gh rough

o women

ti palatial

Ghoti Feeding & Growth

LO: extrapolate effects of the environment on feeding and growth of marine fish

Fresh Water vs Marine

Table 1.1 Comparison of traits of freshwater and marine teleost fish eggs and larvae.

Early life-history trait	Freshwater	Marine
Egg diameter (median, mm)	1.70[a]	1.02[a]
Egg buoyancy	Mostly negative[a]	Mostly positive[a]
Incubation period (days)	10.9 ± 0.27[a]	7.0 ± 0.33[a]
Hatching length (median, mm)	5.40[a]	2.87[a]
Hatching dry weight (μg)	359.7 ± 72.8	37.6 ± 6.4
Metamorphic dry weight (mg)	9.3 ± 1.6	10.8 ± 0.95
Larval duration (days)	20.7 ± 1.1	36.1 ± 1.1
Metabolic rate ($\mu l\ O_2\ mg^{-1}\ h^{-1}$)	2.8 ± 0.4	5.9 ± 0.4
Ingestion rate ($\mu g\ \mu g^{-1}\ day^{-1}$)	0.46 ± 0.09	0.57 ± 0.07
Growth rate ($\mu g\ \mu g^{-1}\ day^{-1}$)	0.18 ± 0.02	0.20 ± 0.01
Growth efficiency	0.32 ± 0.03	0.29 ± 0.3
Instantaneous mortality (day^{-1})	0.16 ± 0.04	0.24 ± 0.02
Expected larval mortality (%)	94.7	99.9
Starvation risk	Lower	Higher
Larval mortality	Density-independent	Density-dependent
Stage for recruitment regulation	Juvenile period	Larval period
Recruitment variability	Lower	Higher

Fuiman 2002

ELH Classification Stages

Table 1.2 Modern intervals (roman text) for early stages of fishes and the criteria (italic text) used to separate them.

Balon (1975b)	Ahlstrom *et al.* (1976)	Snyder (1976)	Hardy (1978)
Eleutheroembryo	Yolk-sac larva	Protolarva	Yolk-sac larva
Yolk absorption	*Yolk absorption*	*First median fin ray*	*Yolk absorption*
Protopterygiolarva	Preflexion larva	Mesolarva	Larva
First median fin rays	*Urostyle flexion*	*Adult median fin ray complement and pelvic buds or fins*	*Adult fin ray complement*
Pterygiolarva	Flexion larva	Metalarva	Prejuvenile
	Adult caudal fin ray complement		
	Postflexion larva		

Fuiman 2002

Setting the Stage

Hjort 1914

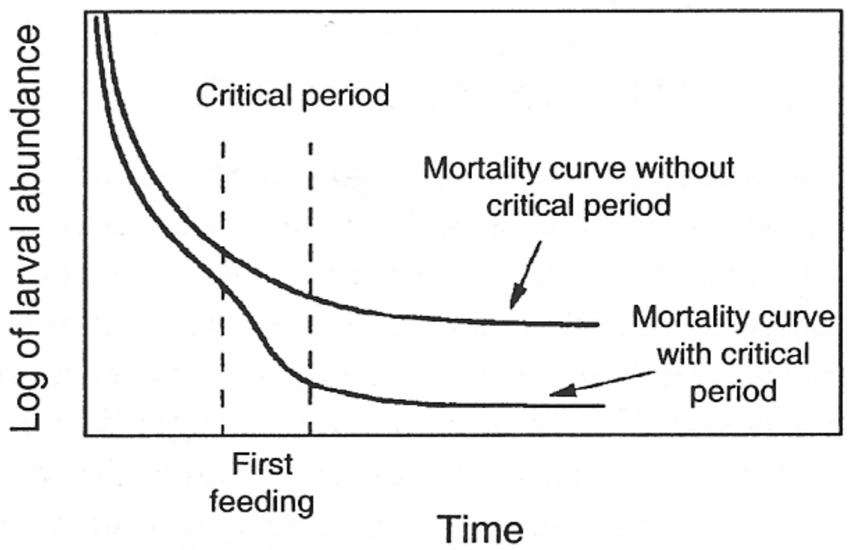
"...it was difficult to avoid the conclusion, that the actual quantity of eggs spawned is not a factor in itself sufficient to determine the numerical value of a year-class."

two hypotheses: (1) feeding during the critical period, and (2) transport away from nursery areas (i.e. Aberrant Drift)

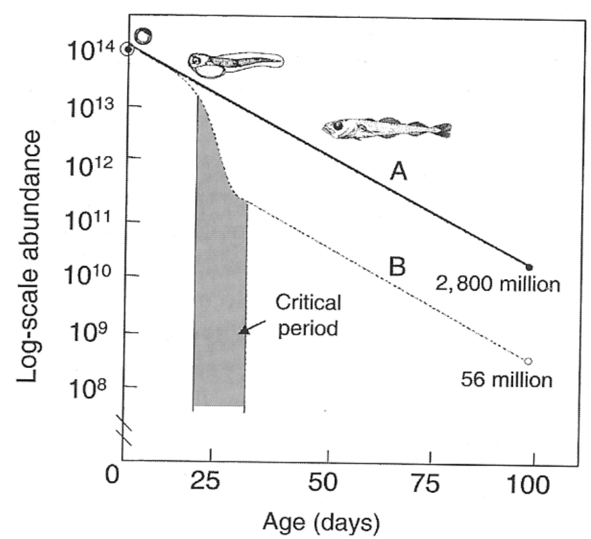
Foundation: Hjort, Cushing, and Lasker

Hjort's Hypotheses

1. Critical Period Hypothesis: when food limited larval mortality high, low mortality when food abundant
2. Aberrant Drift: variation in survival (due to starvation) causes variability in cohort strength



Leggett & Deblois 1994

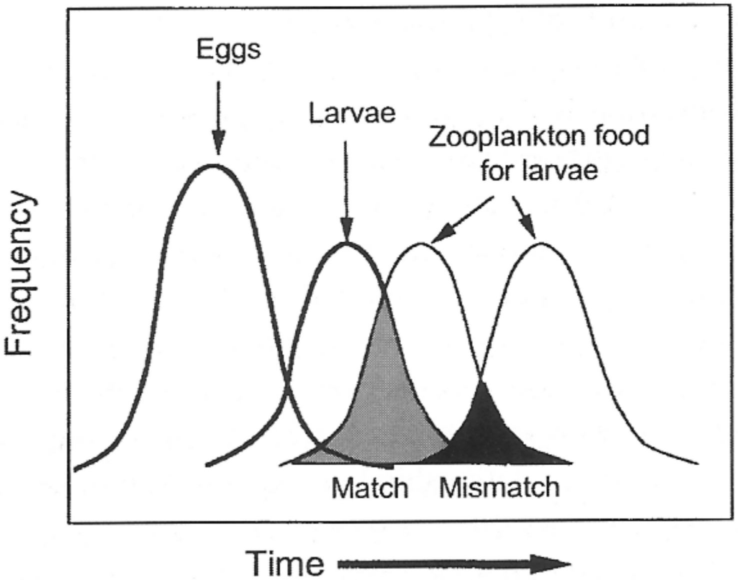


Houde 2002

Cushing Match-Mismatch

- fish spawn in relation to plankton blooms in areas of inferred larval drift from spawning to nursery grounds
- if spawning is fixed and bloom is variable, then survival and recruitment will be variable

- added critical depth (total photosynthesis balanced by plant respiration) as space limitation for primary and secondary production
- Advantage: removes restriction of starvation-based mortality during a critical period, can occur at any time
- empirical evidence to support hypothesis is equivocal

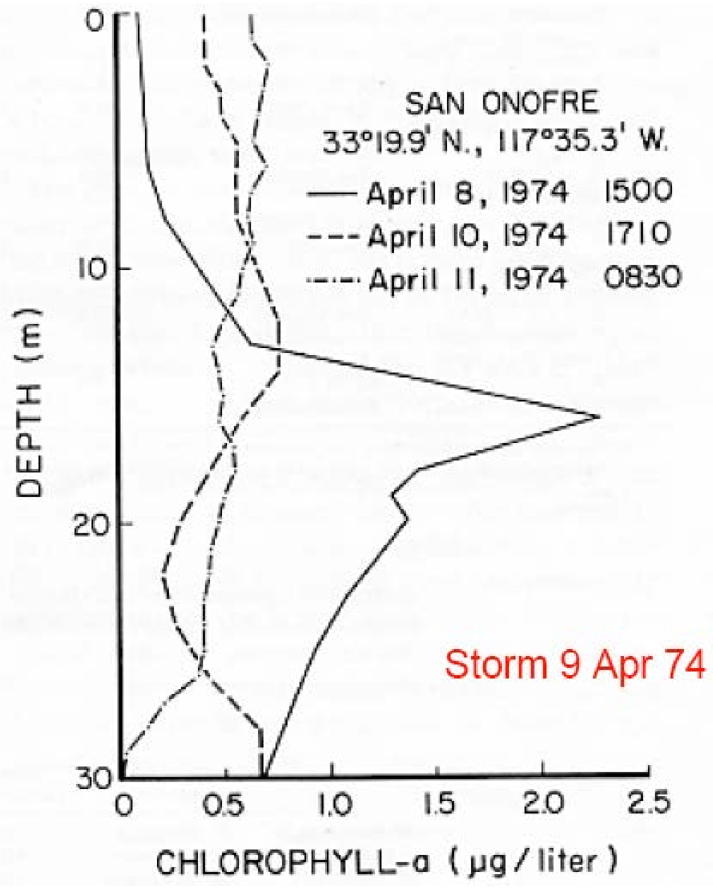


What's wrong with this picture?

Cushing 1972, 1974

Lasker's Stable Ocean Hypothesis

- average concentration of food in the sea is less than that necessary for fish larvae to grow and survive in the lab
- concentrations of food were associated with chlorophyll maximum layers in stratified water
- storm events disperse layers



Result:

- recruitment will be low during stormy years; correlate recruitment with cube-of-the-wind-speed (i.e. turbulence), upwelling, and wind-curl indices

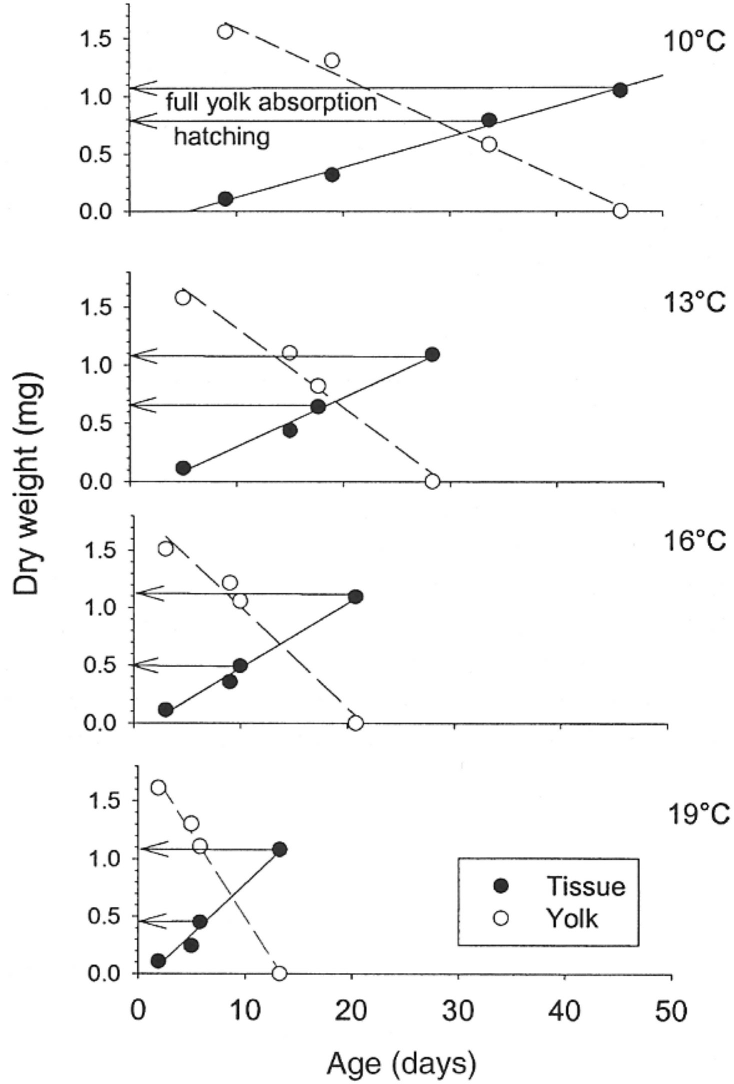
- tested using captive anchovy larvae feed in water from specific depths, inspect gut contents

Yolk-sac Duration

- transition from endogenous to exogenous nutrition

- species, egg size, and temperature dependent

- energy conversion efficiencies ~ 34-52%



1.08 mg dry wt at transition, regardless of temperature 10-19^{o}C

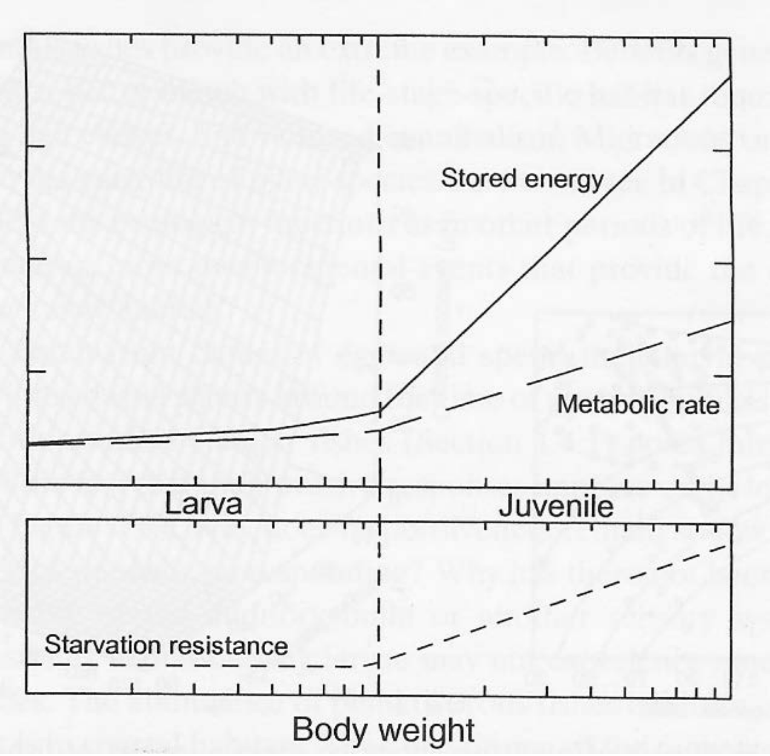
Kamler et al. 1998

Larval First Feeding & Starvation

- starvation resistance: balance between metabolism and energy reserves

- point of no return related to body size (i.e. energy reserves) and temperature: 5-10^{o}C 20-35 days, 25-30^{o}C 4-5 days

- starvation risk lowers with age/size: lower wt-specific metabolism, higher energy reserves, improved sensory and swimming performance, increased prey size range



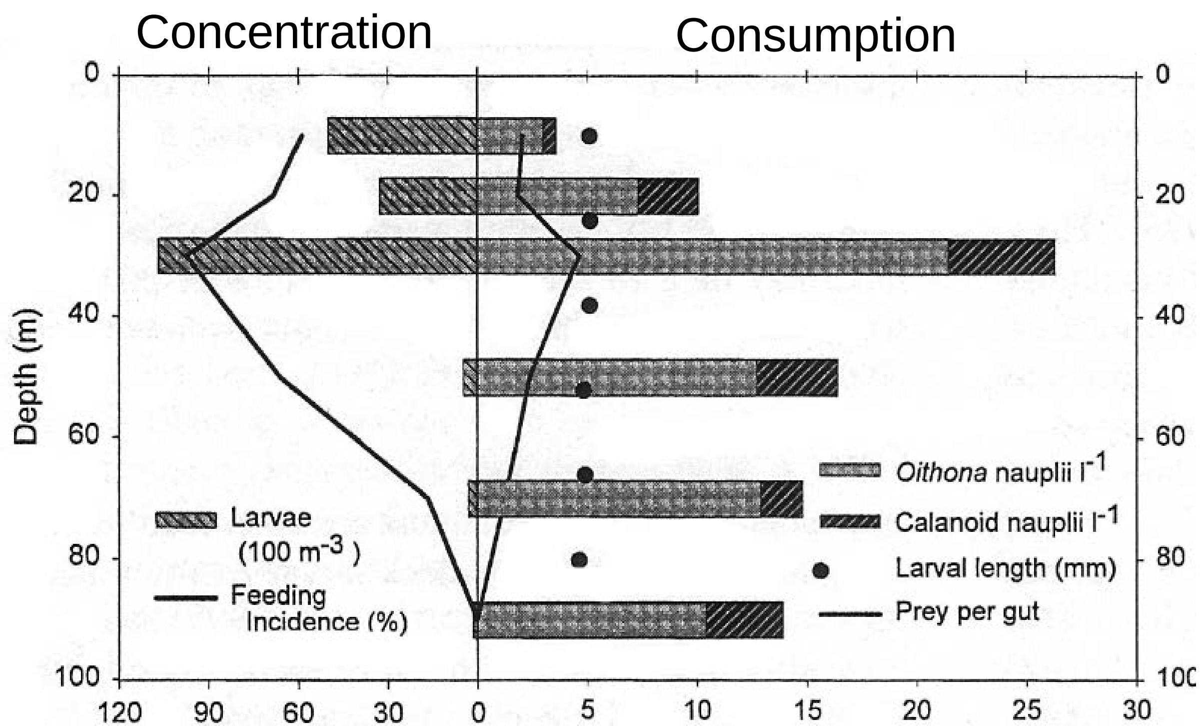
Example

- walleye pollock up to 32% mortality day^{-1} for first feeding larvae ≤ 6.5 mm; 100 – 400 μm prey diameter (Theilacker et al. 1996)

Fuiman 2002

Walleye Pollock Larval Feeding

- modify swimming in presence of food: turn more frequently, slower, more horizontal than vertical orientation
- vertical orientation used to change depth
- all help maximize contact rates with prey



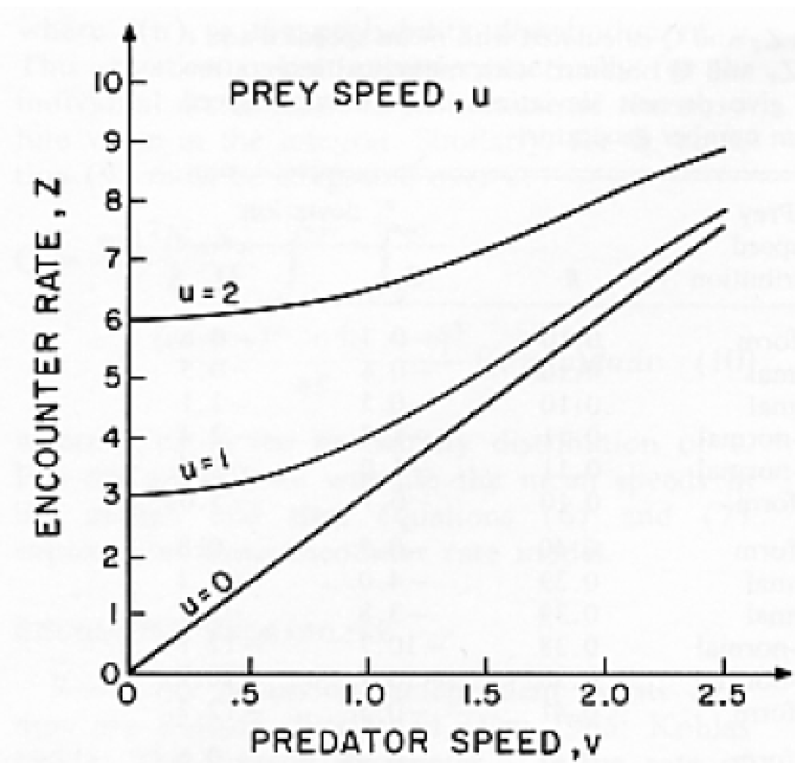
- diet: copepod nauplii, rotifers
- depth preference 30 m with prey

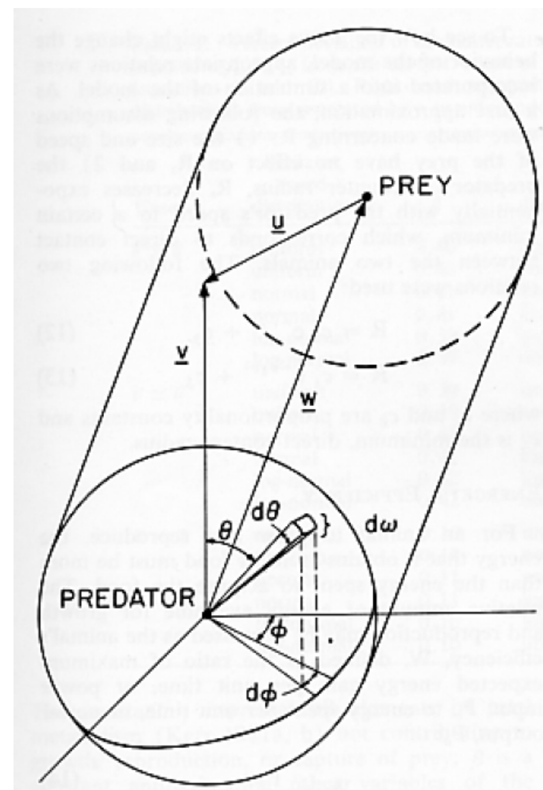
Hillgruber et al. 1995

Potential Contact Rates

Relevant Factors: predator speed, prey speed, water motion

Gerritsen & Strickler (1977): encounter probabilities based on predator and prey speeds





Potential Contact Rates

Rothschild and Osborne (1988): added turbulence (i.e. water motion) to model

$$A = \frac{(u^2 + 3v^2)}{3v} \rightarrow \frac{(u^2 + 3v^2 + 4w^2)}{3(v^2 + w^2)^{1/2}} \text{ for } v > u$$

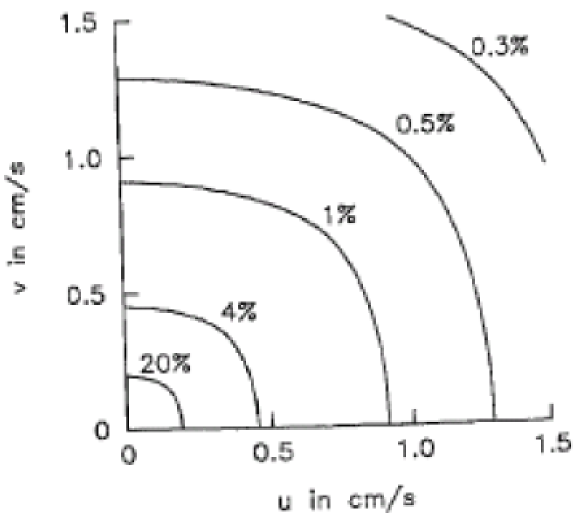
$$A = \frac{(v^2 + 3u^2)}{3u} \rightarrow \frac{(v^2 + 3u^2 + 4w^2)}{3(u^2 + w^2)^{1/2}} \text{ for } u > v$$

A = relative velocity of predator and prey

u = prey velocity

v = predator velocity

w = rms turbulent velocity



w = 0.1 cm s^{-1} turbulent velocity

- contours show contact rates as a function of *u* and *v*
- provides link between ocean and individual scale events (i.e. circulation to feeding)

Growth General Characteristics

- indeterminate due to buoyancy

- size (length, weight) is a monotonic increasing function of age, can seasonally fluctuate

- growth products are capable of growth: exponential and allometric

- specific growth rate (d log(W)/dt) is a declining function with age, acceleration of growth is always negative (d^2 log(W)/dt)

- specific growth rate declines (i.e. slower with age)

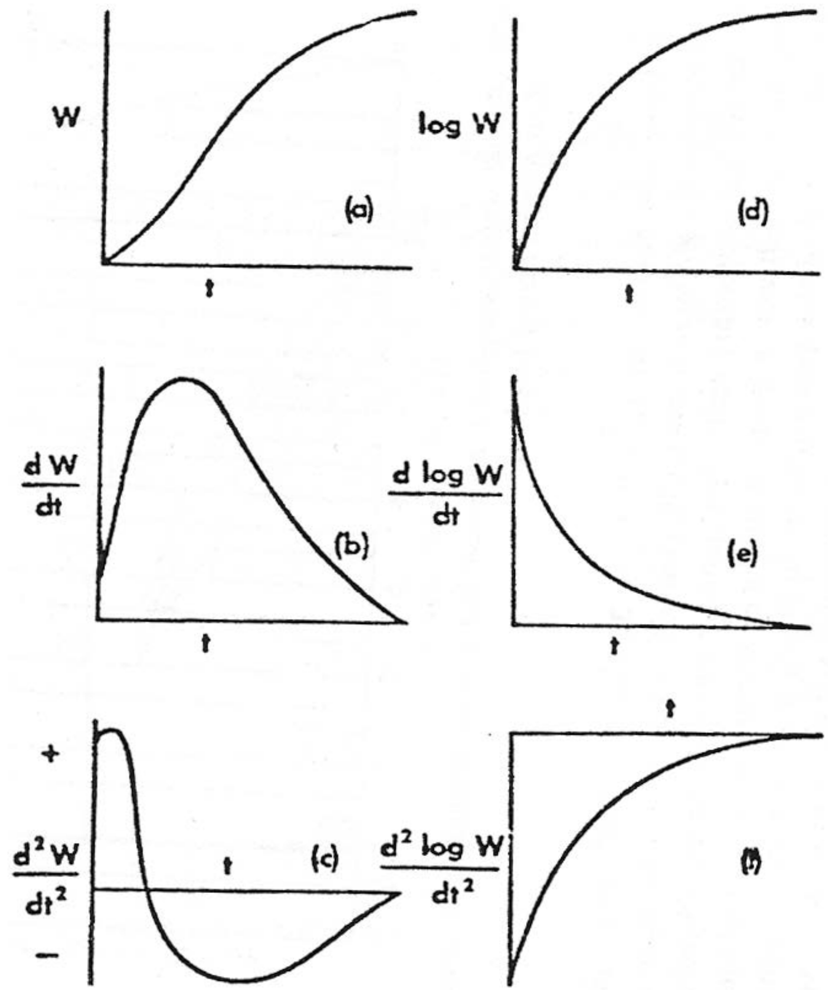
Growth General Characteristics

Linear Logarithmic

growth

growth rate

change in growth rate



Factors Affecting Growth

- parents: egg size, genetics (tough to demonstrate due to plasticity)

- temperature: regulates metabolism and activity (low at extremes)

- food size: preference limited by mouth gape size

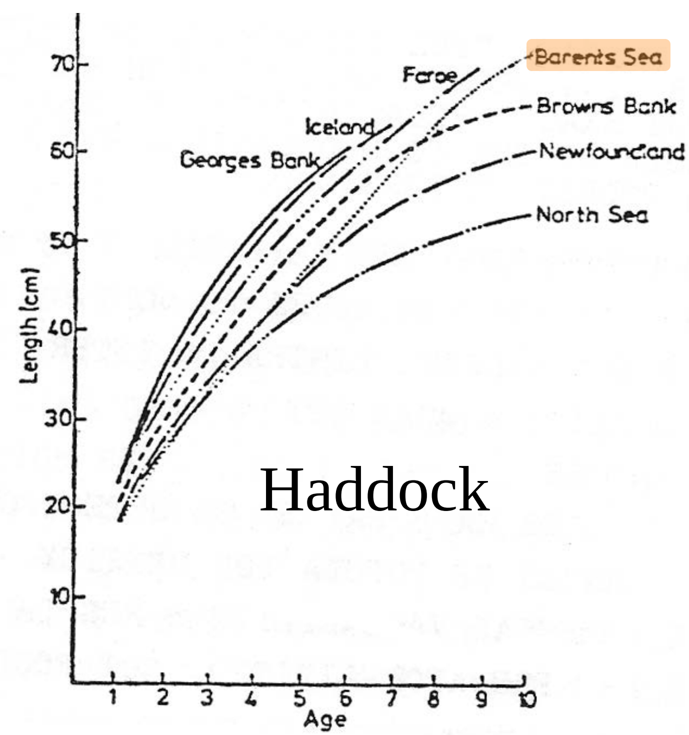
- food quality: energy density (max. energy gain per bite)

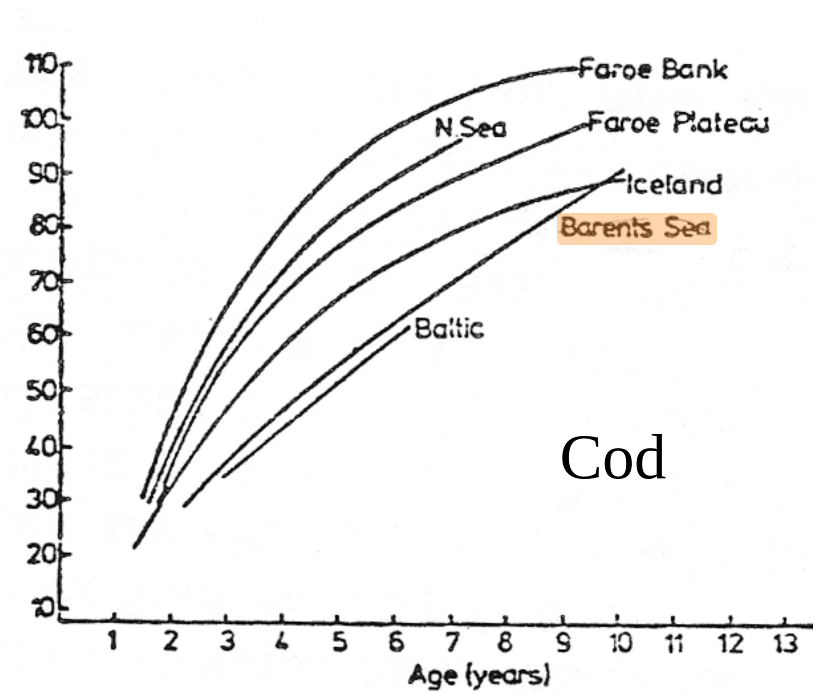
- density-dependent effects (from ponds to open ocean)

Food Size Effects

Haddock and Cod – compare Barents Sea growth curves (linear) to others (exponentially declining)

- growth independent of age (i.e. constant), prey switching from plankton to capelin



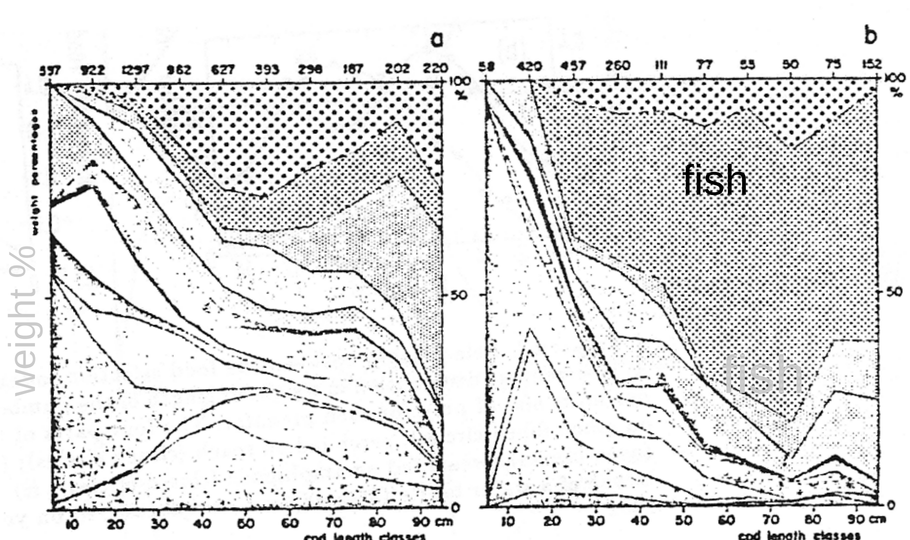


Food Size Effects

North Sea Cod

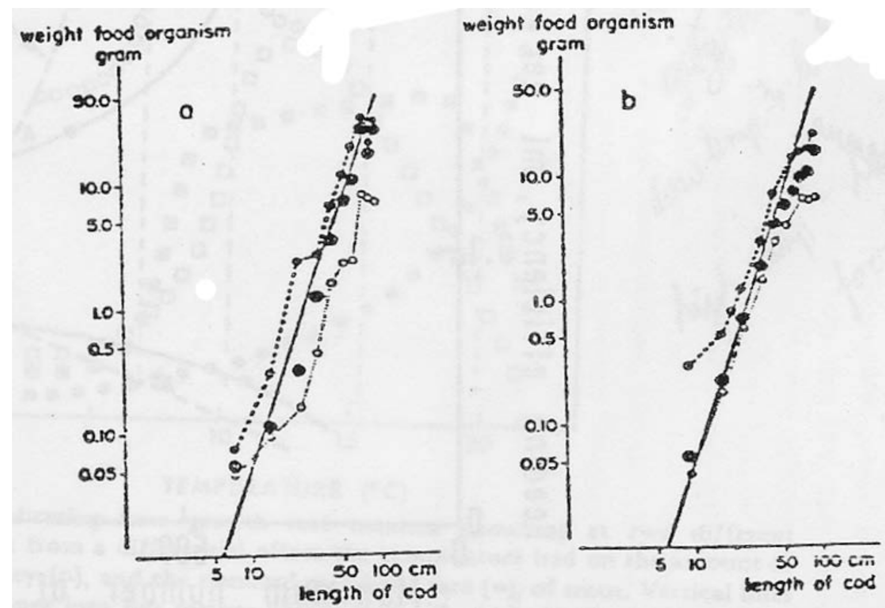
- southern: initially grow faster then decline, diet changes
- northern: make full transition to piscivory, water temperature lower

south north



length (cm)

north south



Density-Dependent Effects?

Plaice and Haddock in North Sea

- growth changes before (fishing), during (no fishing), and after (fishing) World War II (Beverton & Holt 1957) (natural experiment)

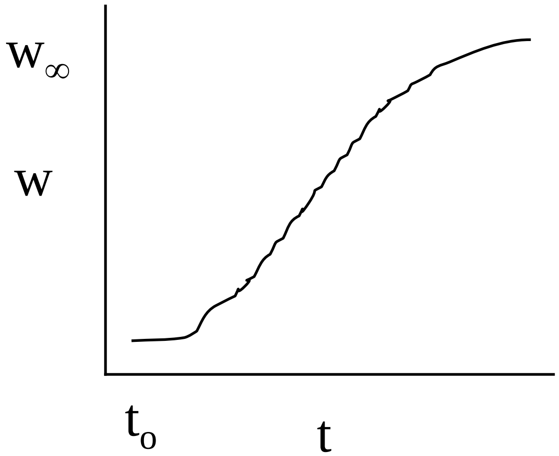
- Plaice: no difference in growth before and after WW II despite population doubling in biomass, terminal weight from 3.2 kg to 2.2 kg during war, density 3x higher

- Haddock: negative relation between abundance and length in west and central Atlantic but not eastern N. Sea.

Generally density-dependent growth observed among younger than older fish, more prevalent in space-limited conditions (e.g. aquaculture, ponds, lakes)

Growth Models

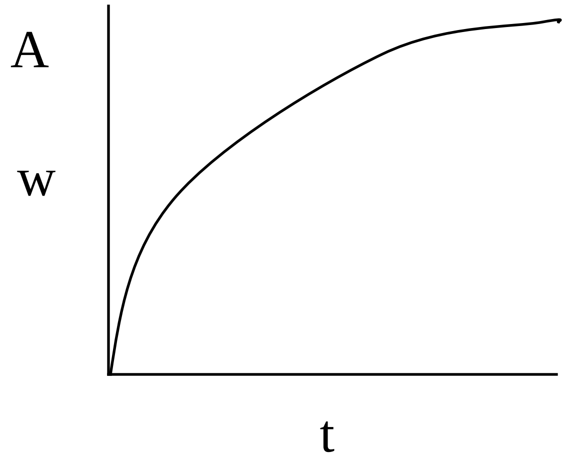
von Bertalanffy



asymmetric sigmoid

$$W_t = W_\infty \left(1 - e^{-K(t-t_0)}\right)^3$$

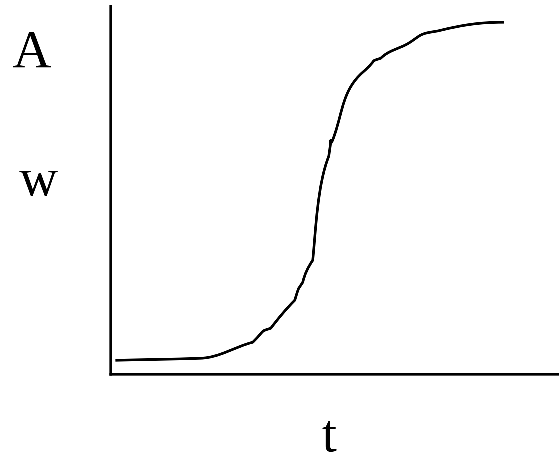
Gompertz



exponentially declining

$$W_t = A e^{(-b e^{-ct})}$$

Logistic



symmetric sigmoid

$$W_t = \frac{A}{1 + b e^{-Akt}}$$