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 m³), nets (10’s - 1000’s m³)

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

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Technology</th>
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<tr>
<td>Late 1800s</td>
<td>Wire rope and winches</td>
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<td>1950s, 1960s</td>
<td>Electrified cables and release mechanisms</td>
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<td>1960s, 1970s</td>
<td>Transistorized electronics and acoustic telemetry</td>
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<td>1970s, 1980s</td>
<td>Micro-computers</td>
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<td>1980s, 1990s</td>
<td>Electro-optical cable and advanced optical–acoustical components</td>
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<td>Beyond 2000</td>
<td>Miniaturized components, ultra high storage capacity, lower power components, longer battery life, higher telemetry rates</td>
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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)
- single or paired, 0.5 – 1m diameter, flow meter in mouth, various mesh sizes

CalCOFI Bongo net (1993)
- 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 m², 8 m² 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
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
Continuous Plankton Recorder

- 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

Hardy 1926
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
- first Reighard (1894), Hensen (1895)
- 122 wide x 30 cm tall x 240 cm long
- no opening/closing until 1951 (c)
- epi-benthos sled
Zooplankton Processing

Skjoldal et al. 2013
Continuous Underway Fish Egg Sampler

Checkley et al. 1997

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

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

Herman 1988

Davis et al. 1992
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
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
Retention in Spawning Area

% Overall

% By Month

% By Year
Simulated Connectivity: 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