Growth heterogeneity in predatory fish larvae

Biotic and abiotic influences

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Occurrence of size variation

- Multimodal size distributions are present in both populations and cohorts of animals and terrestrial plants
- Size heterogeneity and growth depensation are very common features in fish, particularly in recently domesticated species

Body weight variation of larvae at hatching

Species name	Larval weight (mg)	Initial CV_{weight} (%)
Salmo salar	69.5	7.5
Oncorhynchus mykiss	55.7	7.5
Acipenser baeri	18.3	8.1
Dicentrarchus labrax	0.5	20
Perca fluviatilis	0.8	15-20
Perca flavescens	0.5	8-10
Clarias gariepinus	1.6	9.2
Heterobranchus longifilis	2	12.3
Cyprinus carpio	1.2	10
Carassius auratus	1.1	9
Brycon moorei	1.5	11
Oreochromis niloticus	10.7	11

Consequences of size variation in larviculture

- Reduced efficiency of the feeding schedule
- Increased agonistic behaviour and competition for food
- Ultimately, emergence of cannibalism or significant increase of its impact on population dynamics in predatory species

Type I cannibalism

Type II cannibalism

Factors involved in size variation

Interaction of 4 primary factors

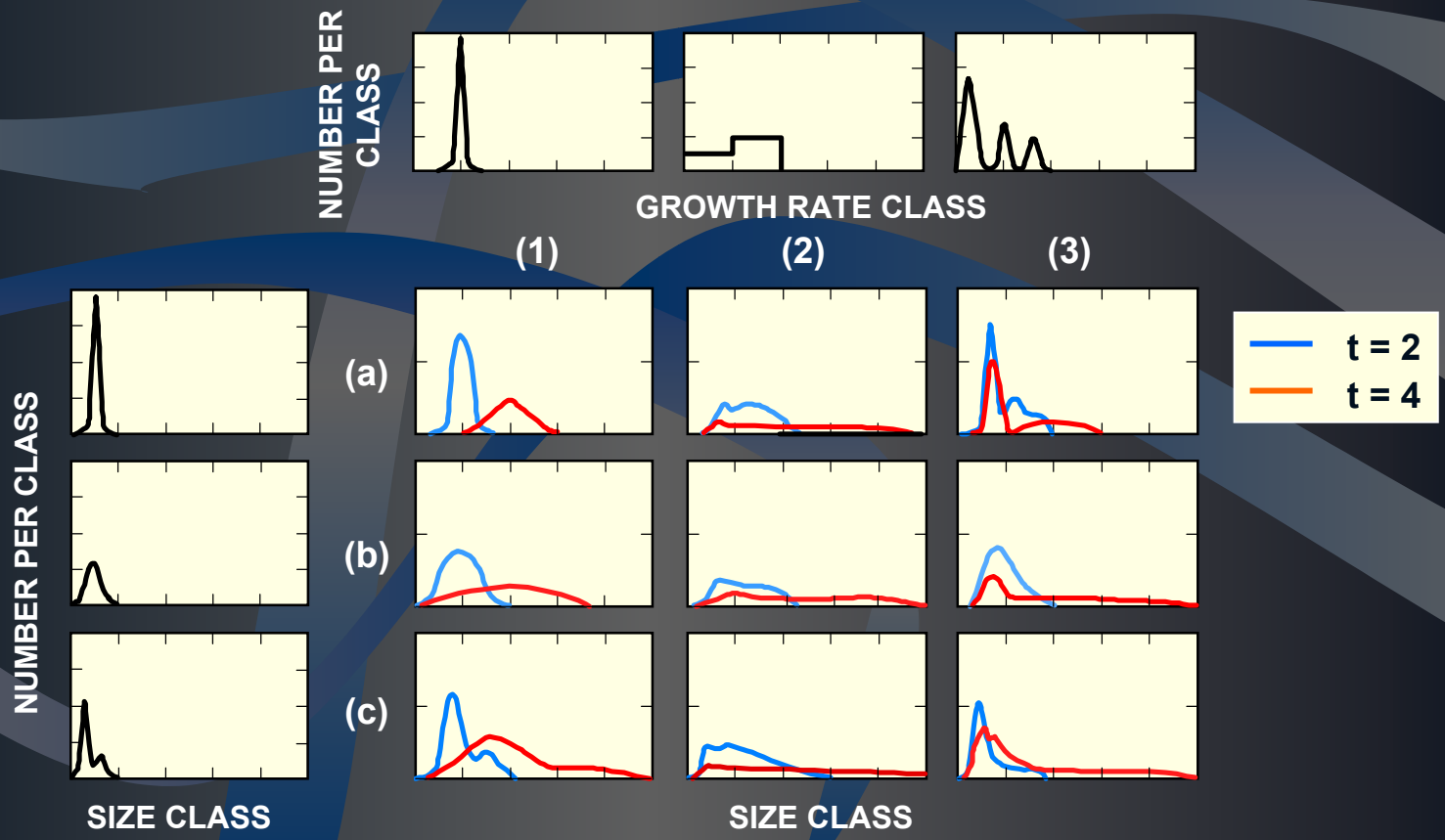
1. initial size distribution
2. distribution of growth rates resulting from differences among individuals
3. size and time dependence of each individual's growth rate (interaction of the life history pattern with the environment)
4. mortality affecting size classes differently

- different combinations of the primary factors might produce similar final size distributions
- a variety of biotic and abiotic mechanisms may affect each of these factors in a manner that produces the same result

Interaction of initial size distribution and growth-rate distribution

Modified from Huston & DeAngelis, Am. Nat., 1987

Assuming that : - a simple growth model ($W_t = W_o e^{rt}$) is applicable
- mortality rate = 0 (regardless of size class)



Biological mechanisms producing size variation among larvae

All mechanisms can be classified as :

- **Inherent** : mechanisms with a strong genetic component, expressed to some degree under any environmental conditions
- **Imposed** : mechanisms that require certain biotic or abiotic conditions to be manifested
- **Interactive** : mechanisms that may require interactions between individuals to be expressed
- **Noninteractive** : mechanisms that may not require interactions between individuals to be expressed

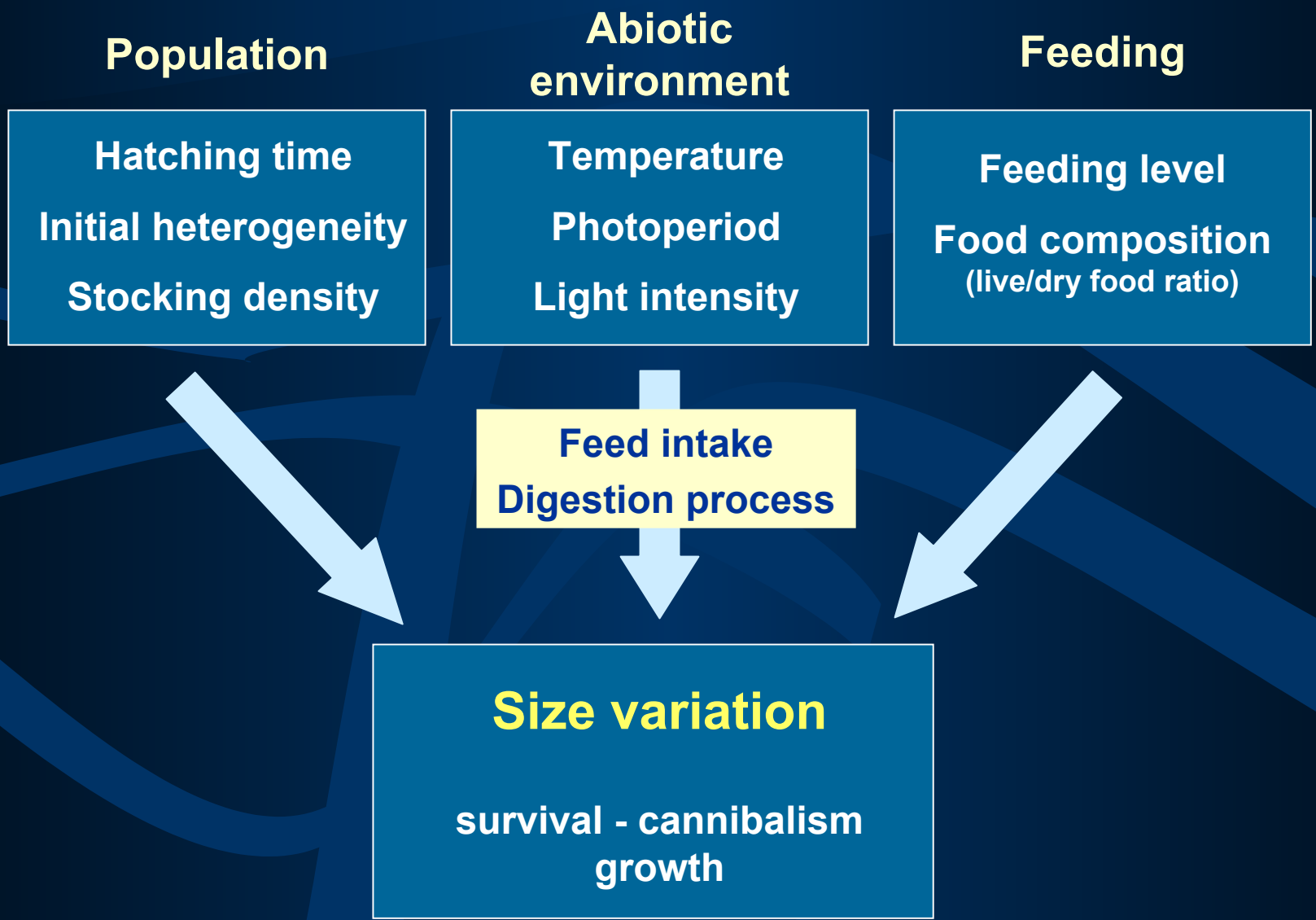
Biological mechanisms producing size variation among larvae (2)

Adapted from Huston & DeAngelis, Am. Nat., 1987

	Noninteractive	Interactive
Inherent	Genetic variation Change in morpho-physiology	Change in morpho-physiology
Imposed	Temporal heterogeneity Hatching Temperature Photoperiod & light intensity Spatial heterogeneity Abiotic resources Food availability/size Temperature Mortality Density-independent	Competition Photoperiod & light intensity Turbidity Food availability Stocking density Mortality Cannibalism Density-dependent

Selection of experimental variables

Eurasian perch & European seabass as comparative models



General methodology

Facilities and fish

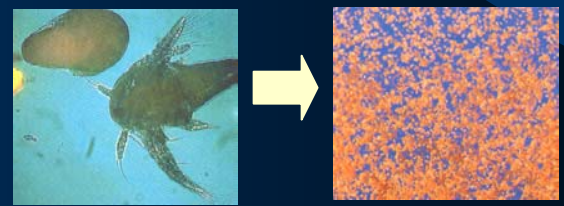
- Sibling fish reared in recirculating system, under optimal physico-chemical conditions for both species
- **2 stages of development** : larvae and post-larvae (weaning stage)

Feeding

- **Artemia** nauplii from day 3 to day 21 in **perch** larvae

- **Brachionus plicatilis** then **Artemia** nauplii in **seabass** larvae

- Weaning phase in **both species** by progressive replacement of **Artemia** nauplii by **dry food**



Hatching time
Material & Methods

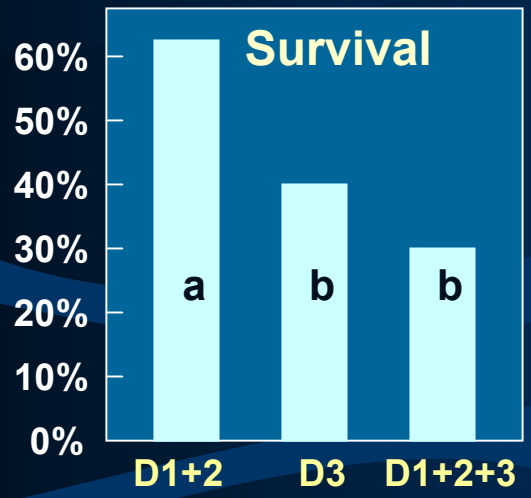
- Rearing of larvae hatched from the same egg batches in pure (same age larvae) or mixed (different ages) populations

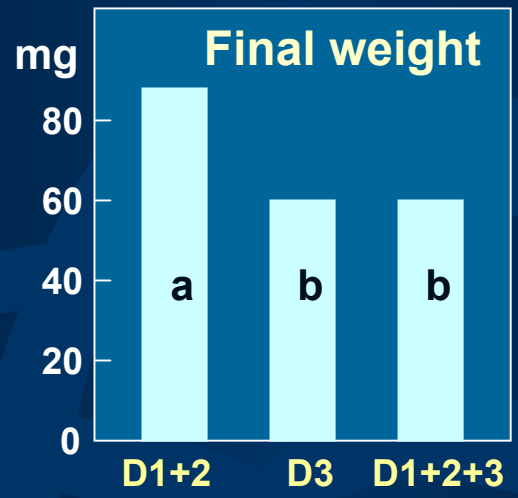
- Labelling of larvae hatched on day 3 (perch) or on day 1 (seabass) by immersion in alizarine red solution

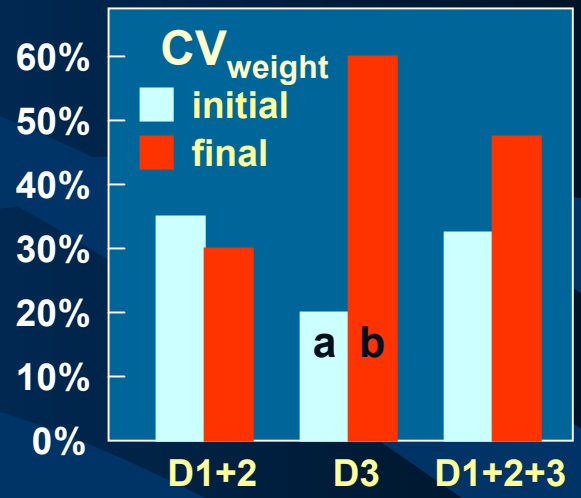
- Identification of labelled larvae in the final sampling by observation of labelled otoliths in epifluorescence microscopy

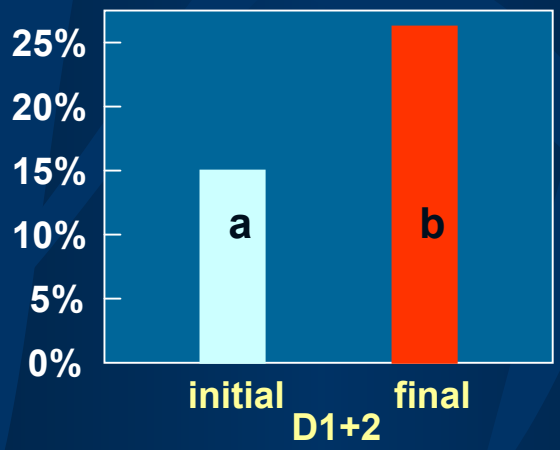
Hatching time in perch

Results





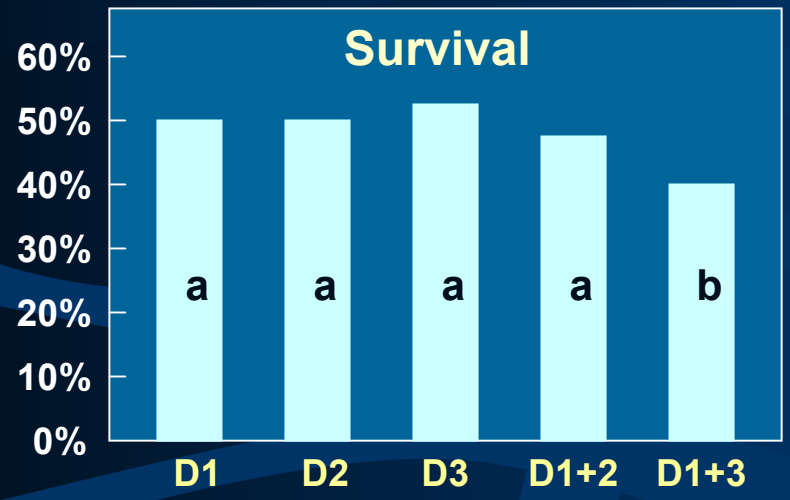


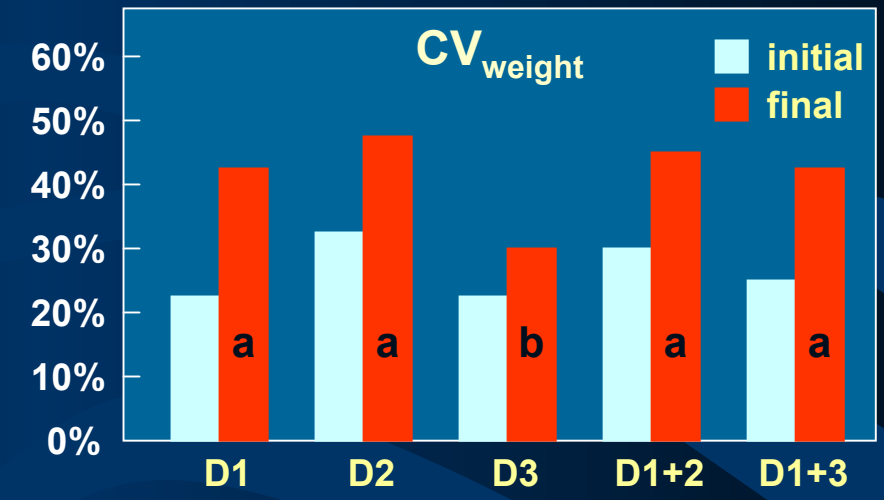


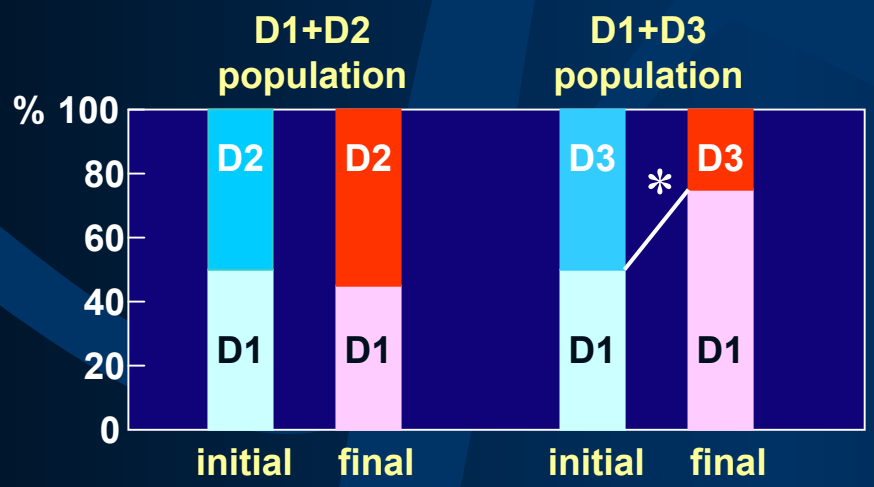
Proportion of larvae hatched on D1+2 in D1+2+3 mixed population

Hatching time in seabass

Results







Proportion of larvae hatched on day 1 within the initial and final mixed populations

Initial size heterogeneity

Material & Methods

Perch : larvae of 9mg and post-larvae of 85mg

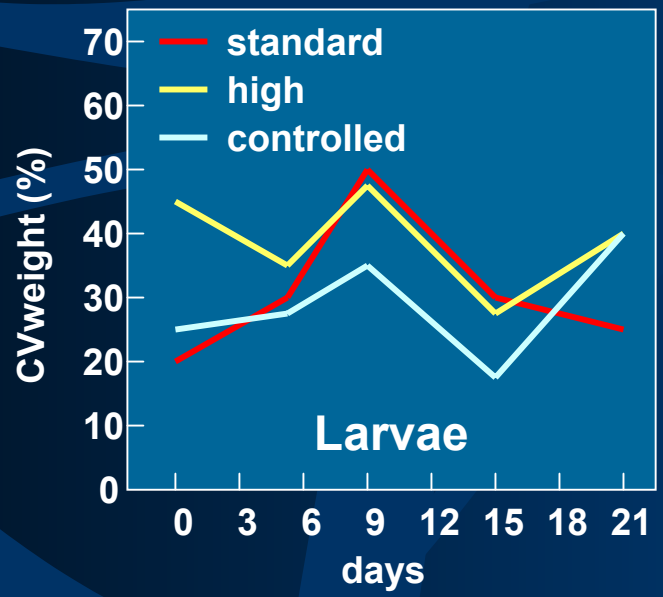
Seabass : post-larvae of 33mg

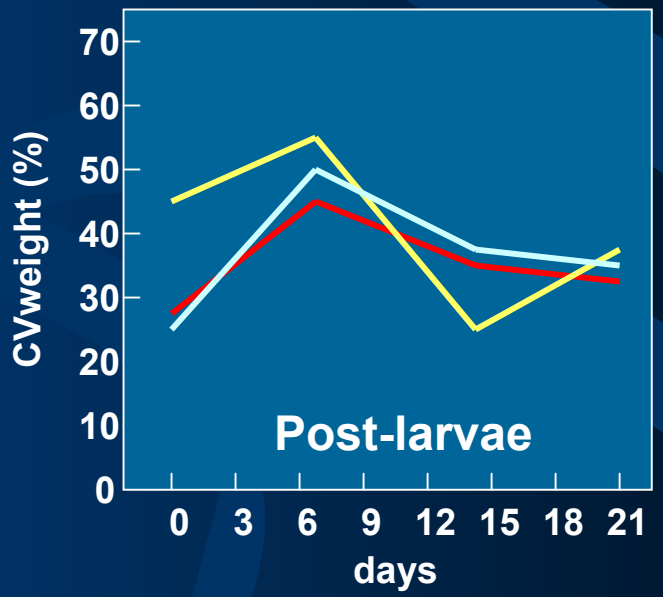
- Standard heterogeneity : larvae of same age reared under standard conditions
- High heterogeneity : larvae reared at 2 different densities to create size differences
- Controlled heterogeneity : same as standard, but weekly size-sorting of fish by removing potential cannibals and replacing them by medium size

Initial size heterogeneity in perch

Results

- No significant effect of size-sorting on survival, cannibalism and growth in perch larvae
- A significant increase of mortality due to cannibalism at high initial heterogeneity in perch post-larvae





- A fluctuating evolution of size heterogeneity due to a combination of differential growth and differential mortality

Stocking density
Material & Methods

Perch

- **Larvae (0.9 mg)**
  - Low density : 10 fish L^{-1}
  - Medium density : 32 fish L^{-1}
  - High density : 100 fish L^{-1}
- **Post-larvae (178 mg)**
  - Low density : 1 fish L^{-1}
  - Medium density : 3.2 fish L^{-1}
  - High density : 10 fish L^{-1}

Seabass

- **Larvae (0.45 mg)**

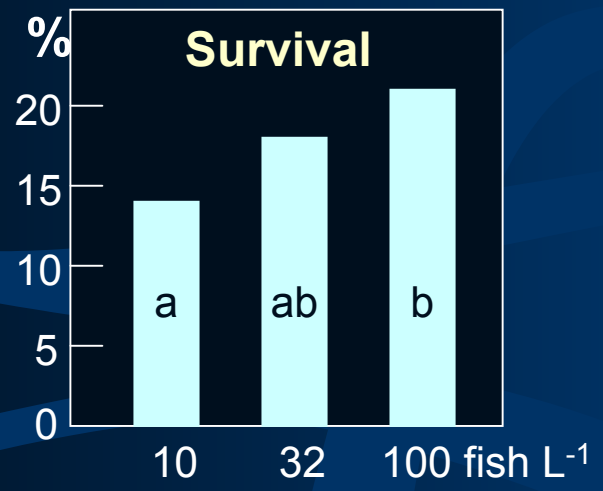
  50 - 100 - 150 - 200 fish L^{-1}
- **Post-larvae (26 mg)**

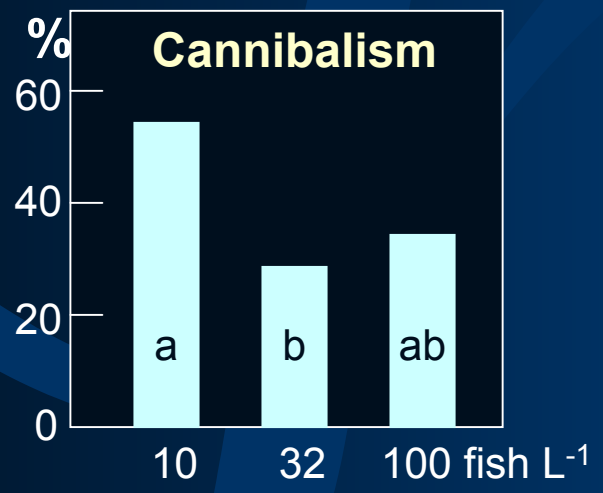
  5 - 10 - 15 - 20 fish L^{-1}

Stocking density in perch

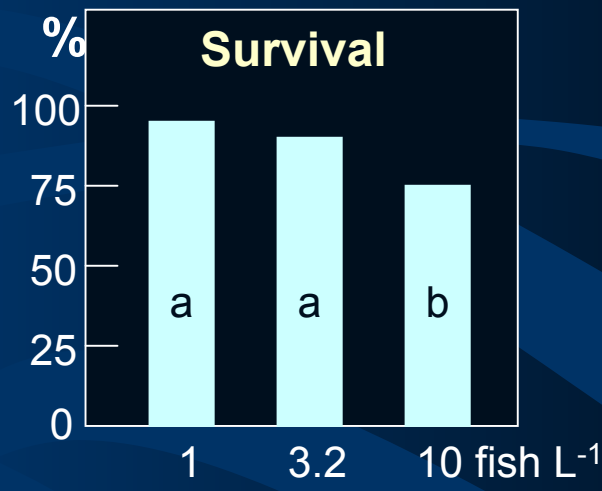
Results (1)

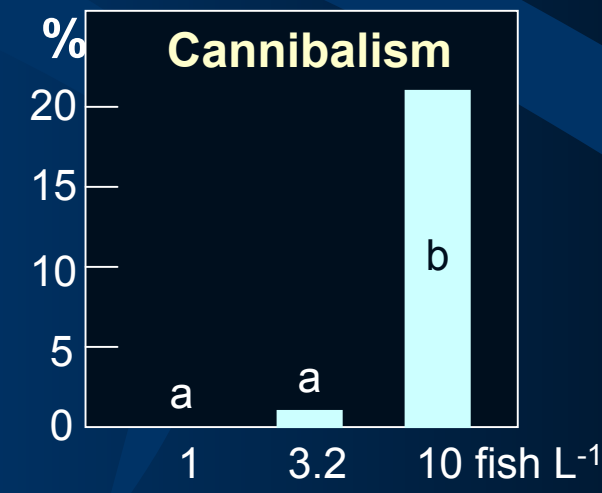
Larvae





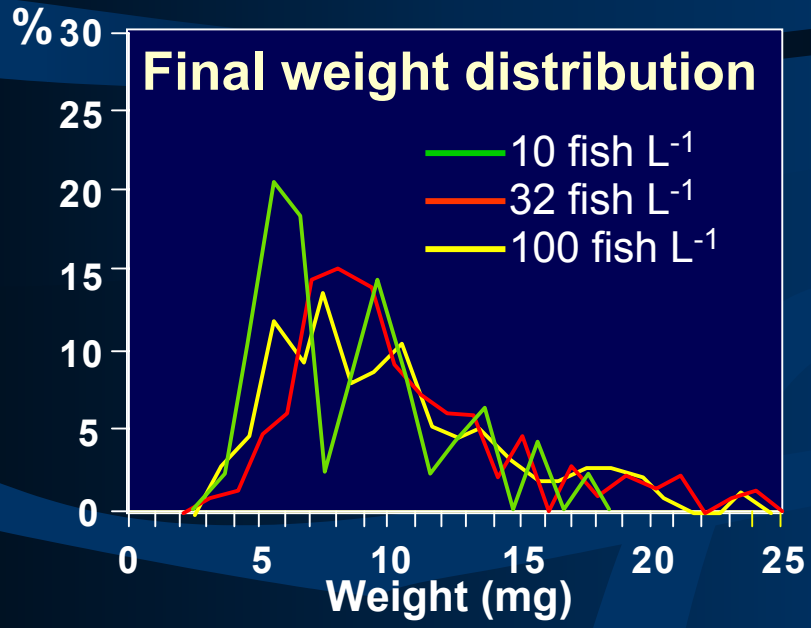
Post-larvae





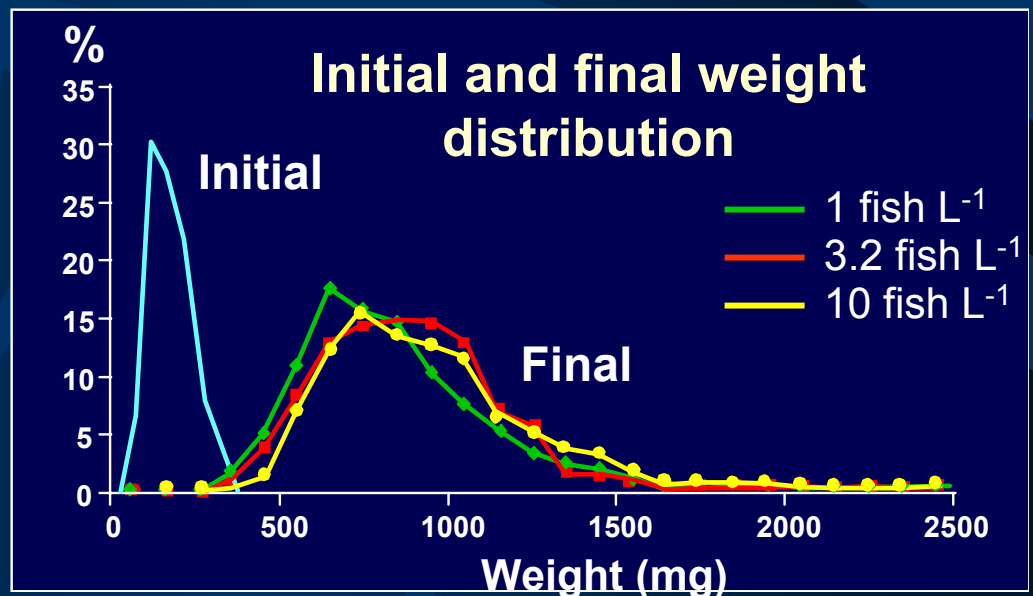
Stocking density in perch

Results (2)



⬅ Larvae

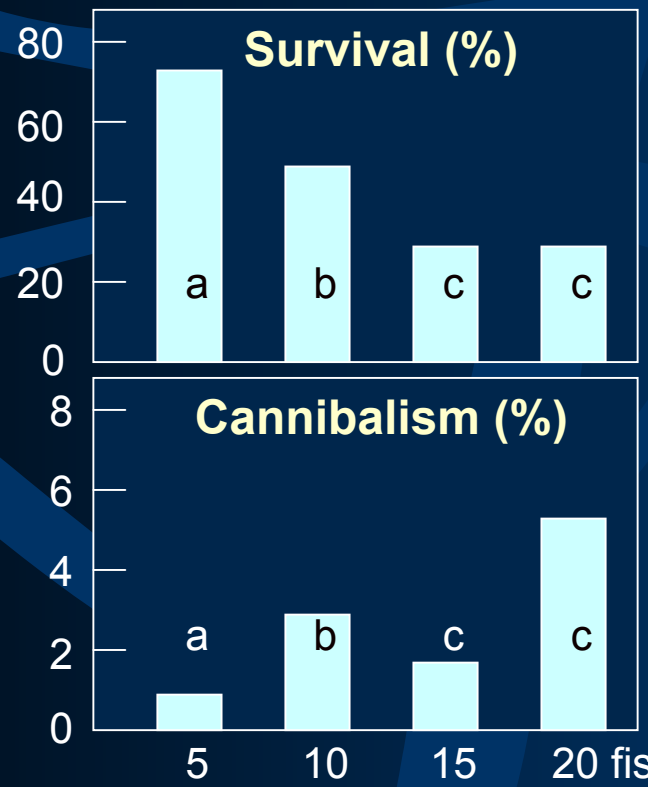
Post-larvae ➡

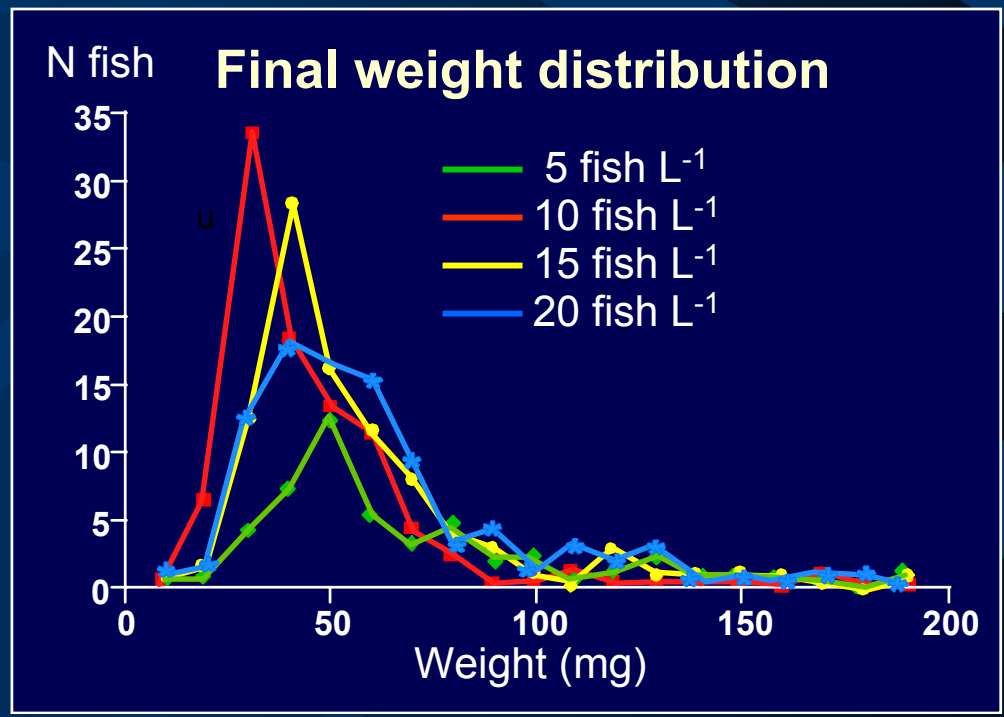


Stocking density in seabass

Results

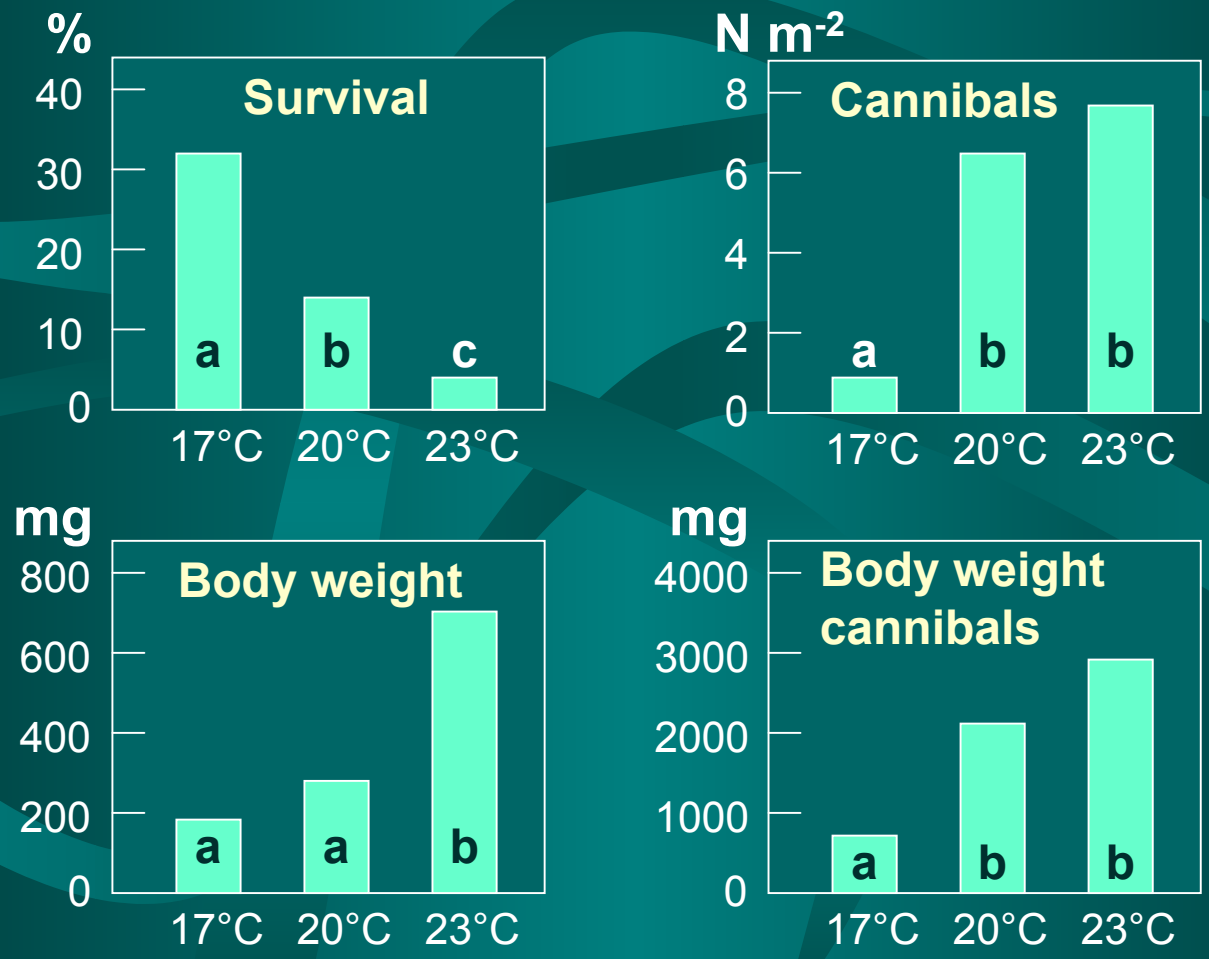
- No significant effect of stocking density in larvae but a significant increase of mortality and cannibalism at high stocking density in seabass post-larvae



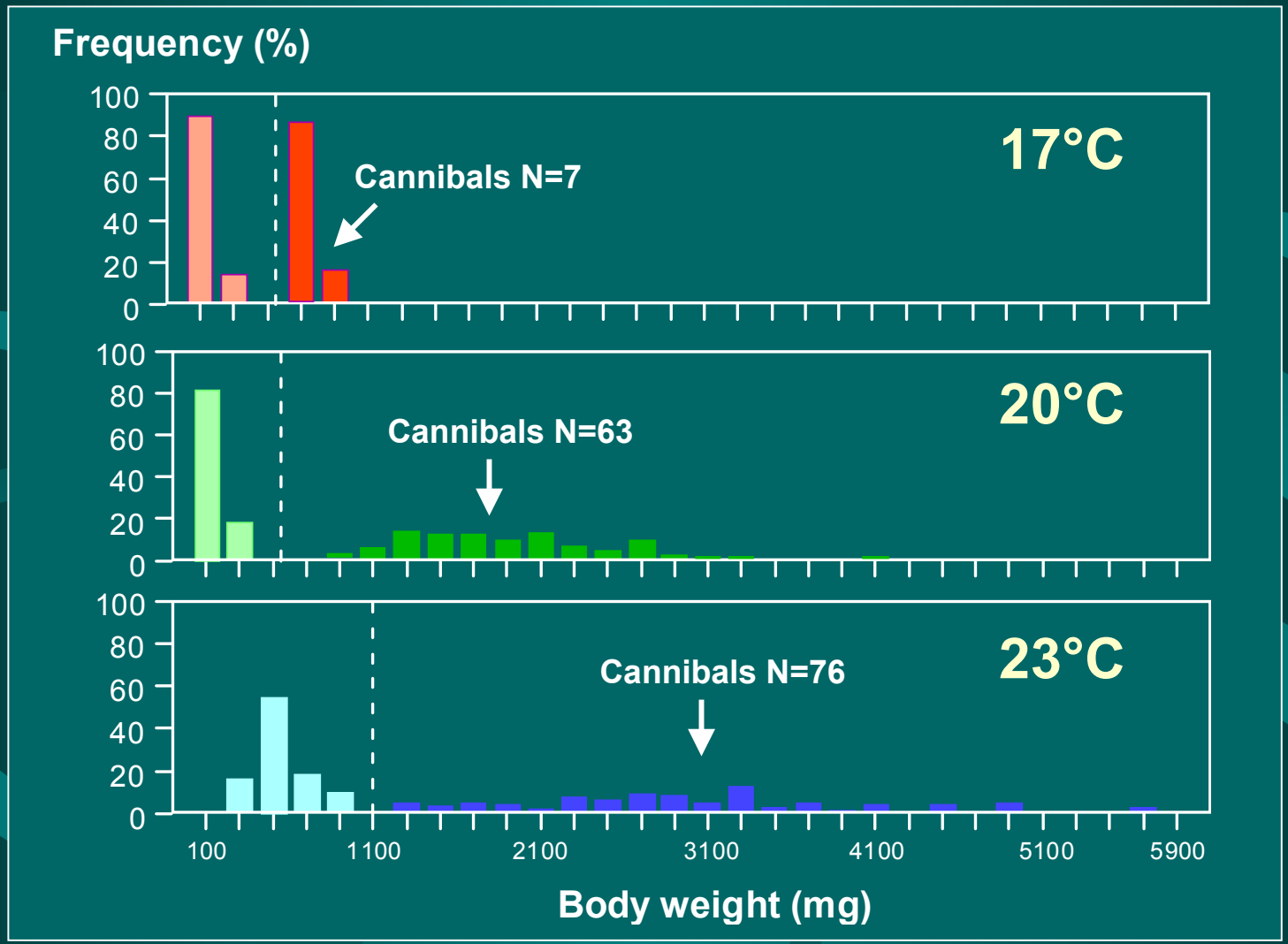


Temperature in perch

Stocking of newly-hatched larvae in 10-m^2 tanks during 45 days at 3 temperatures : **17°C - 20°C - 23°C**

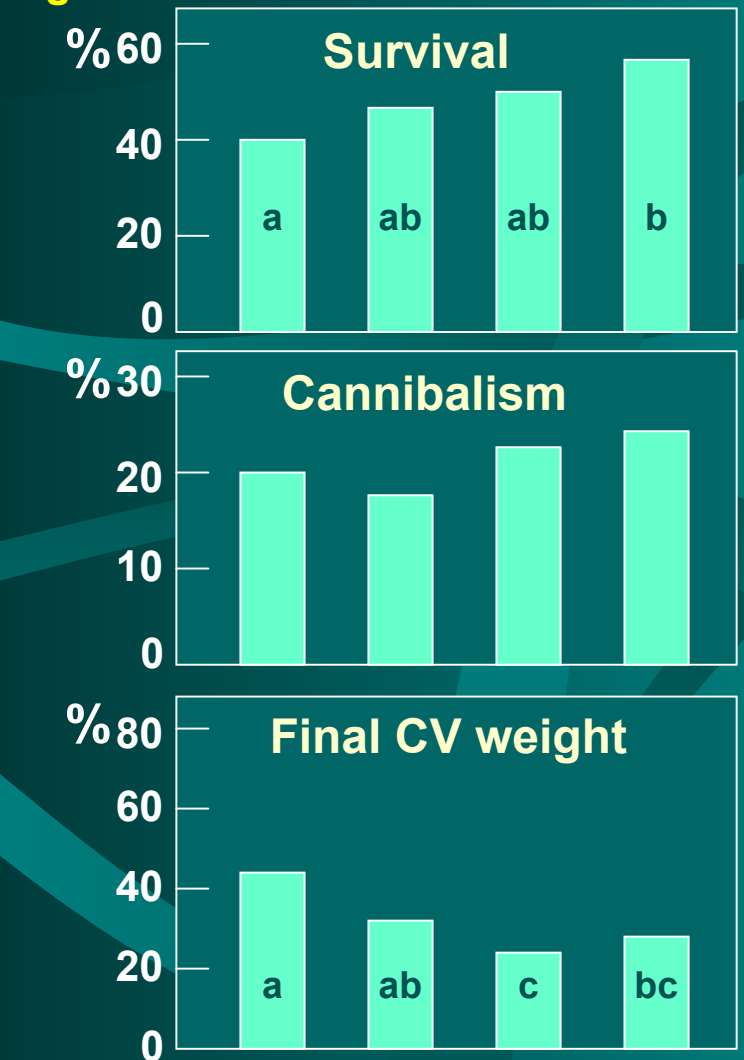


Temperature in perch (2)

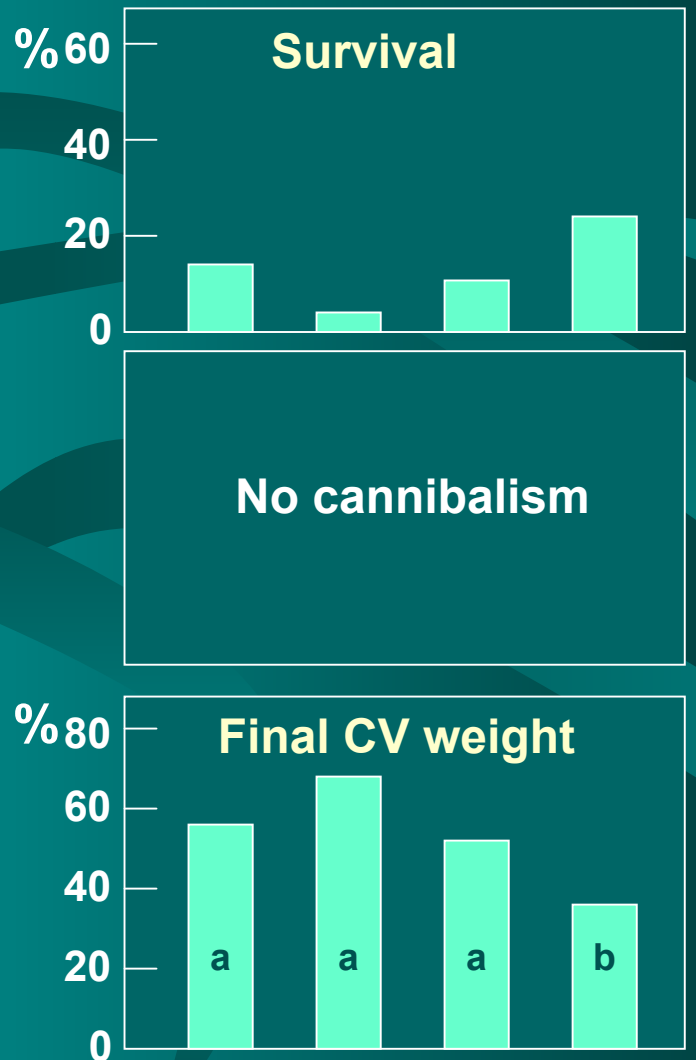


Photoperiod

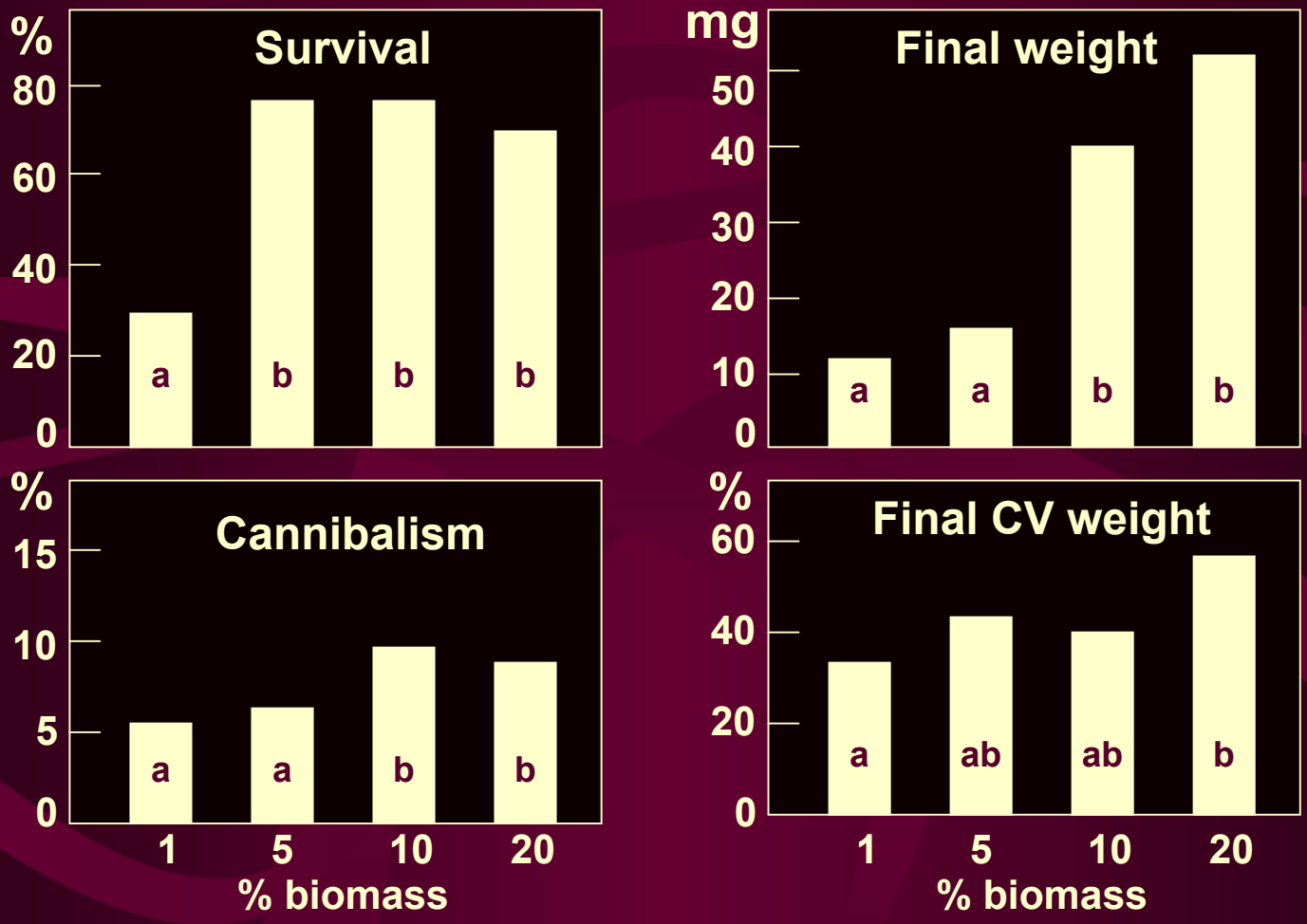
Perch larvae



Seabass larvae



Feeding level in perch larvae



Conclusions

A tentative summary of size variation causes

	Perch		Seabass	
	Larvae	Post larvae	Larvae	Post larvae
Population				
• Hatching time	+		+	
• Initial size variation	–	–	–	+
• Stocking density	–	–	–	–
Environment				
• Temperature	++	++	?	?
• Photoperiod	++	–	++	–
• Light intensity	–	–	?	–
Feeding				
• Feeding level	+	+	?	?
• Food composition	?	–	+	+

Conclusions (cont.)

- many factors are susceptible to induce or enhance growth depensation and multimodality in cultured larval population

- **imposed, interactive variables** (initial size variation, density) appear to affect predominantly survival and growth rather than final size variation

- **imposed, non interactive variables** (temperature, photoperiod, food availability) appear to affect predominantly final size variation, either directly or indirectly via interactive mechanisms such as cannibalism and size-dependent mortality