Kinematics

LO: extrapolate effects of physical conditions on the kinematics of ELH stages of fish

Ocean Kinematics

1. General Circulation: ocean basin stirring due to inertial or climatic forcing
2. Turbulent Mixing: dissipation of mechanical energy - weather events, boundary layers, seiches, and Langmuir cells
3. Transitional range: dissipating energy of turbulence exceeded by water viscosity (R_e = 500 to 2000)
4. Viscous range

Kolmogorov 1941

Passive & Active Locomotion

1. Reynolds Number R_e = advection or inertia /friction

Low

high friction and low velocity or short length scales (molecular viscosity is important)

High

high velocity or long length scales and friction is low

laminar flow

Transition

turbulent flow

R_e=1000

Life at Low Reynolds Numbers

$R_e = u L \rho / v$

= horizontal velocity x Length x density/ molecular viscosity
(horizontal friction)

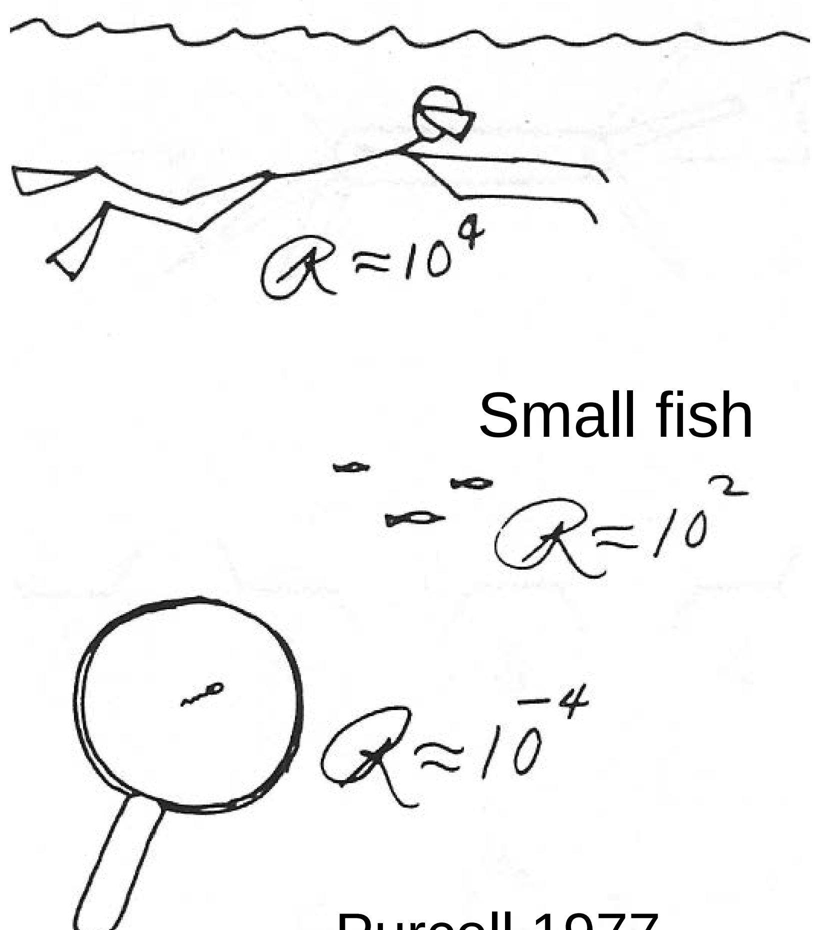
Low R_e (<1) inertial effects negligible since motions are reversible
(i.e. no direction)

Plankton $R_e \sim 10^{-5}$ to 10^{-4}
Chlamydomonas cell 10^{-5} m diameter, *u* 10-5 ms^{-1}(requires 0.5 W kg^{-1})
(Purcell 1977)

What about larval fish?

Relative Reynolds Numbers

Power to
Thrust
efficiency



Small fish

Caudal fin:
96%

flagellum:
1%

Efficiency of fish tail is a function of length

La Barbera 1983

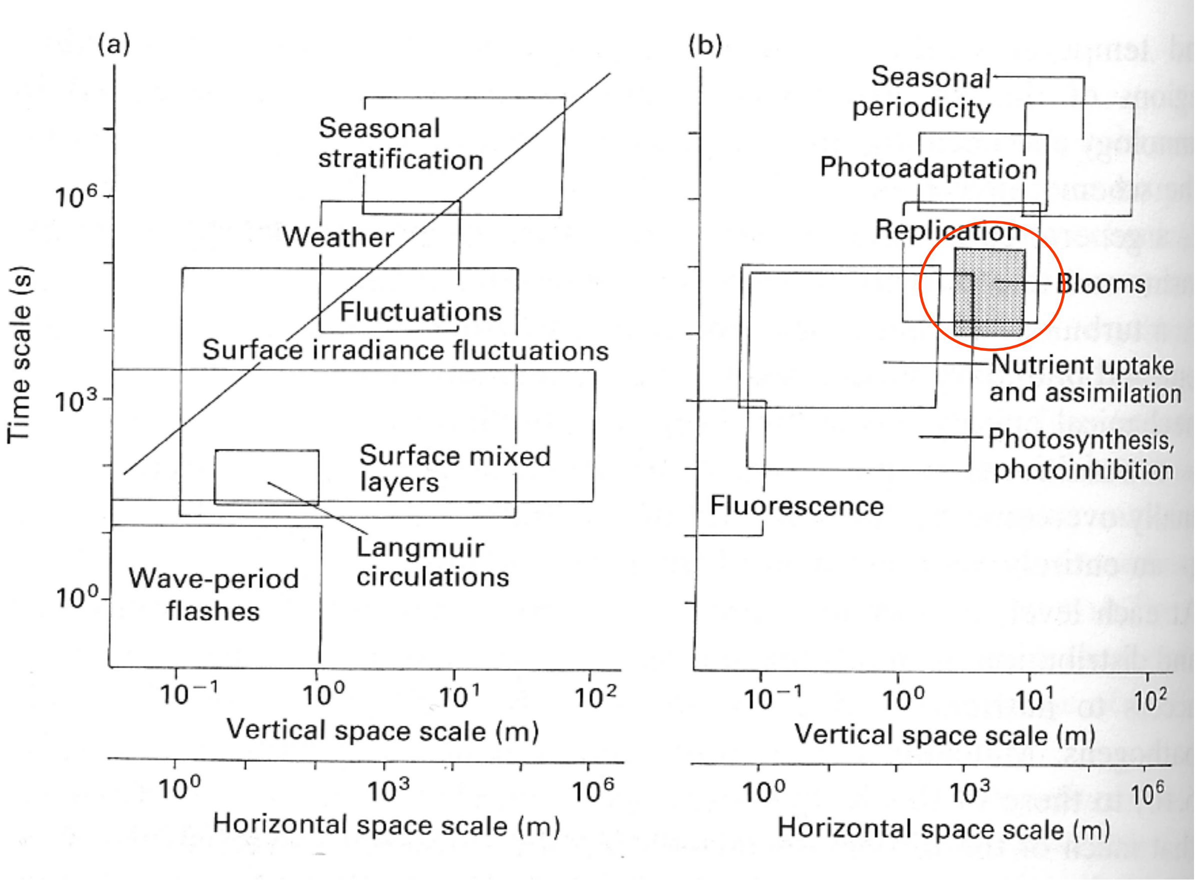
Purcell 1977

(Webb 1977)

Larval Prey Field Scales

Physical Process

Biological Responses

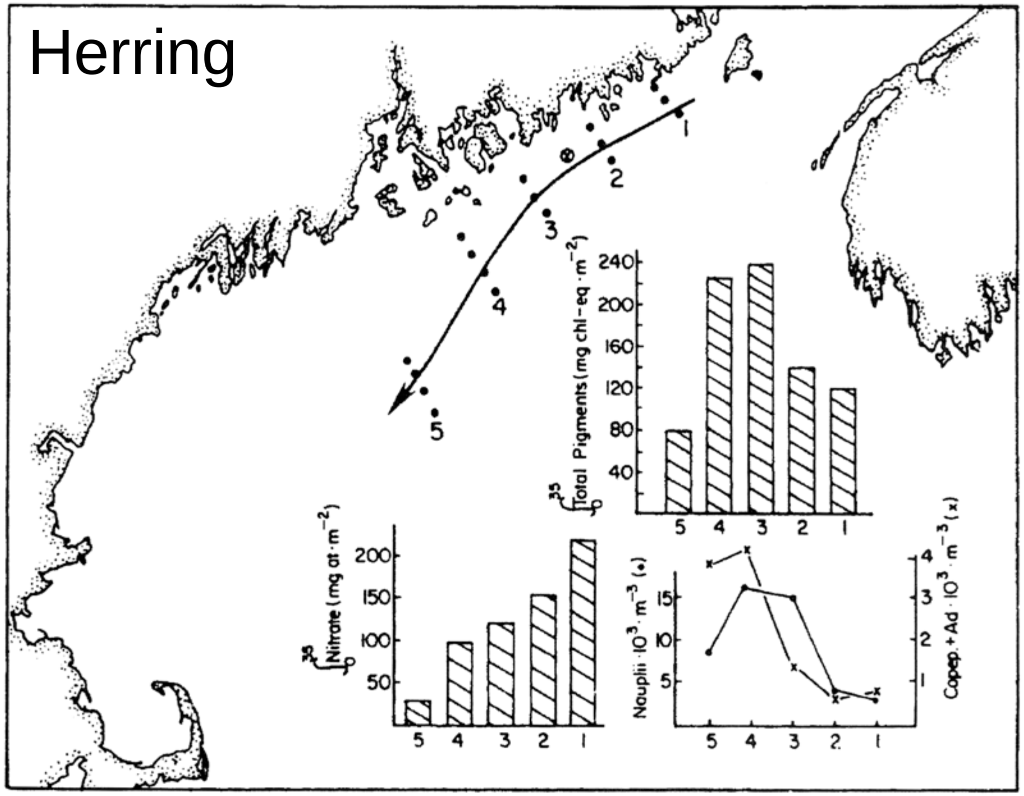


Blooms = Larval fish food

Phytoplankton Stommel Diagram

Reynolds 1994

Hjort's Second Hypothesis Extended

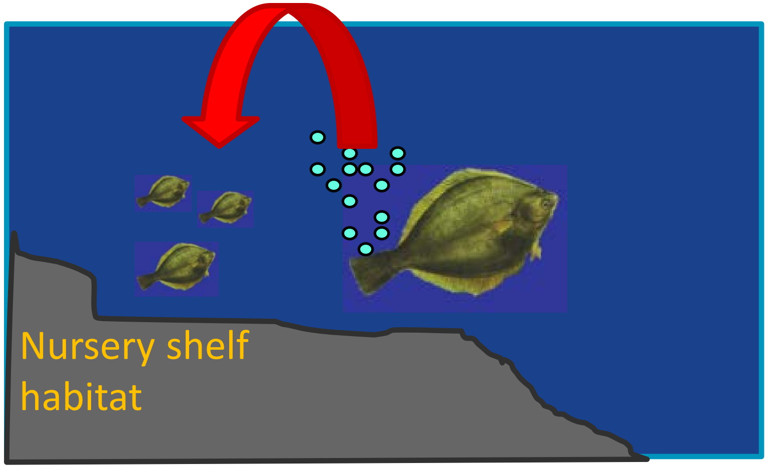


- displacement of spawning products away from nursery areas can be detrimental
- inter-annual differences in ocean circulation will determine transport
- consistent spawning areas: at head of coastal conveyor belts (Townsend 1992), or fronts/gyres member/vagrant hypothesis (Iles & Sinclair 1982)

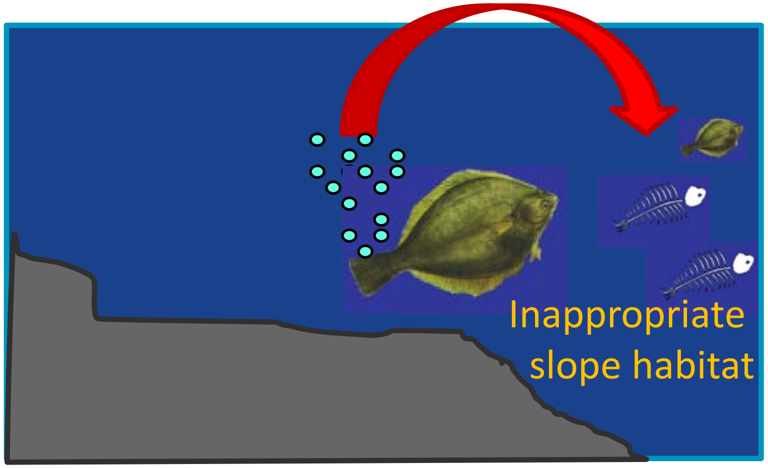
- larvae travel through areas of increased prey
- move to stratified water and bloom

Larval Retention and Drift

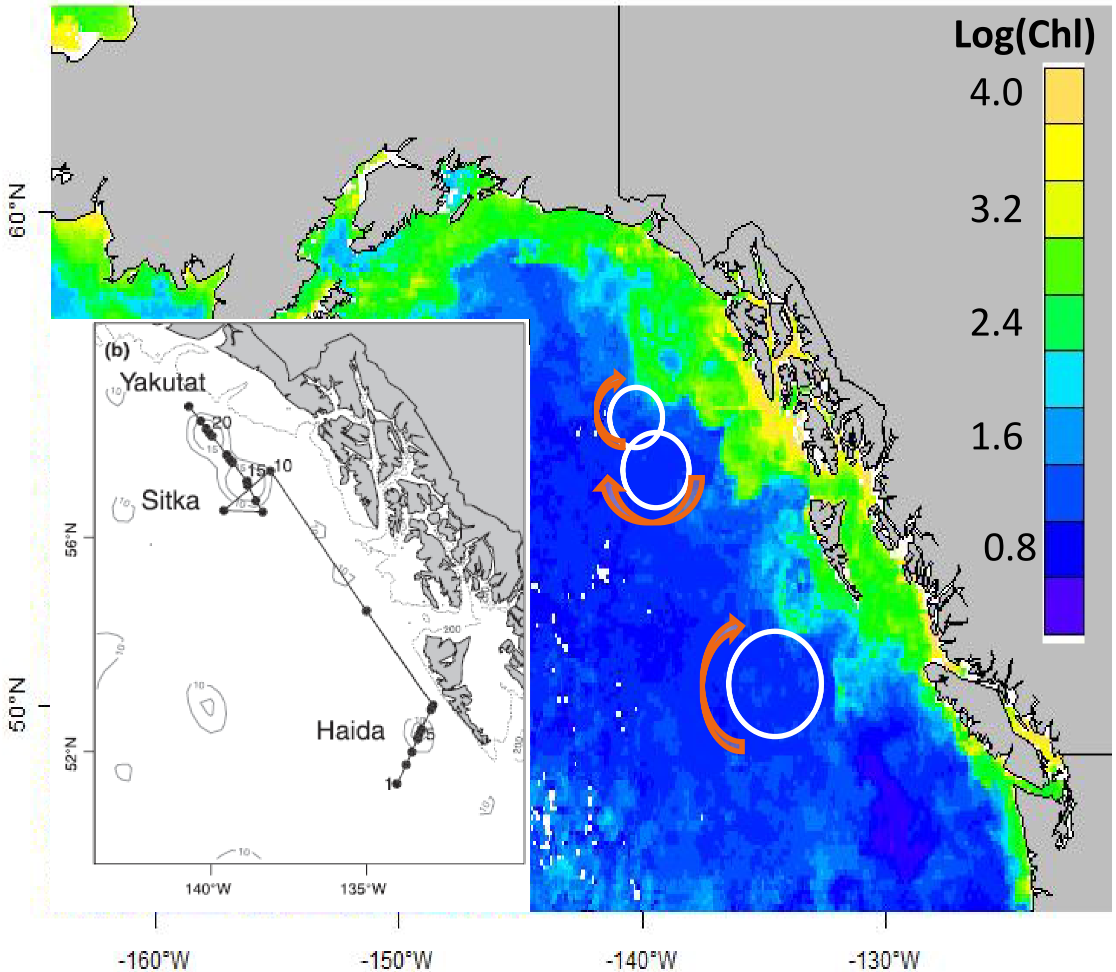
Beneficial



Detrimental



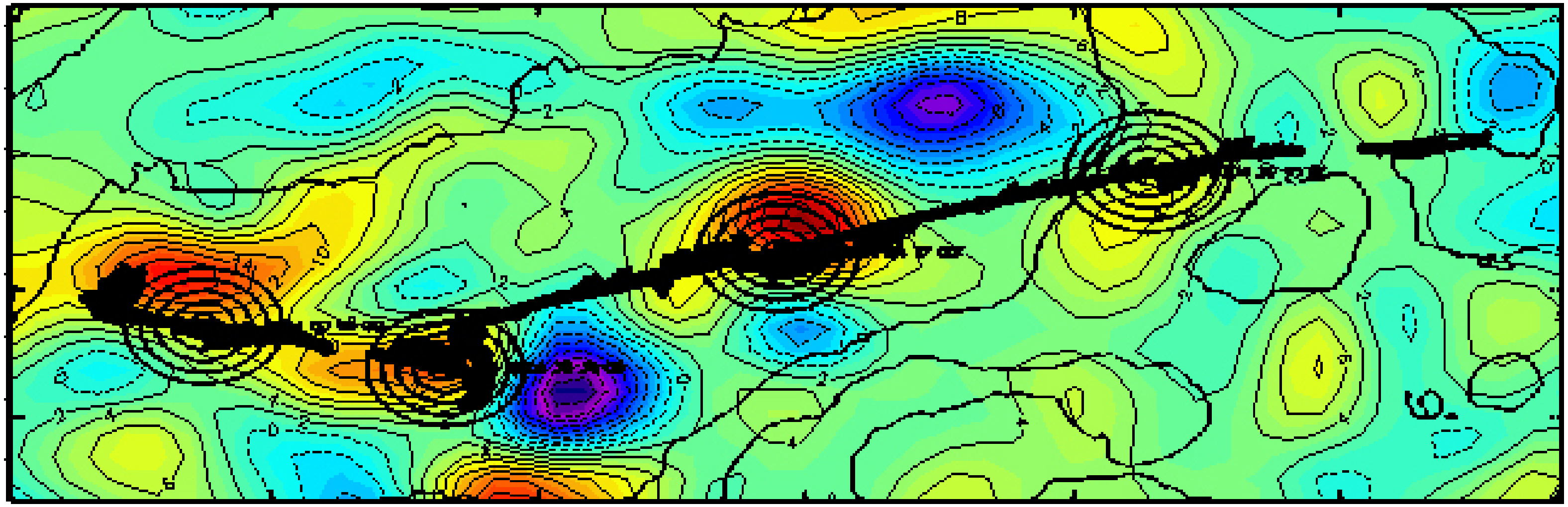
Dispersal through Entrainment and Retention in Gyres



Atwood et al. 2010

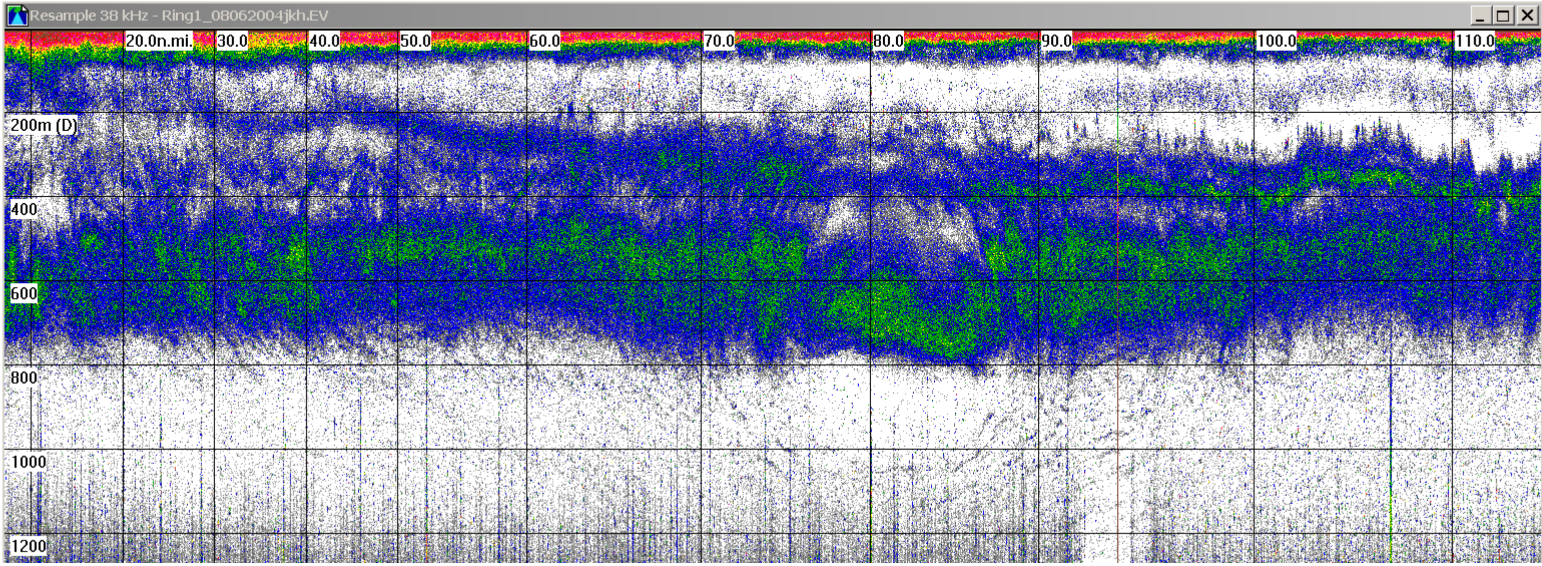
- sampled eggs & larvae across gyres over time
- found species groups within gyres: latitudinal, abundant
- oriented edge, center, outside
- entrainment of zooplankton and larval fish
- Dispersal mechanism?

Mid-Atlantic Ridge Gyres



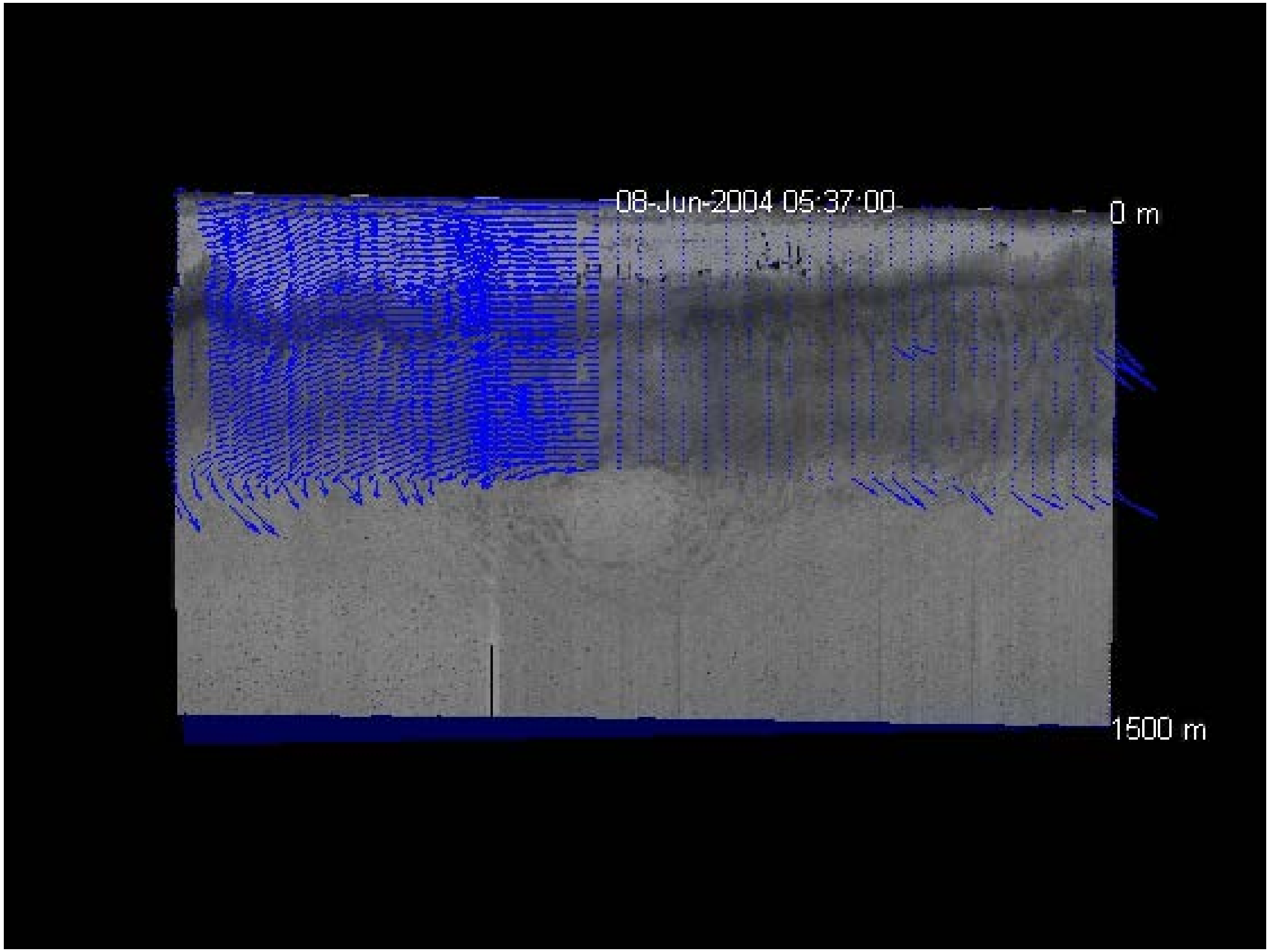
- satellite altimetry (i.e. sea surface height)

Wheel 1
38 kHz



Godø et al. 2012

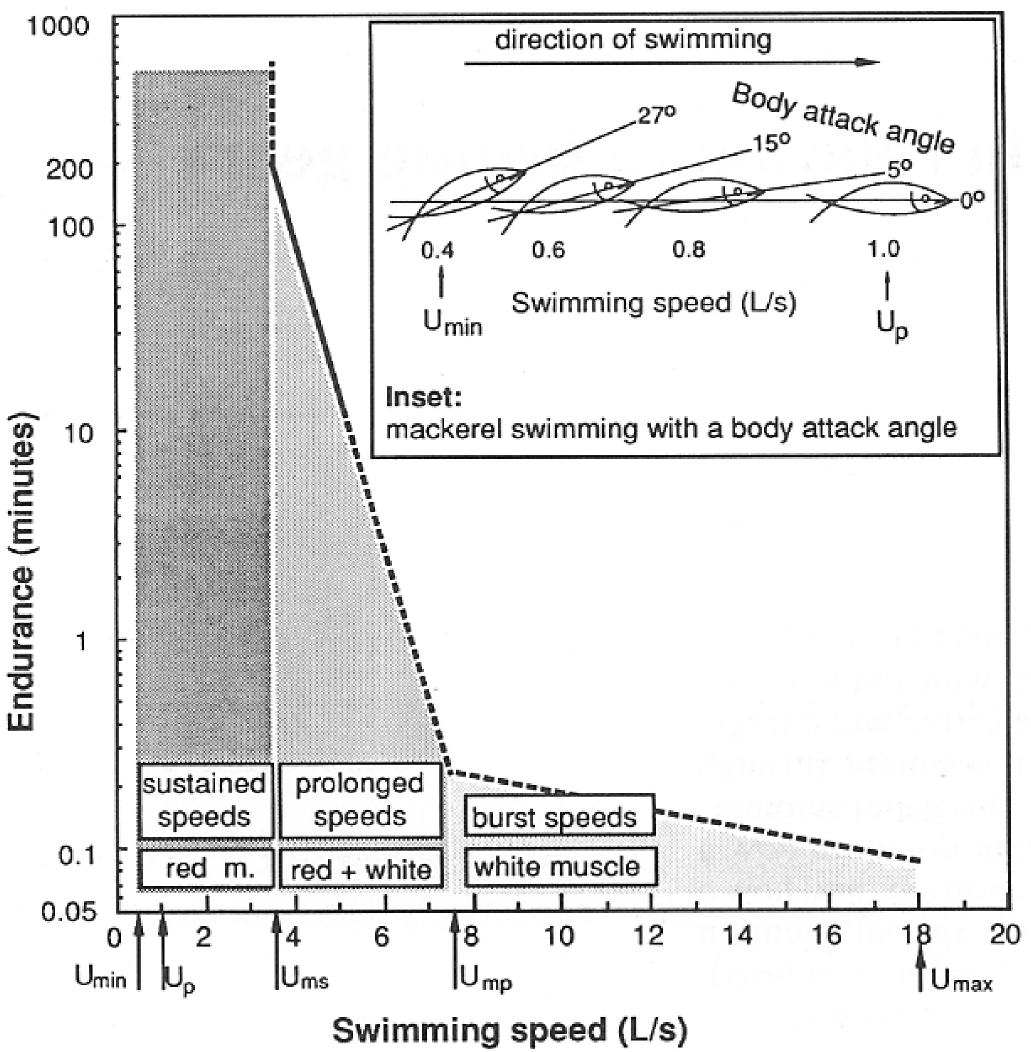
Gyre Flow Patterns



Godø et al. 2012

Swimming Speed and Endurance

Atlantic Mackerel

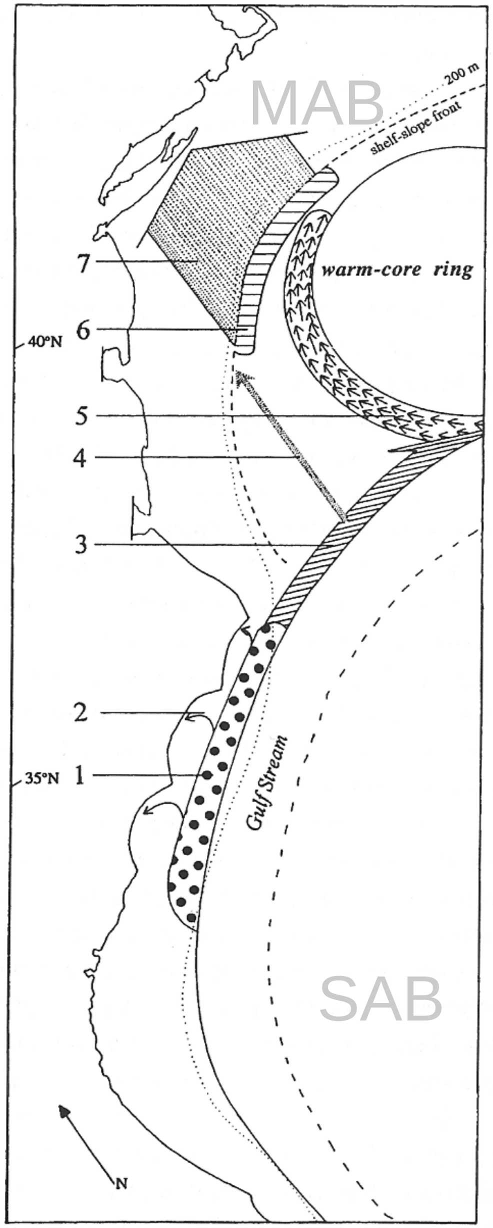


- large range of speeds & endurances
- based on 30 cm fish
- laboratory experiments

min minimum
p preferred
ms max sustained speed
mp max prolonged speed
max maximum

He 1993

Bluefish ELH Transport



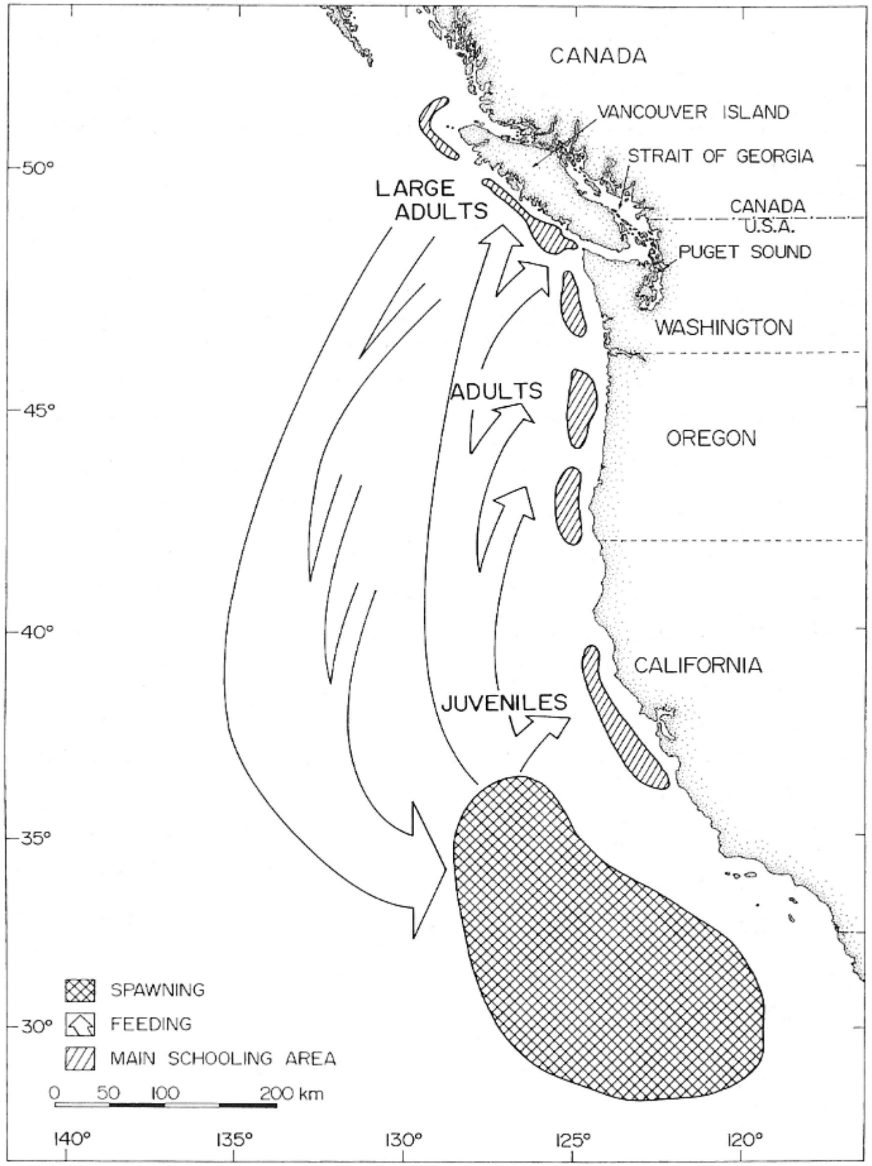
Bluefish (*Pomatomus saltatrix*)

Passive and Active Mechanisms

1. Spawning grounds
2. Larvae in South Atlantic Bight to estuaries
3. Larvae in Gulf Stream to Mid Atlantic Bight
4. Larvae swim to temperature front
5. Warm core ring streamers
6. Shelf-slope temp front accumulates
7. Front dissipates, juveniles swim

Hare & Cowen 1996

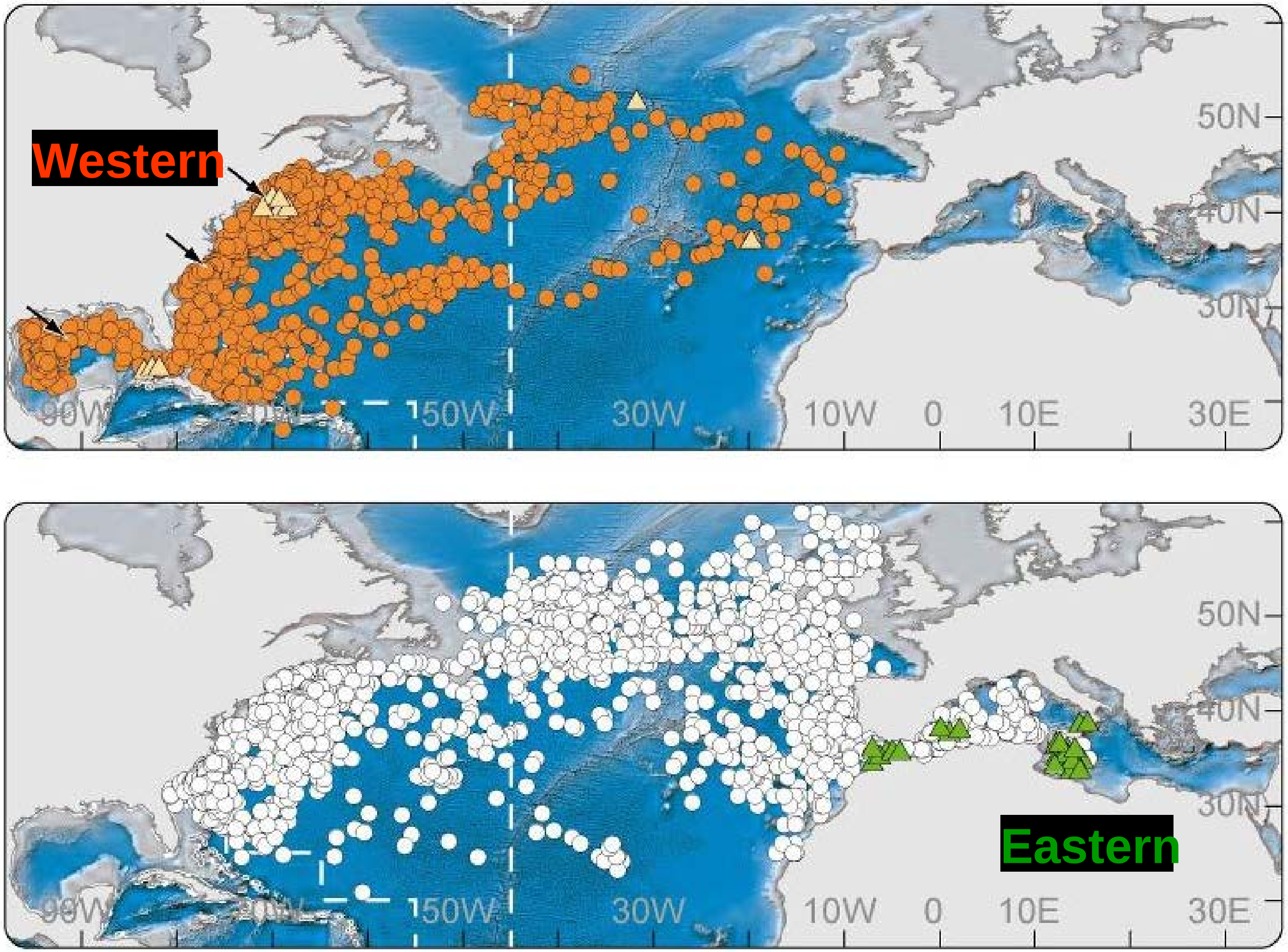
Pacific Hake Annual Cycle



- large distances
- southern spawning location depends on temperature at 100 m
- movement inshore by larvae to brooding/nursery areas

Bailey et al. 1982

Bluefin Tuna Extreme Migration



- common feeding grounds
- separate spawning grounds

Block et al. 2005

Kinematic Influences on Abundance Estimate Surveys

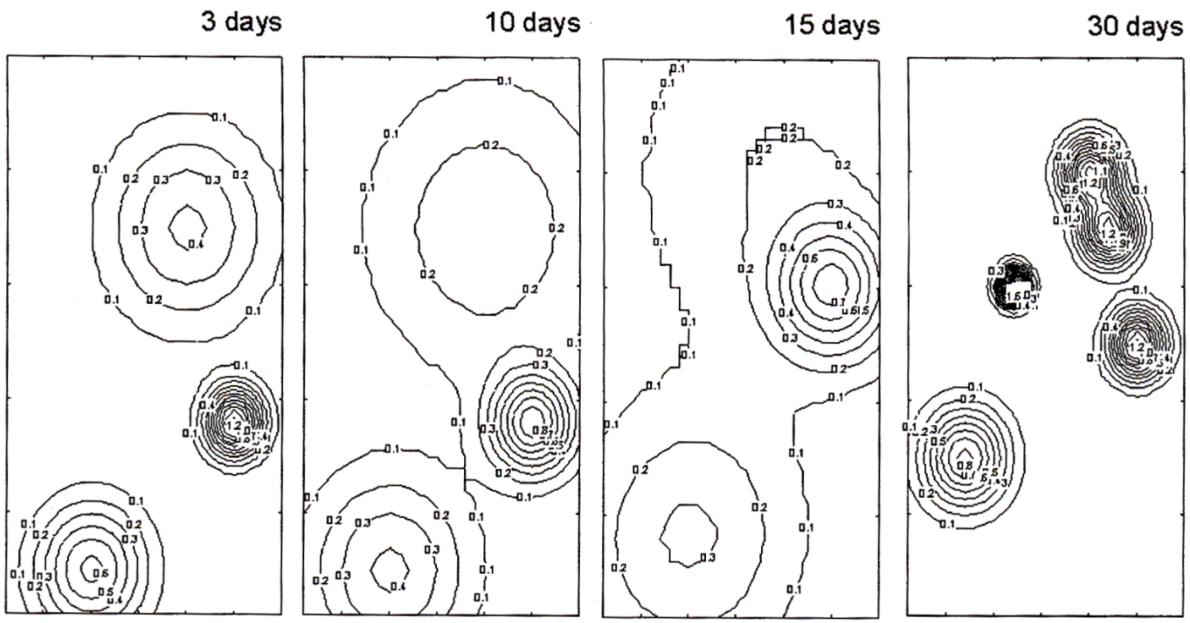
Adults

- migration potentially adds multiplicative error that depends on speed of survey relative to migration
- minimize bias by repeating surveys with and against migration, then averaging survey values

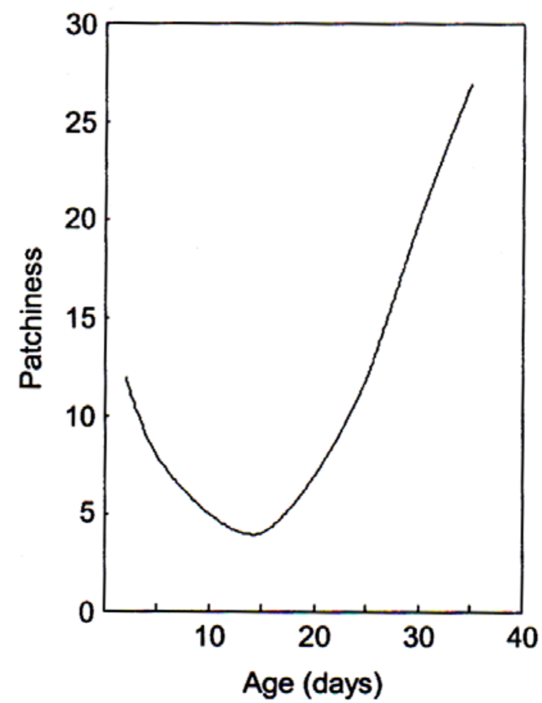
ELH

- variability in density/abundance samples dependent on sample volume, sample resolution, patchiness in larvae
- ‘patchiness’ function of spawning location, egg batch size, advection, predation, time to motility, swimming ability

Passive and Active Kinematic Influences



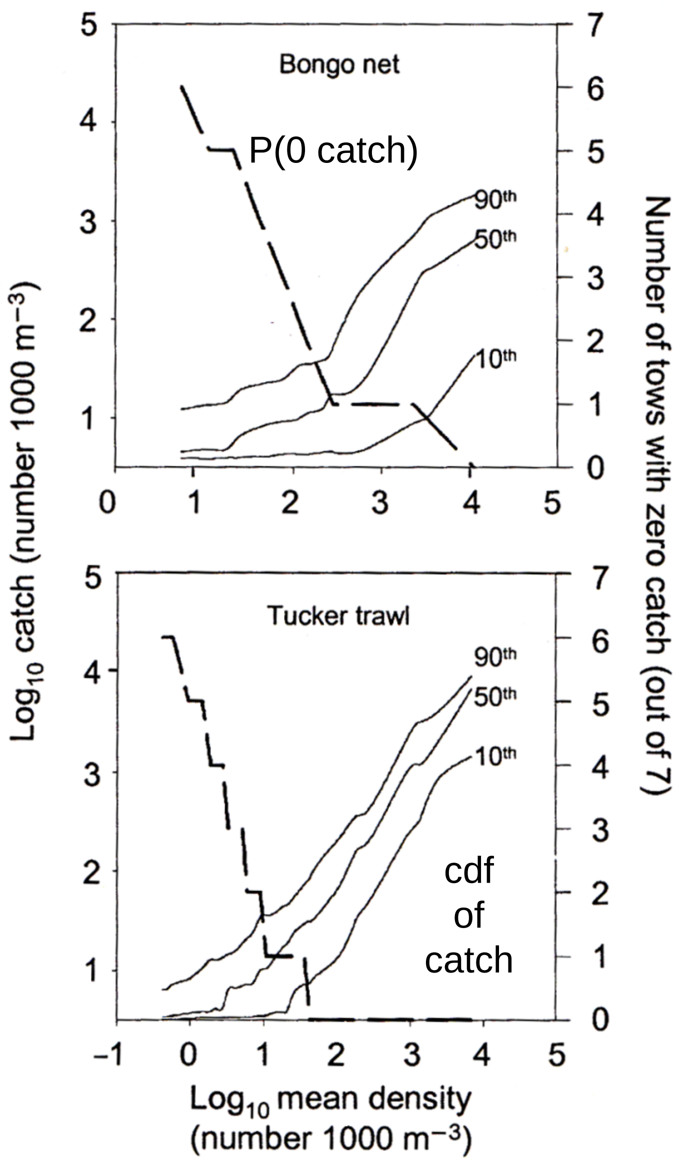
Pacific mackerel
(*Scomber japonicus*)



- eggs dispersed after release
- patchiness decreased (advection) then increased after predation and onset of motility

Matsuura & Hewitt 1995

Kinematic & Gear Influences



- 7 repeated samples over 4 sites, bongo 60 cm diameter, Tucker trawl 2 m square frame
- densities changed over time
- larger volume sample can detect lower densities (left tails)
- abundance estimates from large volume samples should have higher precision than those from small volumes (Δ 90 and 10^{th} %)

but also gear-dependent selectivity

Pepin & Shears1997