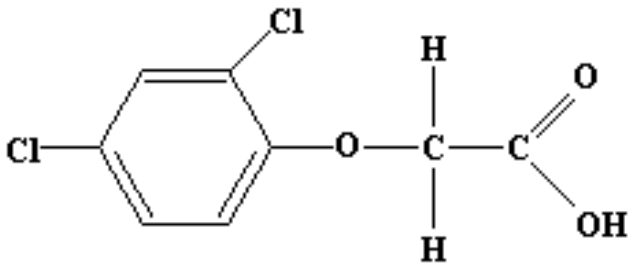


- Planktonic larvae (weeks)
- Benthic juveniles & adults (years)
- Recruitment significant factor in population growth
- Factors that cause larval mortality can affect populations
- Does larval survival differ when veligers or pediveligers are exposed to pesticides?
- Might pesticides affect larval mortality enough to reduce clam population growth?

Pesticides of Interest

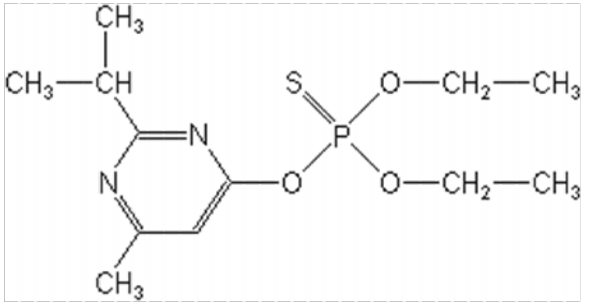
(1). 2,4-D (2,4-dichlorophenoxyacetic acid)
Agway®Super BK 32

- broadleaf herbicide
- neurotoxin, skin & GI irritant
- used until late 1970's
- early season start



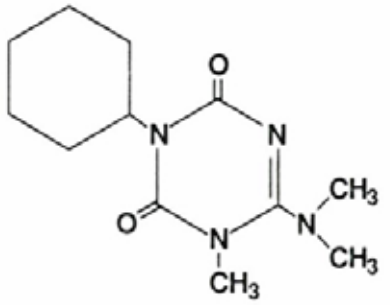
(2). phosmet (Imidan®)

- organophosphate insecticide
- Downeast Maine blueberry fields
- short-lived but more toxic than hexazinone
- April-Aug



(3). hexazinone (Velpar®)

- Downeast Maine blueberry fields
- detected in groundwater (0.2-10 ppb)
- April-May



http://ipm.world.unm.edu/chapters/ware/diazinon.gif, http://www.bugwood.org/PAT/22chemicalstructures.html

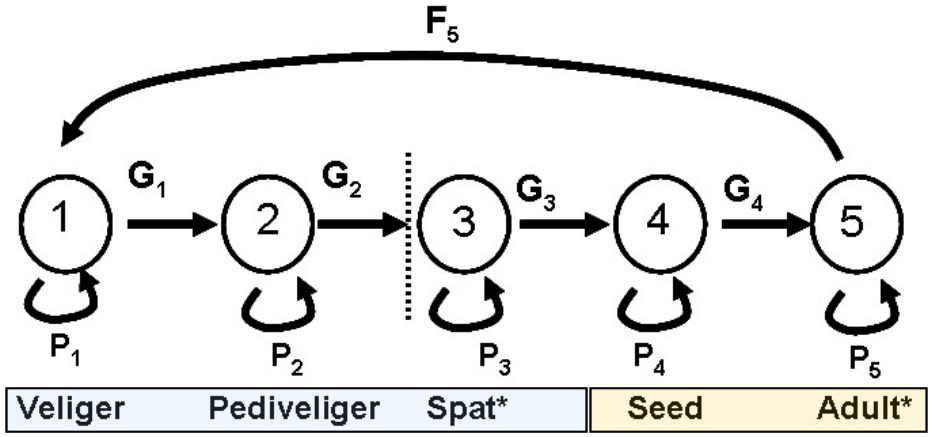
Approach

- Acute, 24h laboratory exposures
  - Beals Island Hatchery
  - Spawned by thermal stimulation
  - Pooled eggs & sperm
  - **Veliger, pediveliger larvae** (15-30/mL) in 4L seawater
  - Dose 0, 0.5, 5, 10, 50 ppm
  - Observed 14 days, mortality & delay-in-stage

  - **Juvenile clams** exposed to 2,4-D ,~300/L
  - Dose 0, 0.5, 5, 10 ppm
  - Observed 14 days, mortality & delay-in-stage
  - Subset followed ~ 2 yrs

- Population modeling
  - Matrix models, MATLAB

Model Structure



*additional transitions not shown

Larval Model

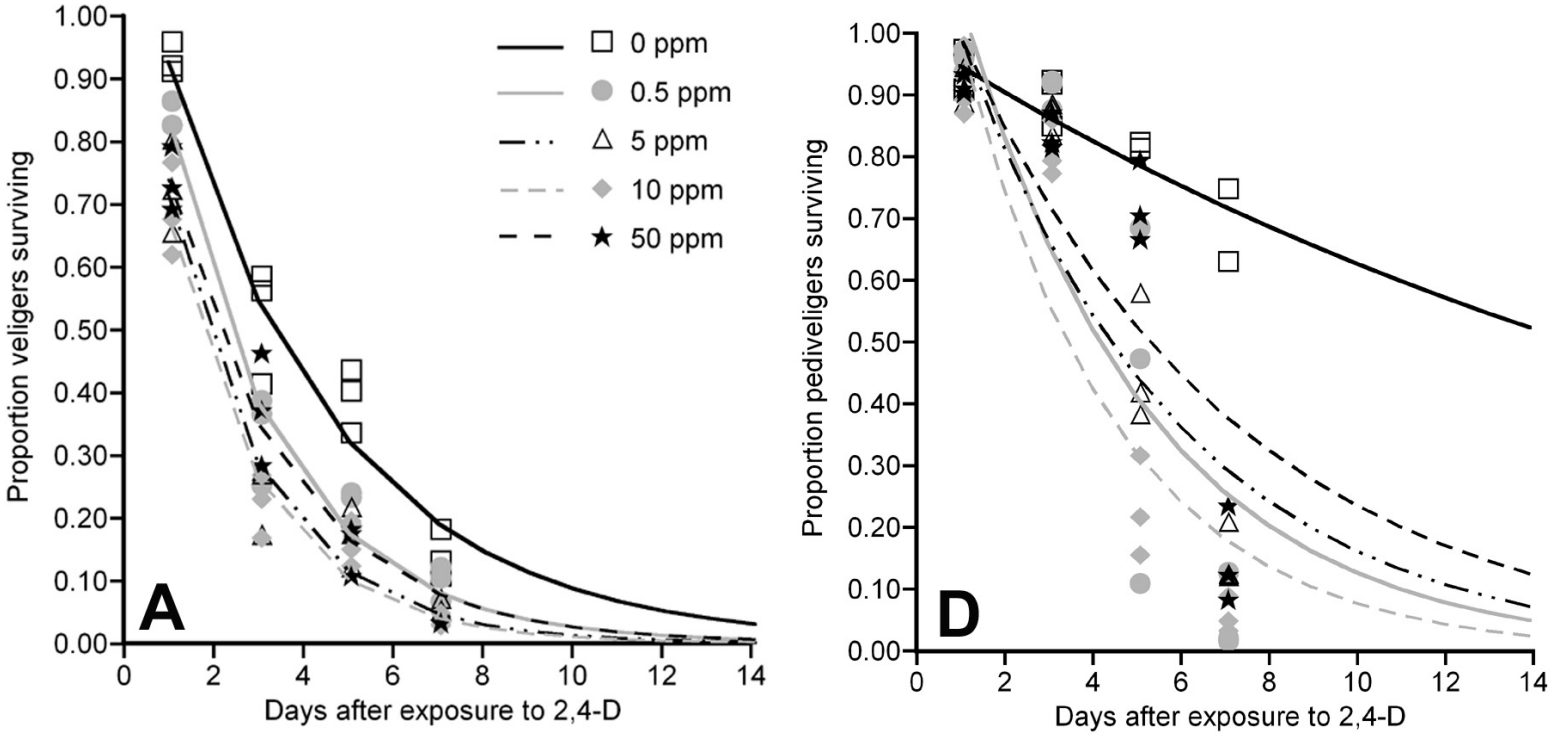
- 2 wk time step, 10 wk total
- Stage/age structured
  - veliger
  - pediveliger
  - 0 -1.9 mm spat
- Output is cumulative proportion surviving to seed (2 mm) (*i.e.*, recruitment)

Adult Model

- 1 yr time step
- Size/stage structured
  - 2.0 – 19.9 mm (juvenile)
  - 20.0 – 29.9 mm (adult)
  - 30.0 - 39.9 mm (adult)
  - 40.0 – 49.9 mm (adult)
  - 50.0 – 59.9 mm (adult)
- Fecundity terms modified by recruitment success
- Durations, growth rate & fecundity derived from Brousseau and Spear & Glude

Brousseau, D.J. 1978. *Fish. Bull*. 76:155-165.
Brousseau, D.J. 1979. *Mar. Biol.* 51:221-227
Spear, H.S.& J.B. Glude. 1957. *Fish. Bull.* 57: 279-292

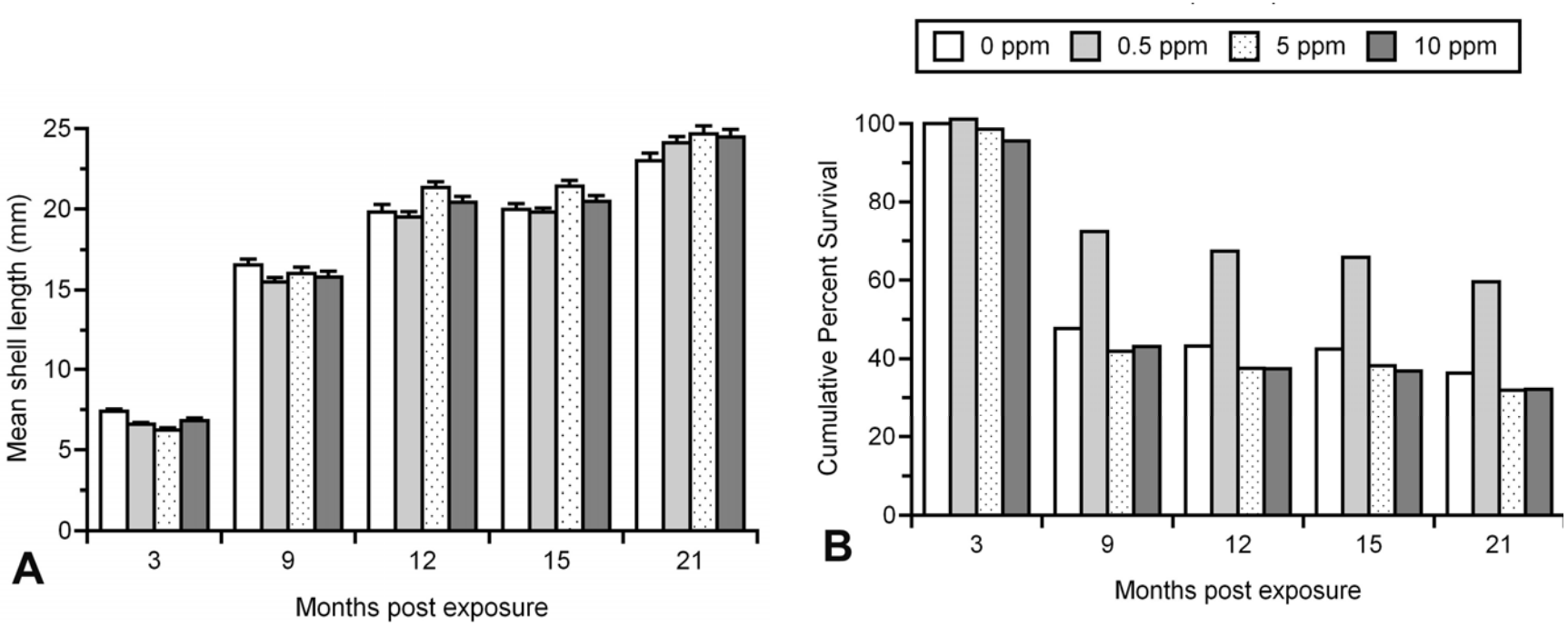
Effect of 2,4-D on larval survival



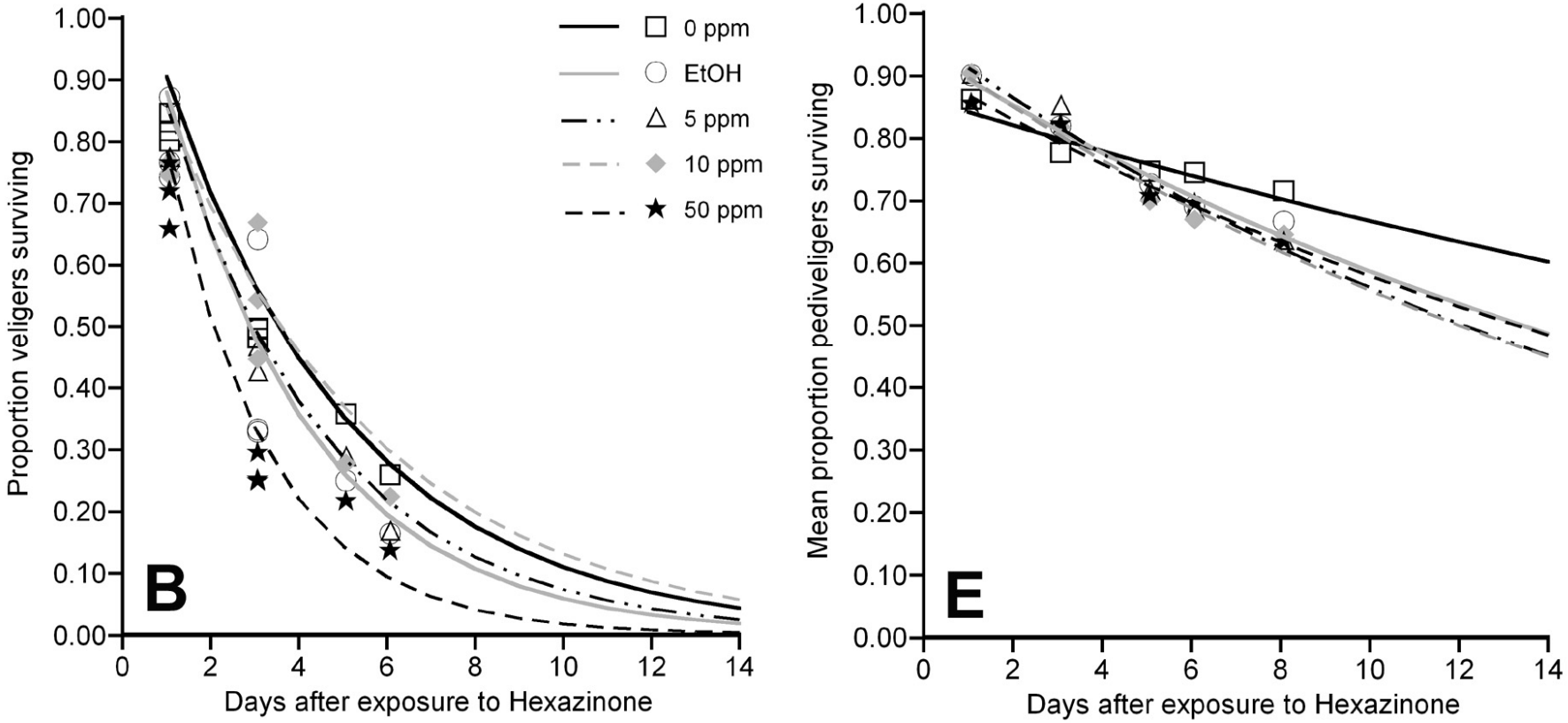
Veligers more sensitive than pediveligers

(Points=laboratory survival, Lines= Forecast survival rates used in the larval model)

Growth & Survival of clams exposed to 2,4-D as juveniles



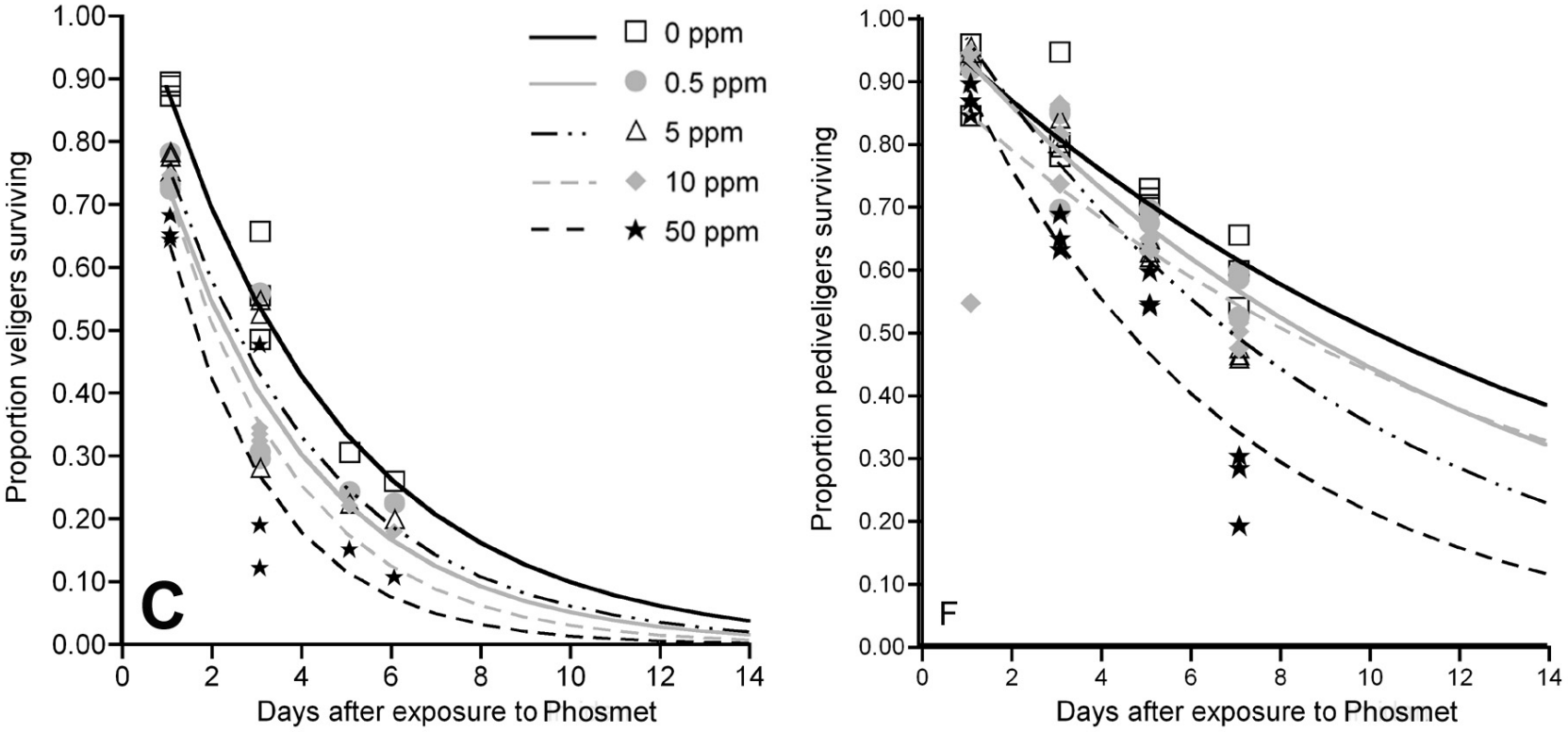
Effect of hexazinone on larval survival



Veligers more sensitive than pediveligers;
Pediveliger survival high

(Points=laboratory survival, Lines= Forecast survival rates used in the larval model)

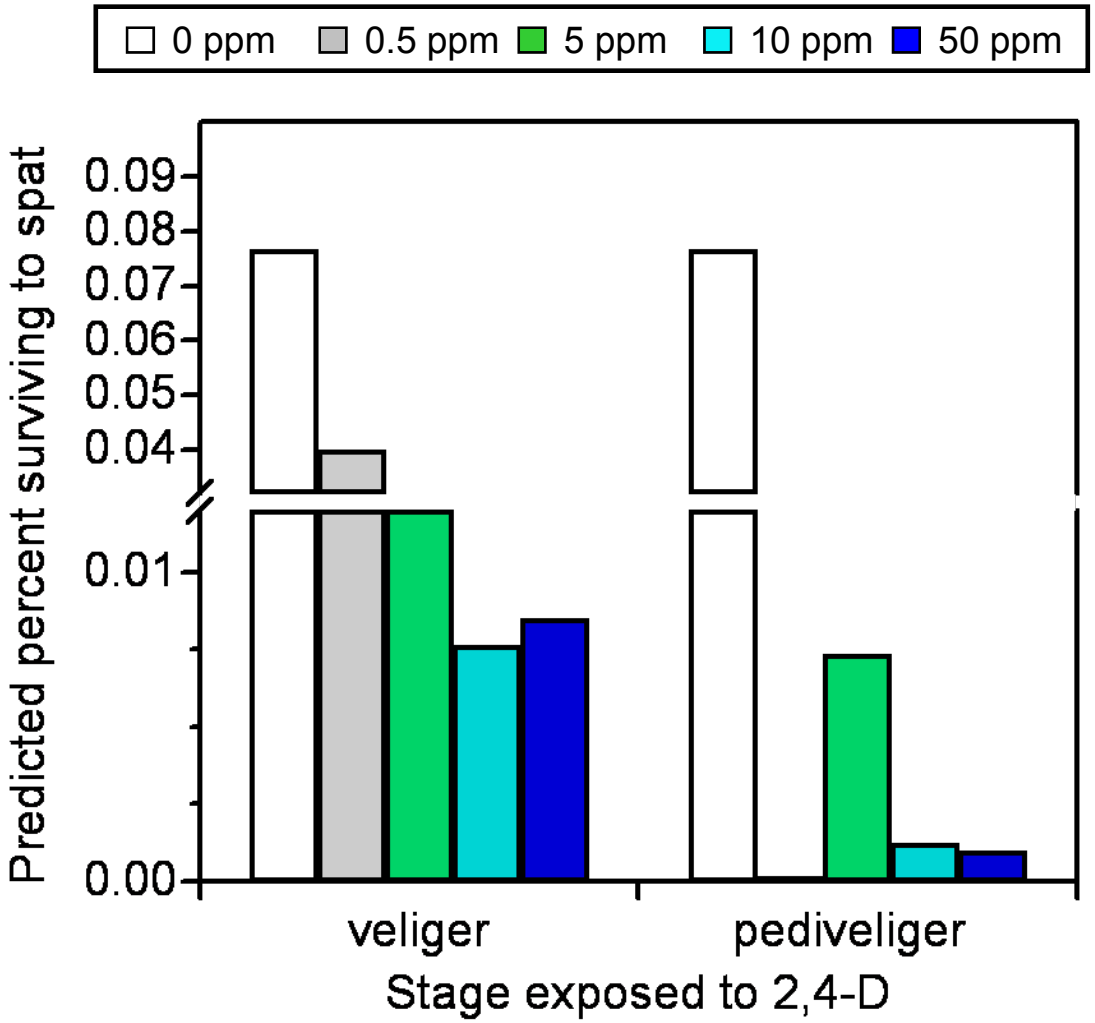
Effect of phosmet on larval survival



Veligers more sensitive than pediveligers;

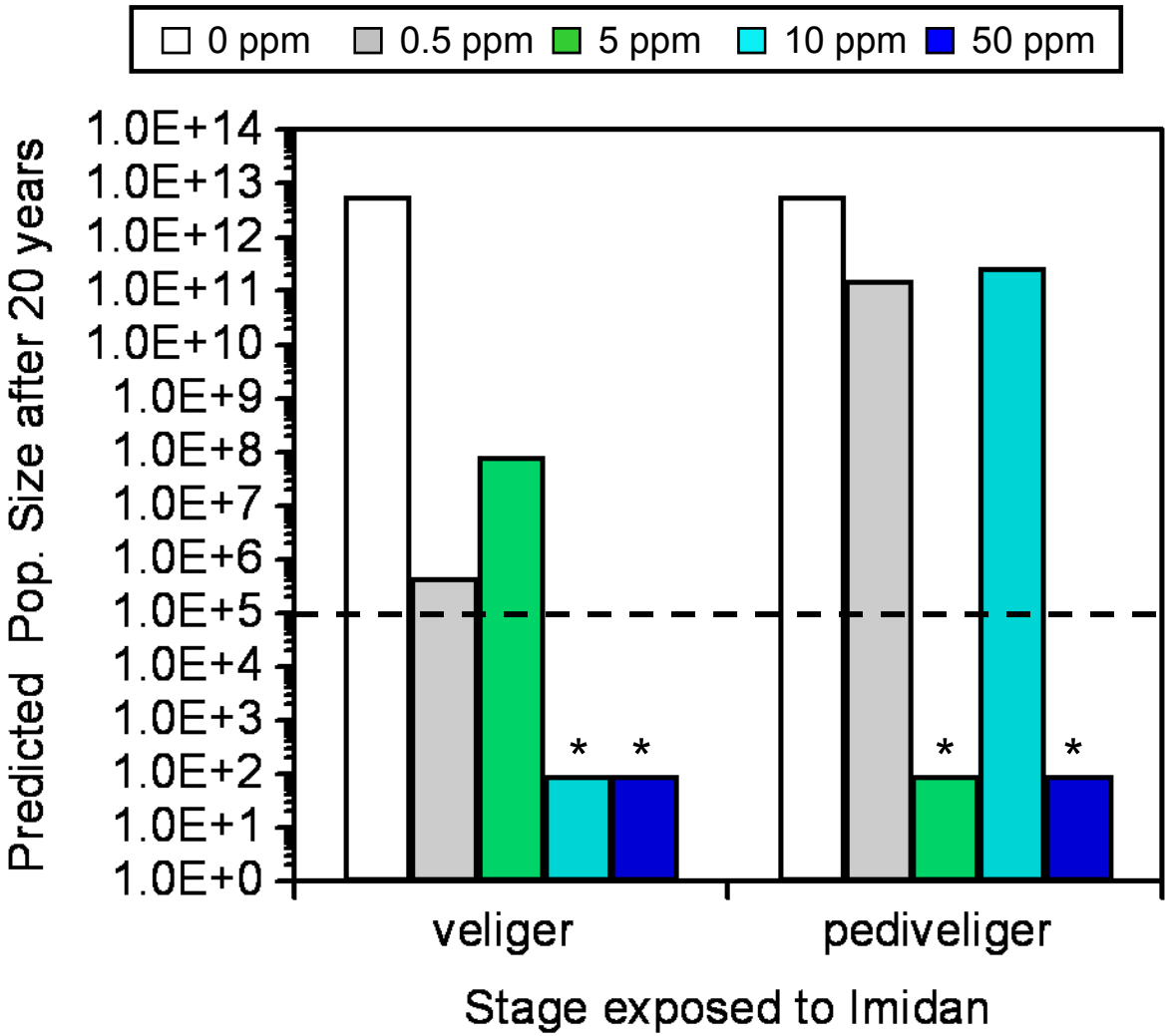
(Points=laboratory survival, Lines= Forecast survival rates used in the larval model)

Model: 2,4-D Effects on Recruitment & Population Size



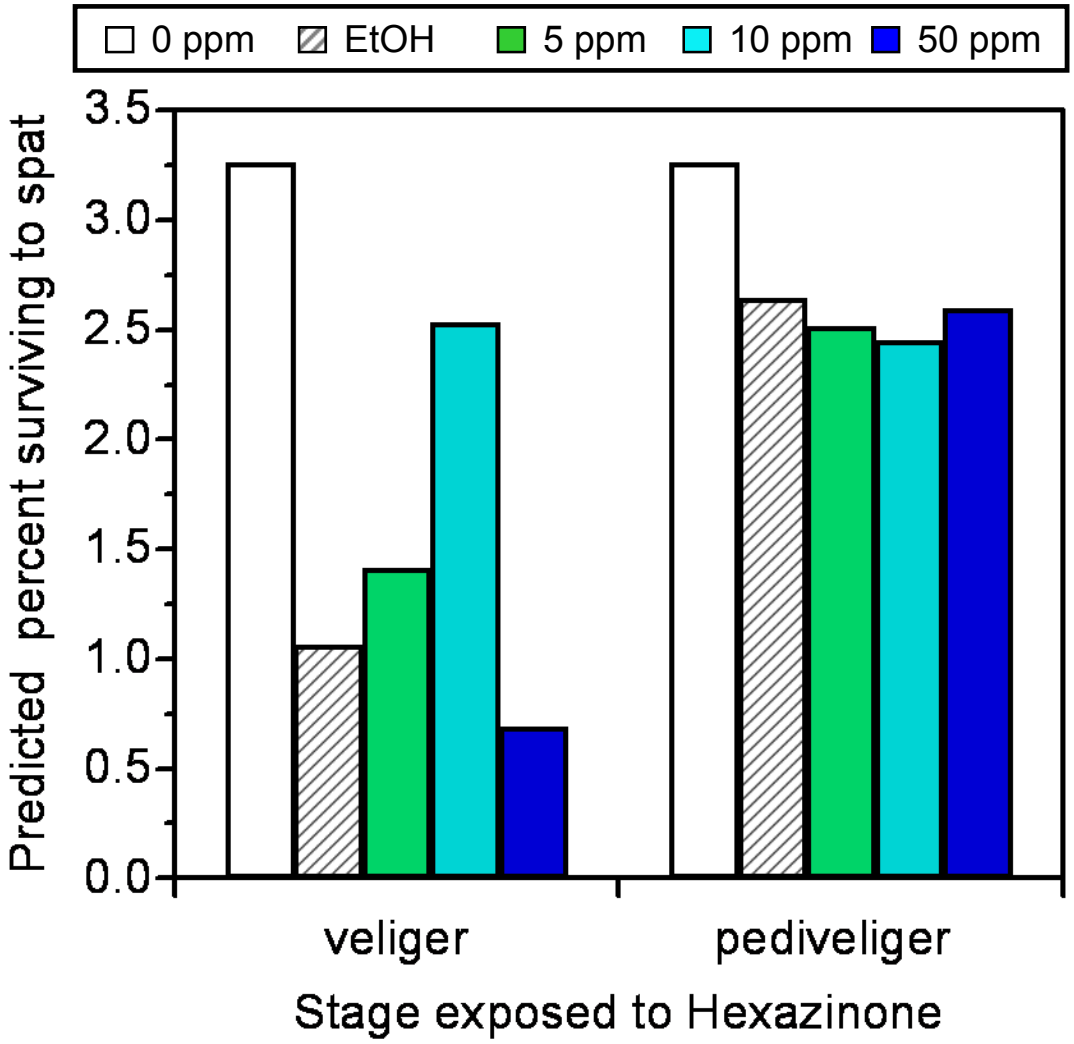
- Estimated <0.1% survive to spat in field
- Exposure to > 5 ppm 2,4-D decreased predicted recruitment by order of magnitude.
- Pediveligers most sensitive
- Lower recruitment translates to lower pop. size

Model: Phosmet Effects on Recruitment & Population Size



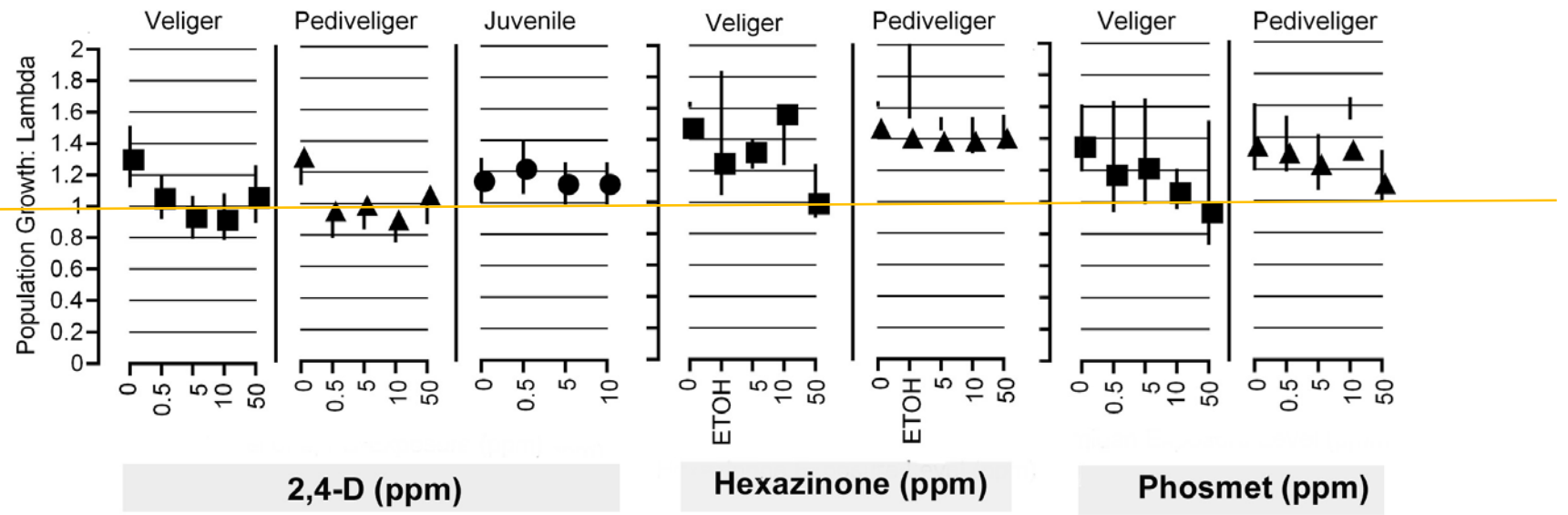
- Veligers more sensitive
- Control & pediveliger survival greater than expected in field
- Populations grew except when yearly recruitment failed (*)

Model: Hexazinone Effects on Recruitment & Population Size



- Veligers more sensitive, but survival >> 2,4-D exposed
- Recruitment higher than expected in field
- Population grew regardless of exposure

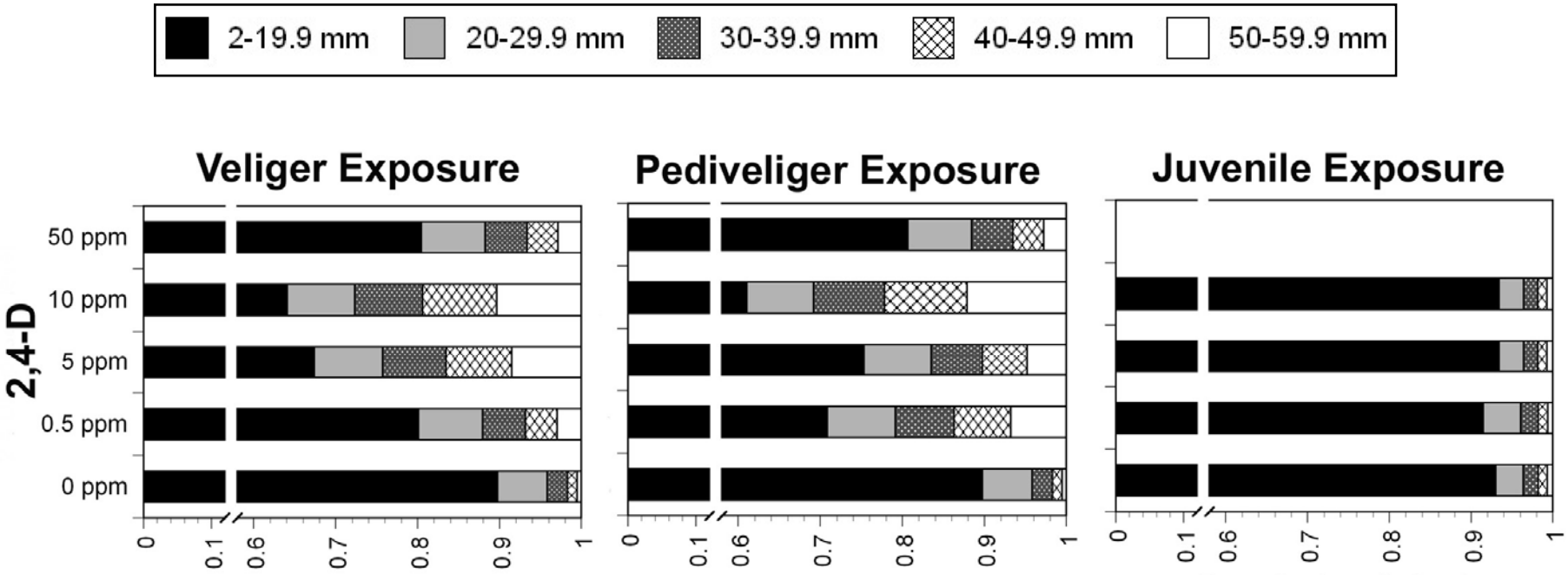
Model: Pesticide effects on population growth rate



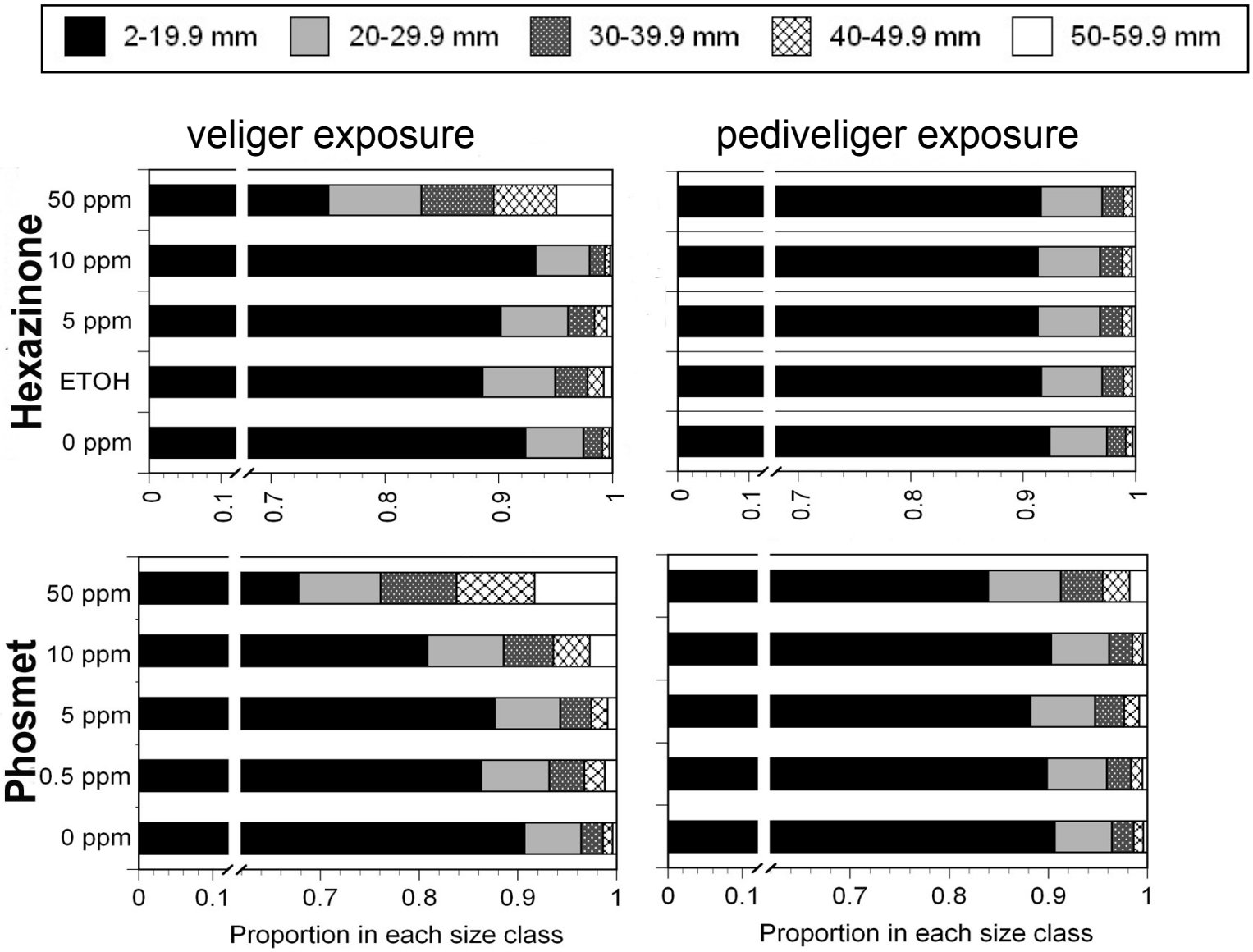
- **Lambda, λ = population growth rate**
- λ > 1 = increasing population; λ < 1 = decreasing population
- **2,4-D** - When veligers & pediveligers exposed population declines, but not when juveniles exposed
- **Hexazinone** - population growth rate positive
- **Phosmet** - effect on population growth rate varied

Model: 2,4-D effects on stable-stage distribution

- Juveniles normally most abundant stage
- Proportion of juvenile clams decreased with increasing 2,4-D dose
- Reduced recruitment
- No change when juveniles exposed



Model: Effect of Hexazinone & Phosmet on Stable-Stage Distribution



Summary & Conclusions

- **2,4-D** significantly reduced survival to spat regardless of larval stage exposed

- **Hexazinone** and **Phosmet** - veligers most sensitive
- Model results show exposure to pesticides during early larval stages can cause **significant** changes in predicted **recruitment, population growth, and stable-stage distributions**
- BUT these changes **depend on** both the larval **stage exposed** and the **pesticide** -- 2,4-D had greatest impact
- Observed population declines likely the result of multiple factors
- Pesticides application after new recruits have settled could reduce the impact on populations

Acknowledgements

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