Ichthyoplankton Sampling Technologies and Modeling

LOs: identify hardware innovations that advanced understanding of marine fish early life histories

describe modeling methods that are used to characterize transport, growth, and survival of ichthyoplankton

Early Efforts

1st Documented Equipment: Thompson (1828) crab & barnacle larvae

Quantitative Samples: Hensen (1895)

What does the sea contain at a given time in the shape of living organisms in the plankton (i.e. numbers and types)?

How does this material vary from season to season and year to year?

Assumed uniform distributions, needed only small samples (10-15% replicate variation, 60-100 nautical mile patches)

- criticized by Haeckel but not until Hardy (1926, 1936) showed patchy distributions
- idea of random or uniform distributions in oceanic waters persisted to 1950's (remember Stommel 1964, Haury et al. 1978)
- gear development paralleled quest to understand plankton distributions

Instrumentation Categories

water bottles (litres), pumps (10's litres - 10's m^3), nets (10's - 1000's m^3)

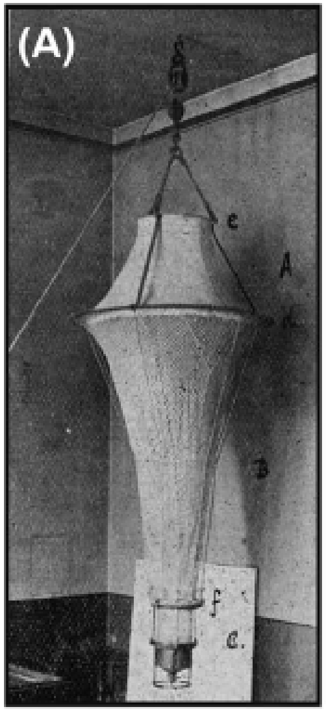
1. Non-opening closing nets (horizontal, vertical, oblique)
2. Planktobenthos net Systems
3. Opening/Closing Systems
4. High Speed Samplers
5. Tucker Trawl and Multiple Net Systems
6. Pumps
7. Optical Systems
8. Acoustic Technologies

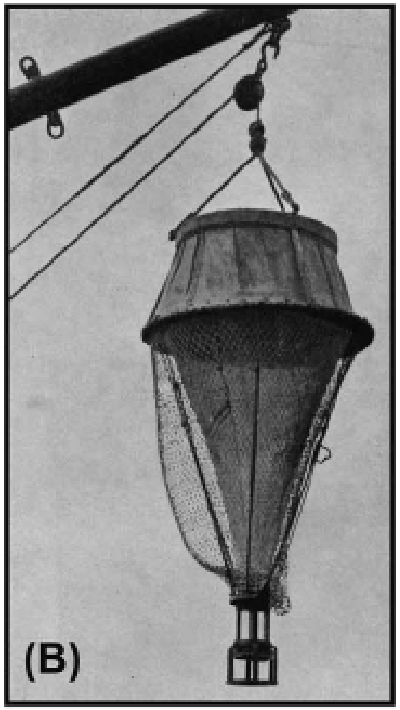
technology enables science, science demands new technology

Timeframe	Technology
Late 1800s	Wire rope and winches
1950s, 1960s	Electrified cables and release mechanisms
1960s, 1970s	Transistorized electronics and acoustic telemetry
1970s, 1980s	Micro-computers
1980s, 1990s	Electro-optical cable and advanced optical–acoustical components
Beyond 2000	Miniaturized components, ultra high storage capacity, lower power components, longer battery life, higher telemetry rates

Non-Opening Closing Nets

Hensen Net (1887)





- 38 or 100 cm diameter ring, silk bolting cloth (0.05 mm)
- vertical tow, bucket codend, no flow measures

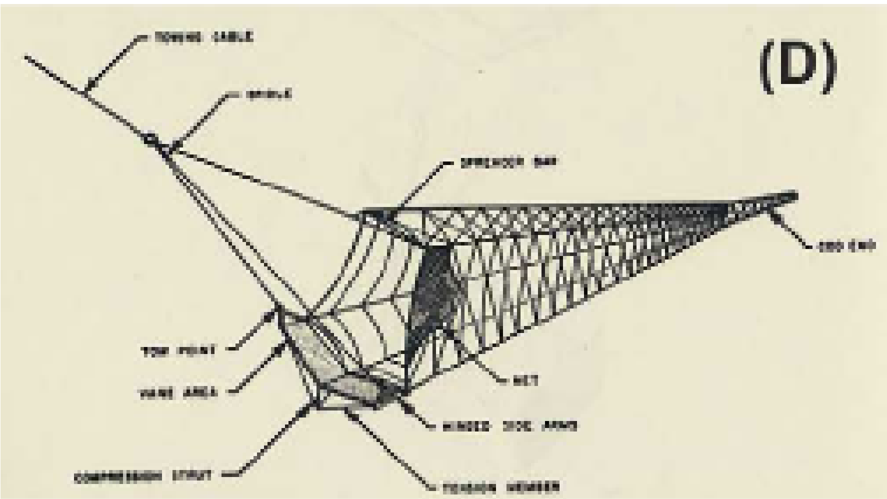
MARMAP Bongo net (1980)

CalCOFI Bongo net (1993)

- single or paired, 0.5 – 1m diameter, flow meter in mouth, various mesh sizes
- vertical or oblique tow, bucket codend

Wiebe & Benfield 2003

Macrozooplankton & Micronekton



Isaacs-Kidd Midwater trawl (1953)

- pentagonal mouth, wing depressor, 4 sizes
- oblique tow up to 8.5 knts

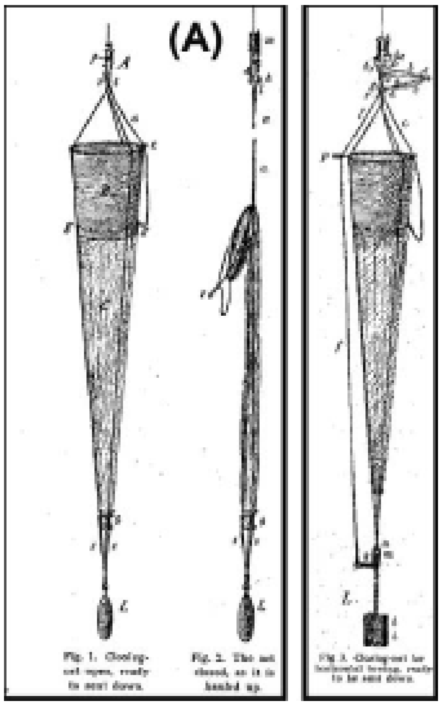
Tucker trawl (1951)

- square mouth (183 x 183 cm), time-depth recorder
- 5 knts, designed to sample DSL (euphausiids, siphonophores, fish)

Opening-Closing Nets: Single Codend

- developed to sample vertical strata in water, mechanical closures

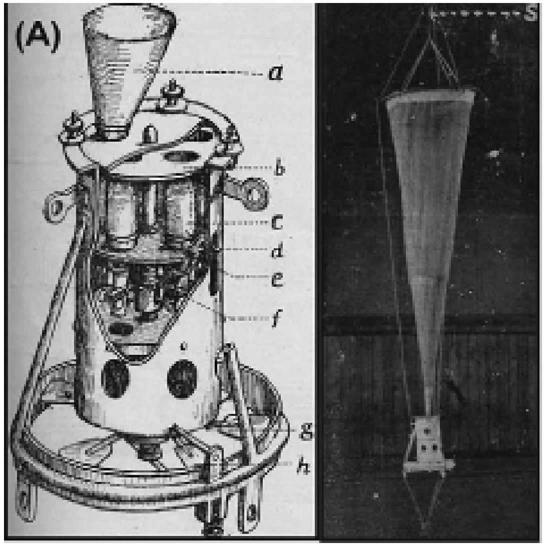
Nansen net
(1915)



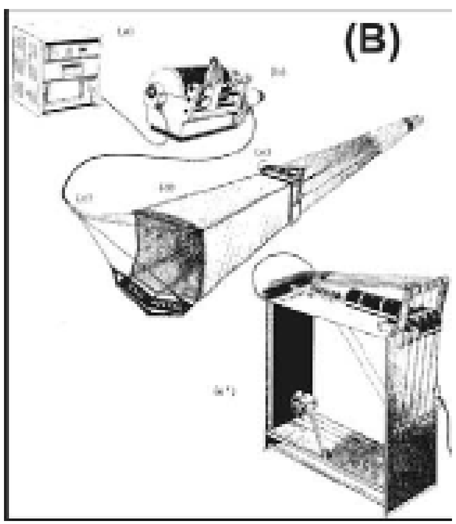
- first of its type
- messenger sent down wire to close net
- multiple nets/messengers added along the wire
- electrical closing developed in 1889
- pressure and time-based closures followed

Contribution: discrete depth sample (no contamination)

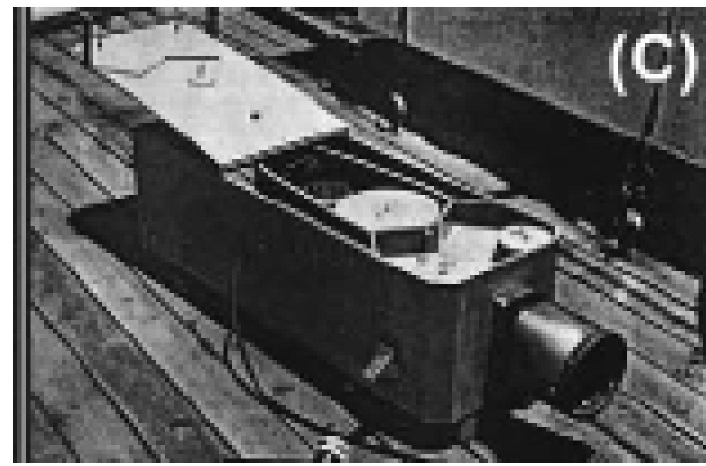
Multiple Codend Systems



- first scaled-up serial sampler, 5 codends on disk (Motoda 1953)



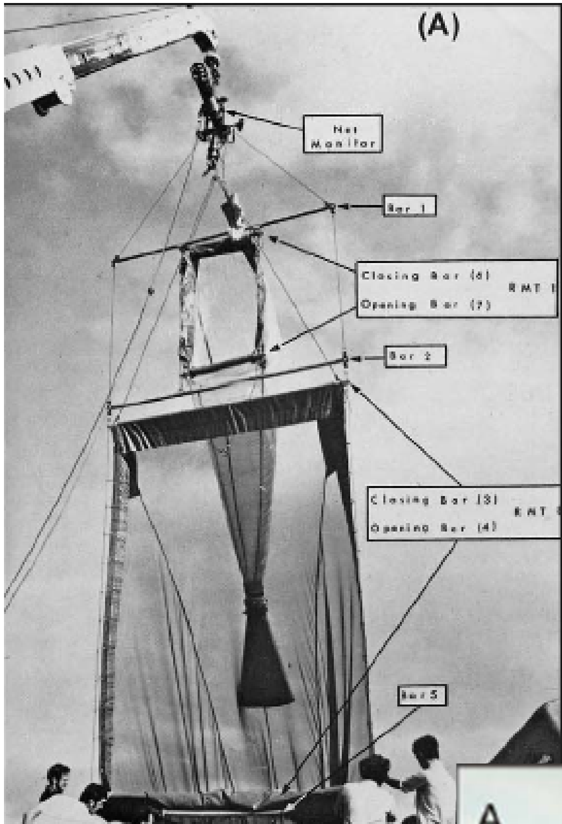
- first multinet MPS (Bé 1962), fit to IKMT sampler



- Longhurst-Hardy plankton recorder (LHPR 1966)

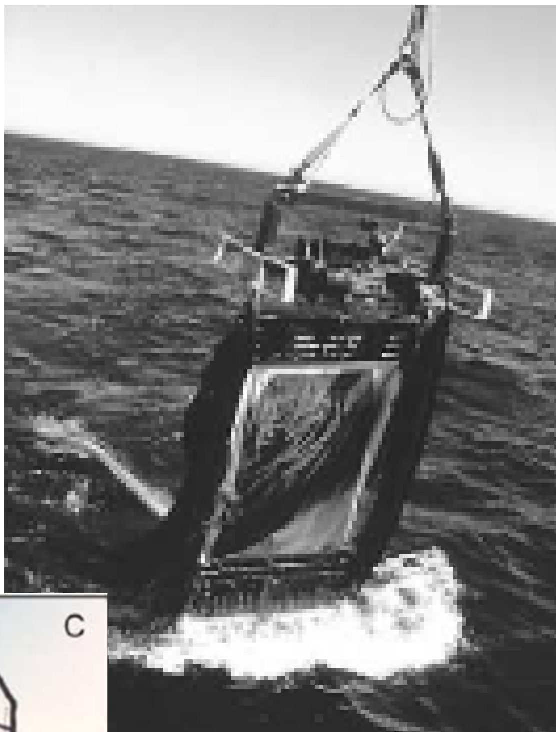
- split samples at codend

Multiple Codend Systems



- Clarke (1969) Rectangular Mouth Opening Trawl (RMT)
- 1 m^2, 8 m^2 mouth openings
- data telemetered to surface
- expanded to multiple nets

- Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) Wiebe et al. 1976
- 9 nets, conducting cable commands

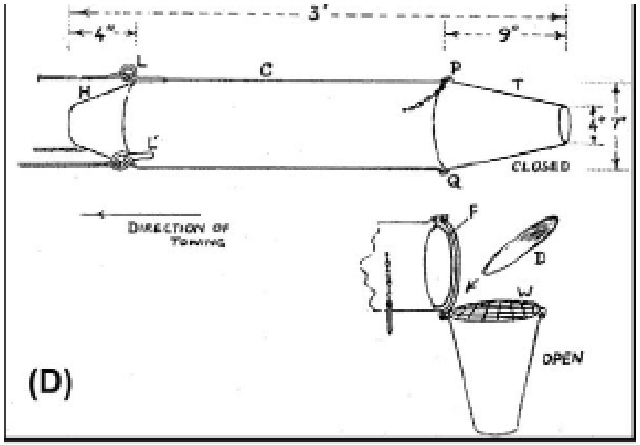


Multinet

MOCNESS

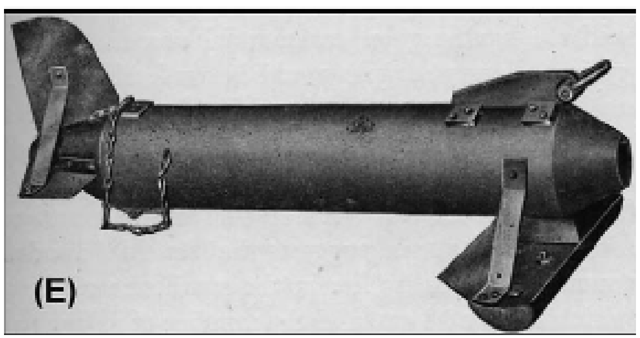
High Speed Samplers

- sample in bad weather, between stations, reduce net avoidance



Hardy Plankton Indicator (1926)

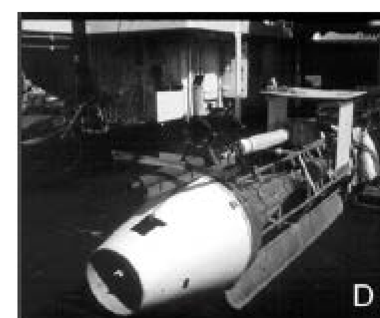
- 17.8 cm diameter, 91.4 cm length, opening 1.5 – 4 cm
- developed to sample plankton for herring fishermen



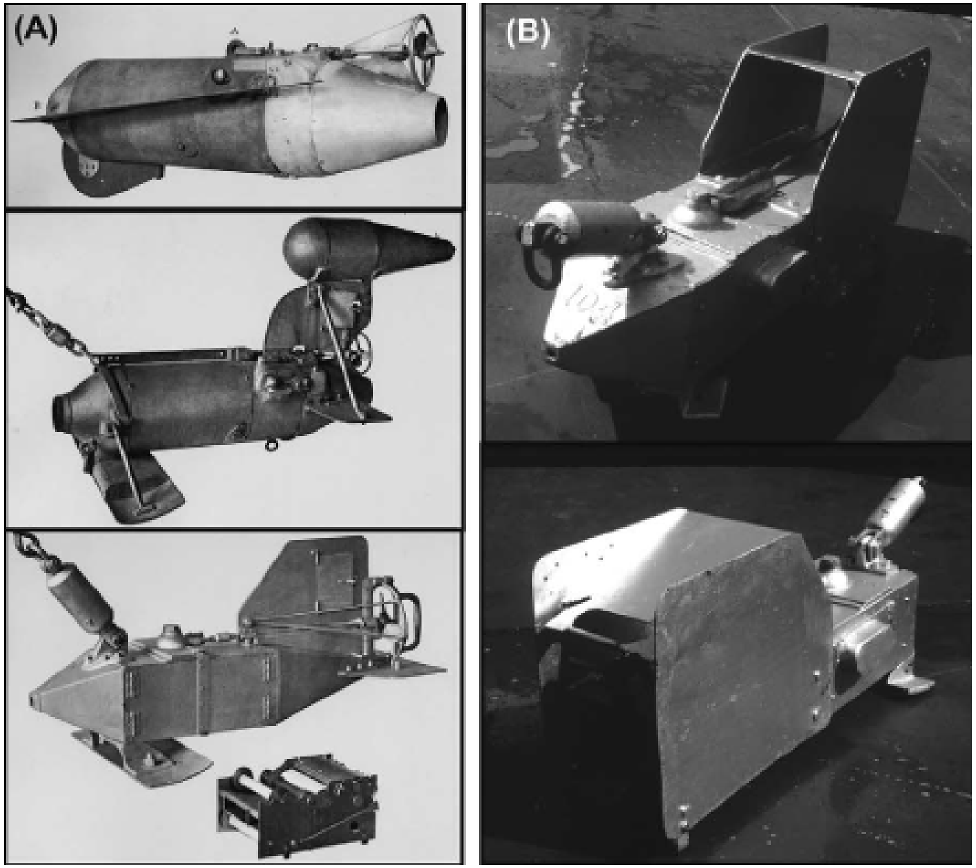
Standard Plankton Indicator (1936)

- 7.6 cm diameter, 56 cm length, depressor, stabilizing fins

LHPR



Continuous Plankton Recorder

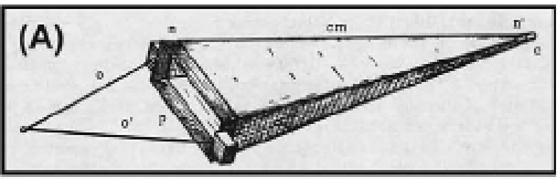


Hardy 1926

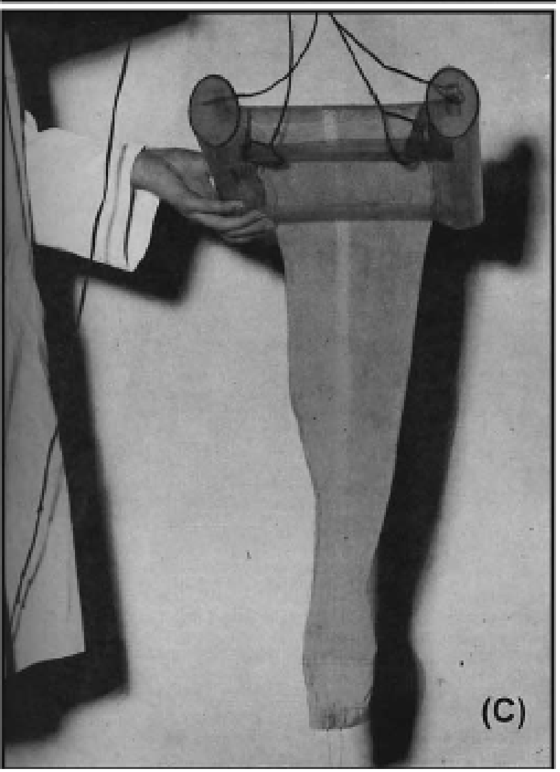
- developed for use in Antarctic
- 87 kg, 50 x 50 x 100 cm
- aperture 1.27 x 1.27 cm
- roll of silk gauze across tunnel to capture plankton, second roll sandwiches plankton
- speeds up to 20 knots, ships of opportunity across N. Atlantic

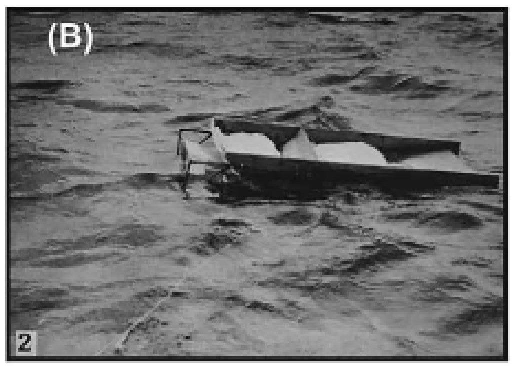
Neuston Nets

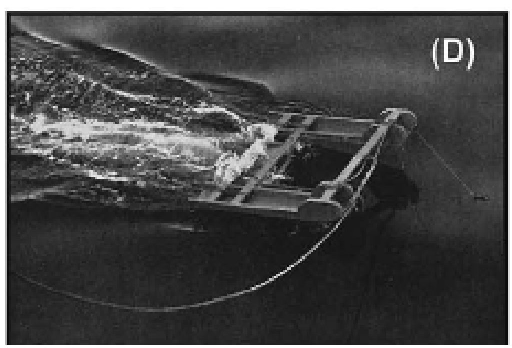
- primarily non-opening/closing, sample top few cms



Zaitsev (1959)



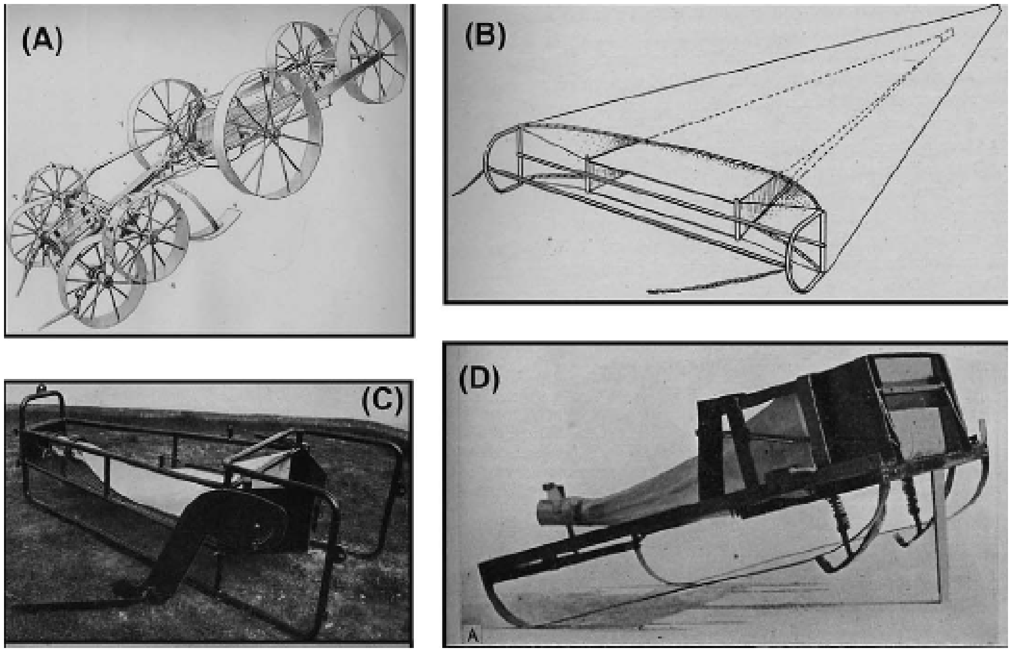




- 60 cm wide x 20 cm tall
- single net or stacked to 100 cm depth
- towed at 1 – 2 knots

Planktobenthos Nets

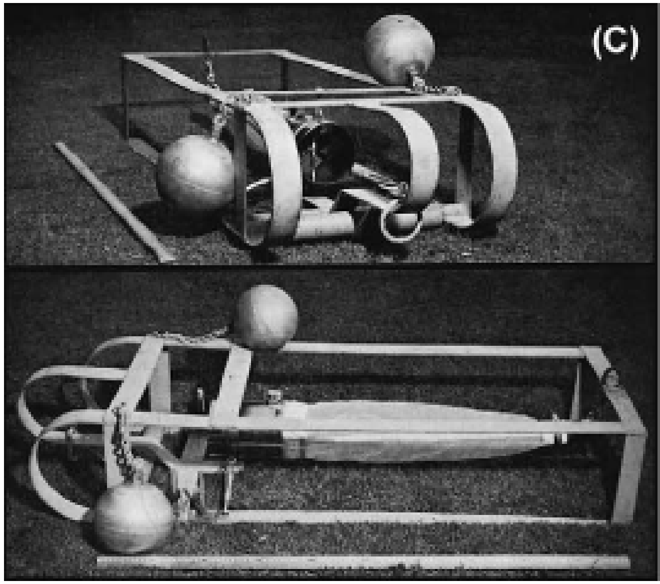
- plankton living near bottom



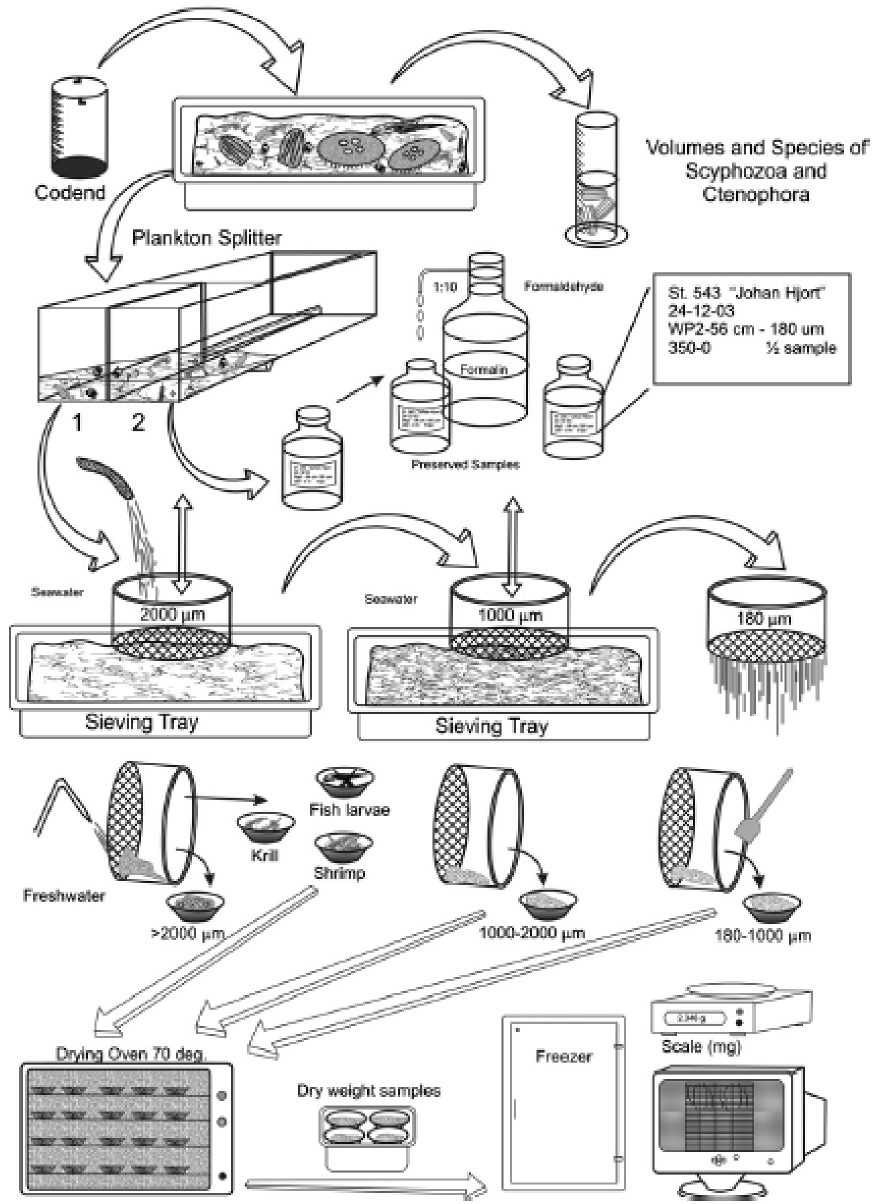
- 122 wide x 30 cm tall x 240 cm long
- no opening/closing until 1951 (c)

- first Reighard (1894), Hensen (1895)

- epi-benthos sled

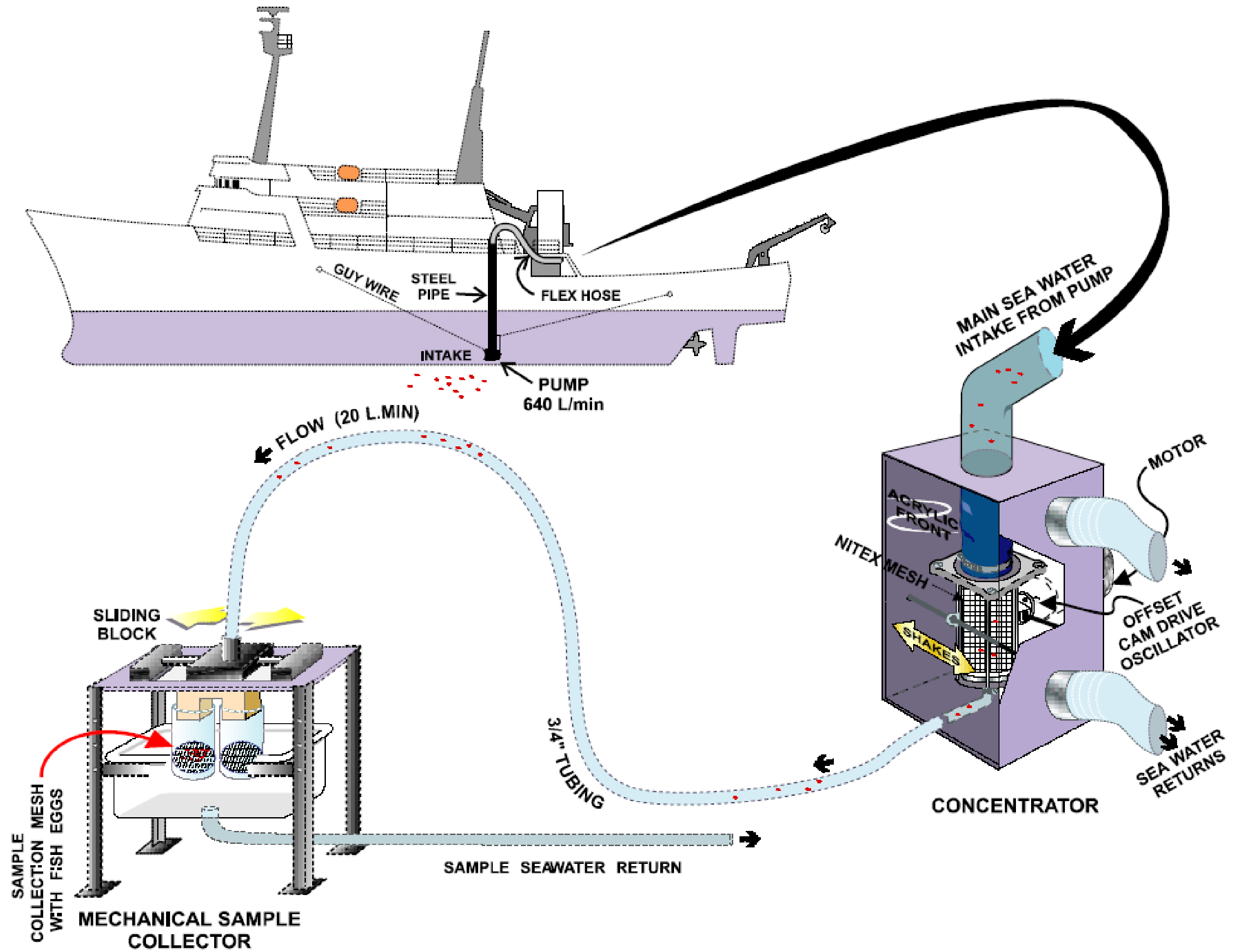


Zooplankton Processing



Skjoldal et al. 2013

Continuous Underway Fish Egg Sampler



http://swfsc.noaa.gov/video.aspx?id=9322&parentmenuid=448

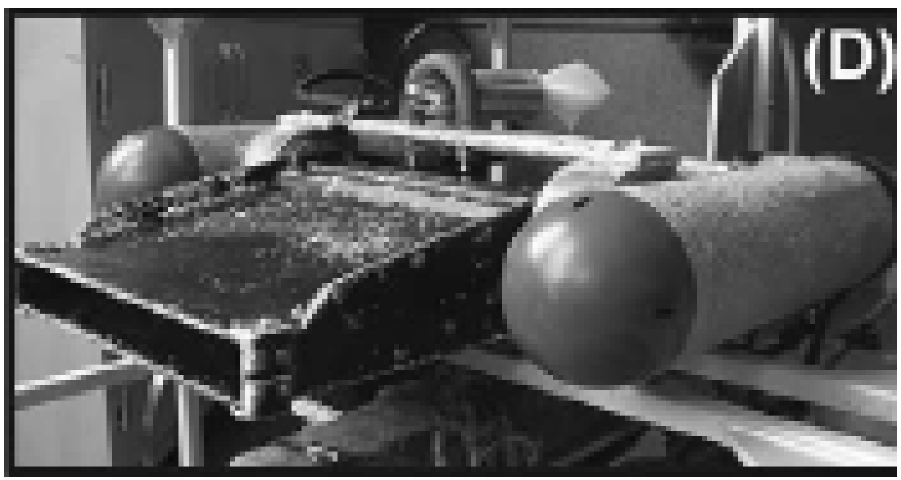
Checkley et al. 1997

Optical Systems

increase horizontal and vertical resolution over nets, limited range

Optical Plankton Recorder

towed, light interruption duration = diameter, equivalent spherical diameters only, size classes



Herman 1988

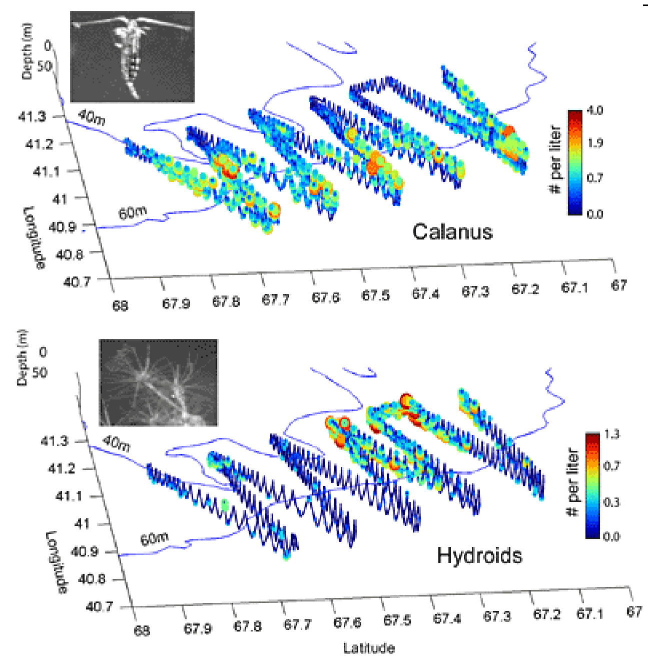
Video Plankton Recorder

towed, strobed pictures, data manually scanned (1 hr = 216 k frames)

Davis et al. 1992

Video Plankton Recorder Montage

Calanus & Hydroids

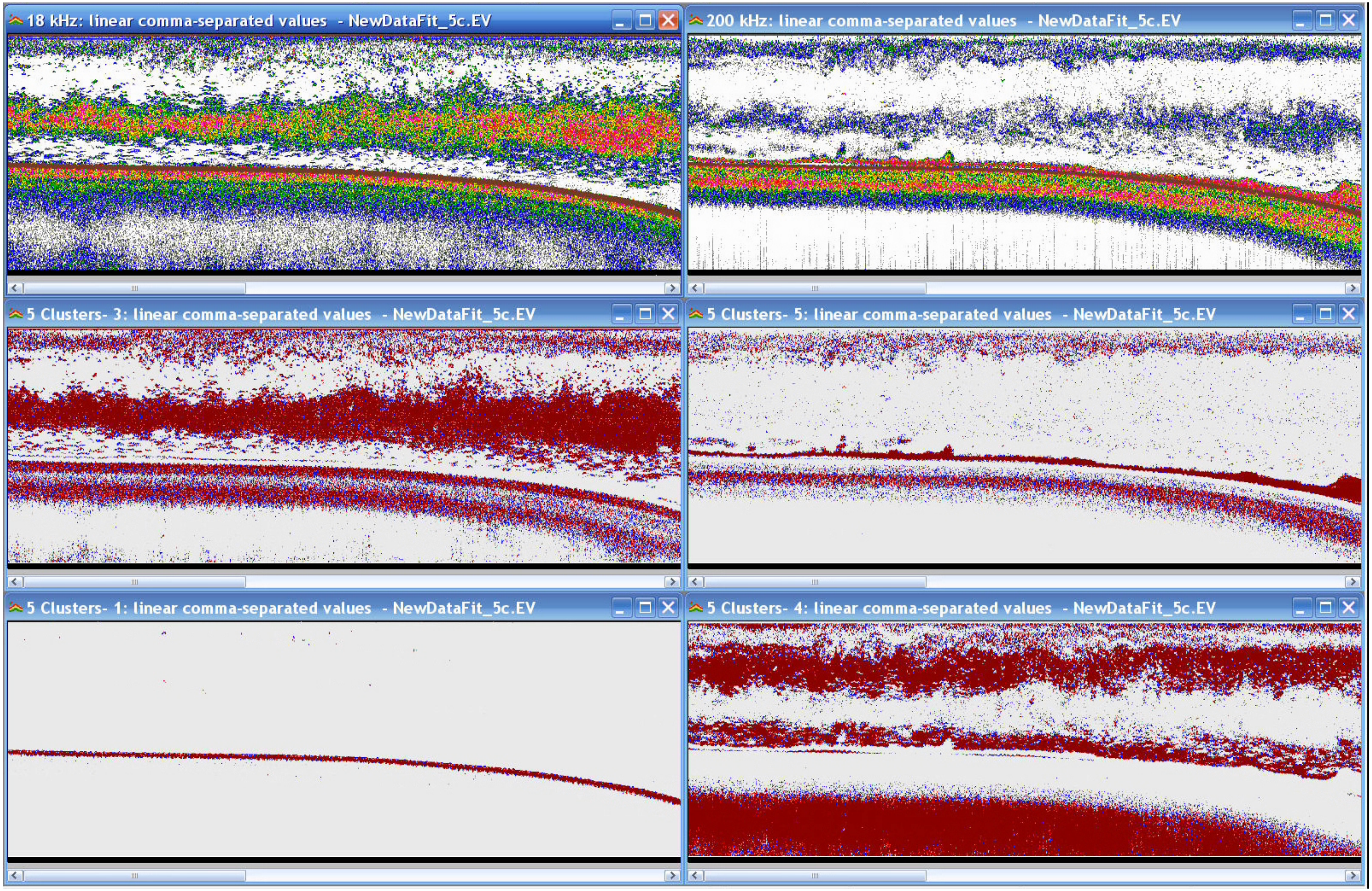


WHOI image

Acoustics and Ichthyoplankton

Probability–based, multifrequency classification

Gulf of Alaska



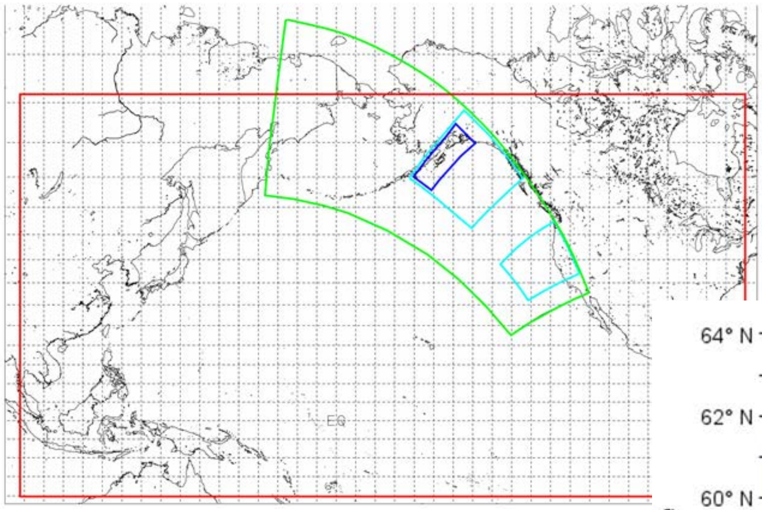
Relative Strengths/Weaknesses

	Nets	Pumps	Acoustics	Optics
Physical Sample	🙂	🙂	☹️	☹️
High Tow Velocity	☹️	☹️	🙂	🙂
Rapid Processing	😐	😐	🙂	😐
Rare Taxa	🙂	☹️	😐	☹️
Fragile Taxa	☹️	☹️	😐	🙂
Fine Vertical Resolution	😐	🙂	🙂	🙂
Fine Horizontal Resolution	☹️	😐	🙂	🙂
High Taxonomic Resolution	🙂	🙂	☹️	😐
Relative Cost	**MEDIUM**	**LOW**	**MEDIUM**	**HIGH**
Low Avoidance	😐	☹️	🙂	😐

courtesy of M. Benfield

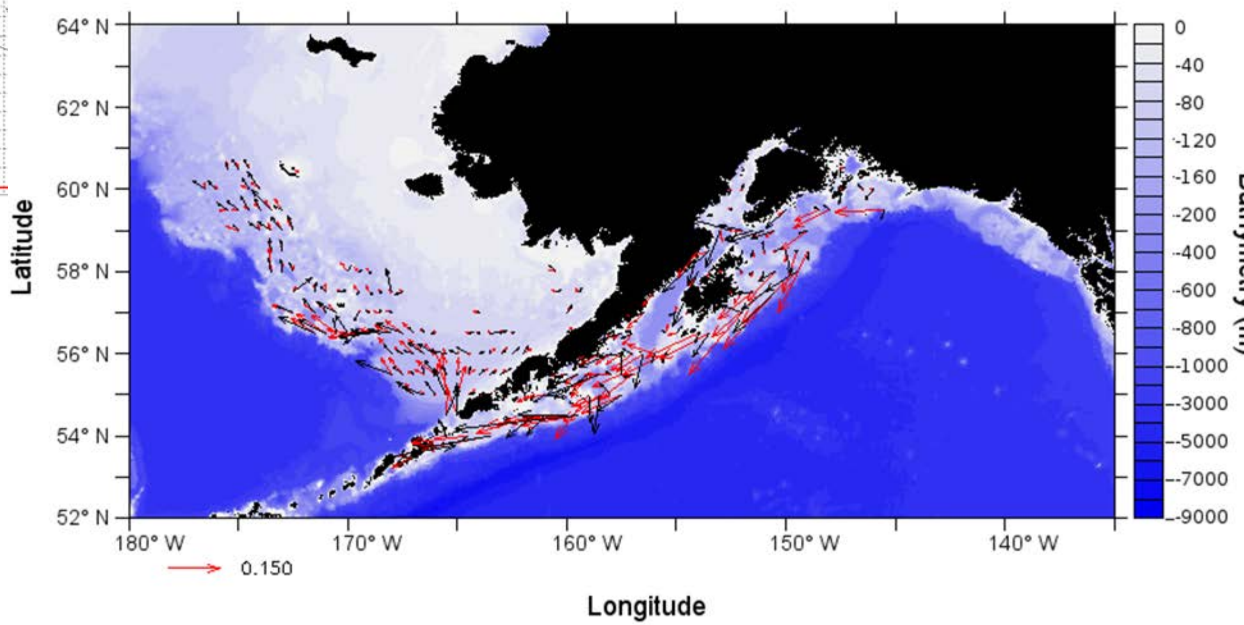
Modeling: Connecting Spawning to Nursery Areas

Interacting Models:
Hydrodynamics, Production (NPZ: nitrogen, phytoplankton, zooplankton), Fish Biology (IBM: Individual Based Model)



Regional Oceanic Modeling System (ROMS): nested 40, 10, 3 km grids

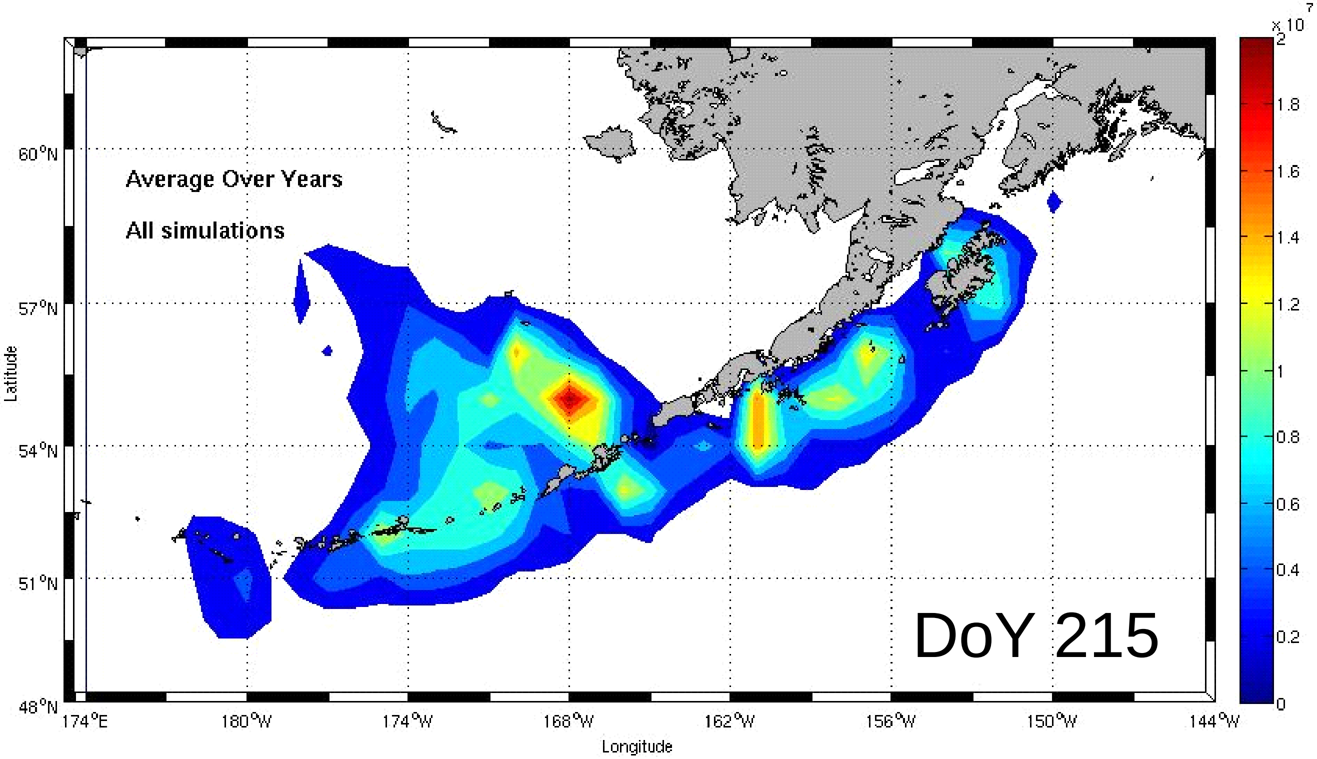
Comparison of modeled (black) to observed (satellite drifter, red) velocities



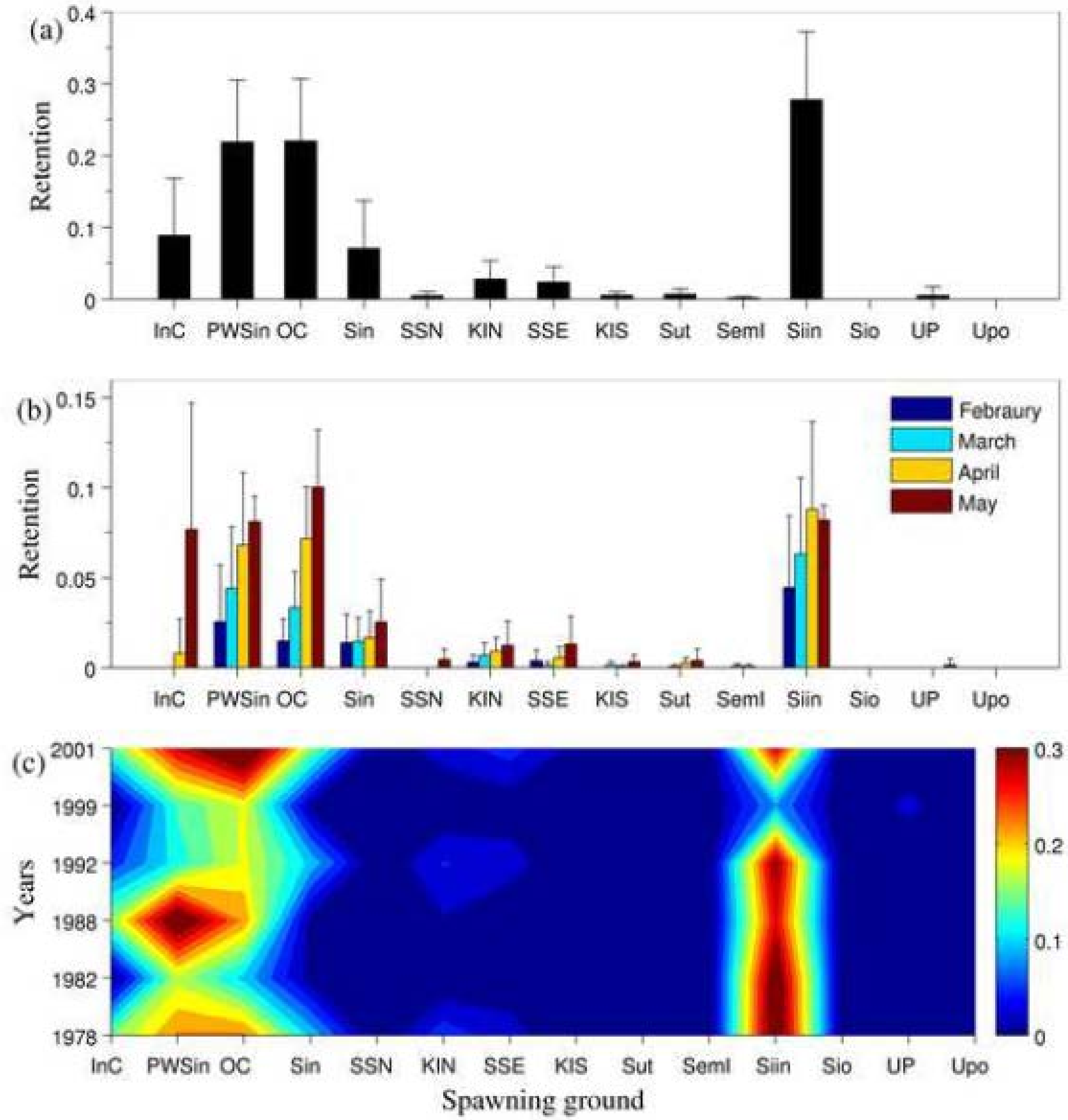
Individual Based Model (IBM)

- Track trajectories of all particles, characterize group or individual
- ELH stages: egg, early larvae, late larvae, juvenile stages
- NPZ model to produce prey field
- juveniles include locomotion, feeding, bioenergetics modules

Average Juvenile Survival
1978, 1982, 1988, 1992, 1999, 2002



Retention in Spawning Area

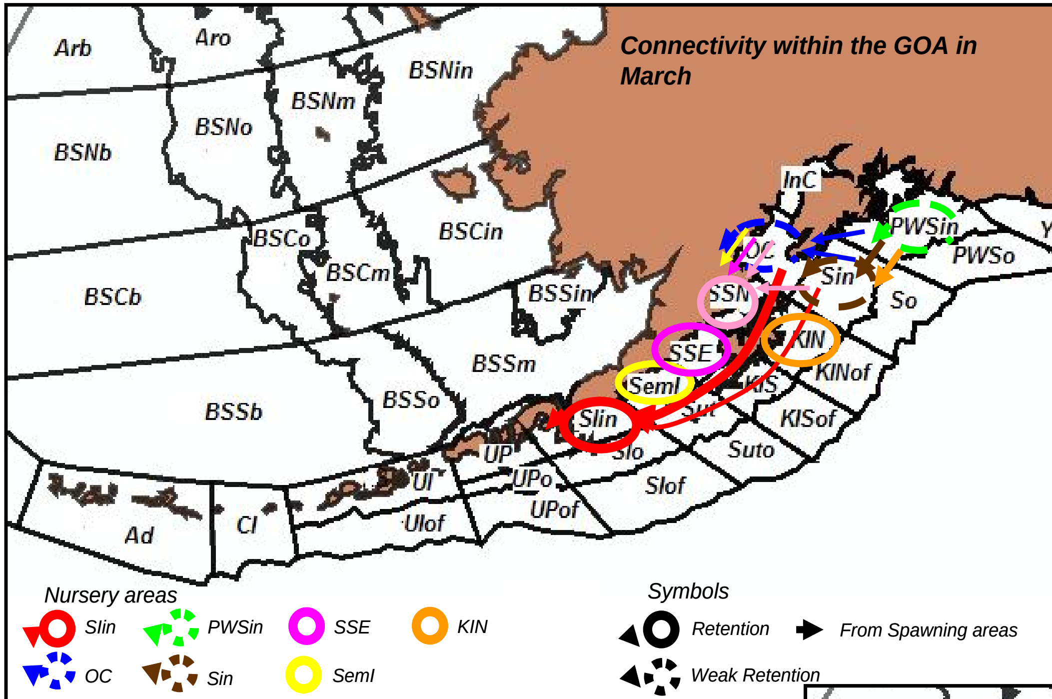


% Overall

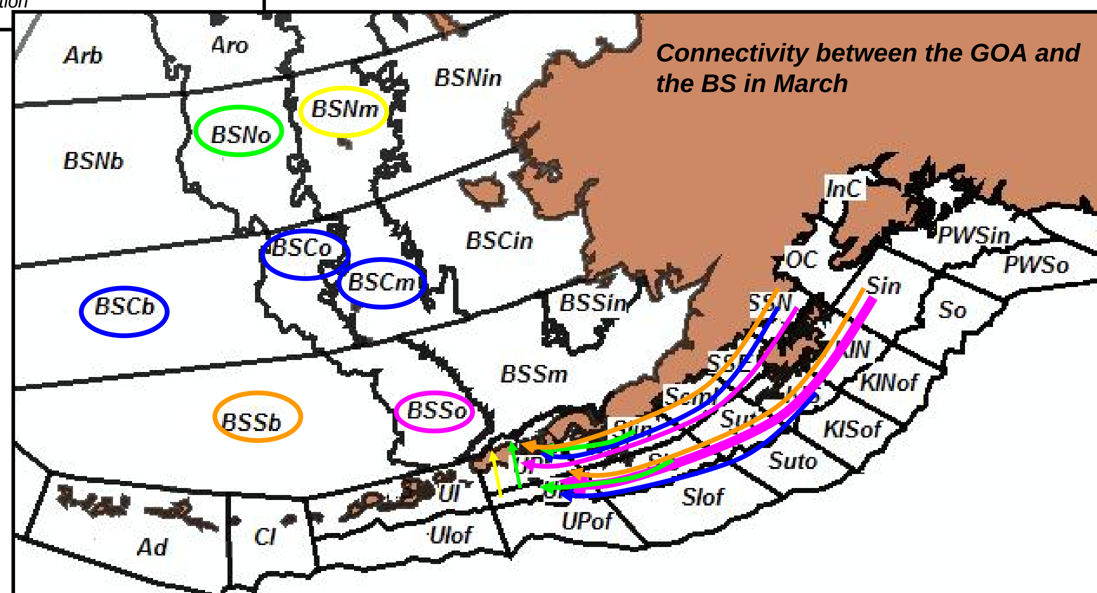
% By Month

% By Year

Simulated Connectivty: March



- Shumagin Islands nursery area in all months
- transport along inner & outer edges of shelf
- number of retention areas increased through year



- Bering Sea transport mainly along outer shelf

Model Case Study Conclusions

- coupled modeling approach combined hydrography, kinematics, growth, demographics
- simulated nursery areas matched observed nursery areas
- Shelikof Strait to Shumagin Islands: 40 – 50% connectivity
- significant export to Bering Sea (implications for S-R index and stock structure)
- other potential spawning areas identified