EURO-BASIN
BASIN SCALE ANALYSIS, SYNTHESIS AND INTEGRATION

Biovolume spectrum theories and their ecological applications during EURO-BASIN

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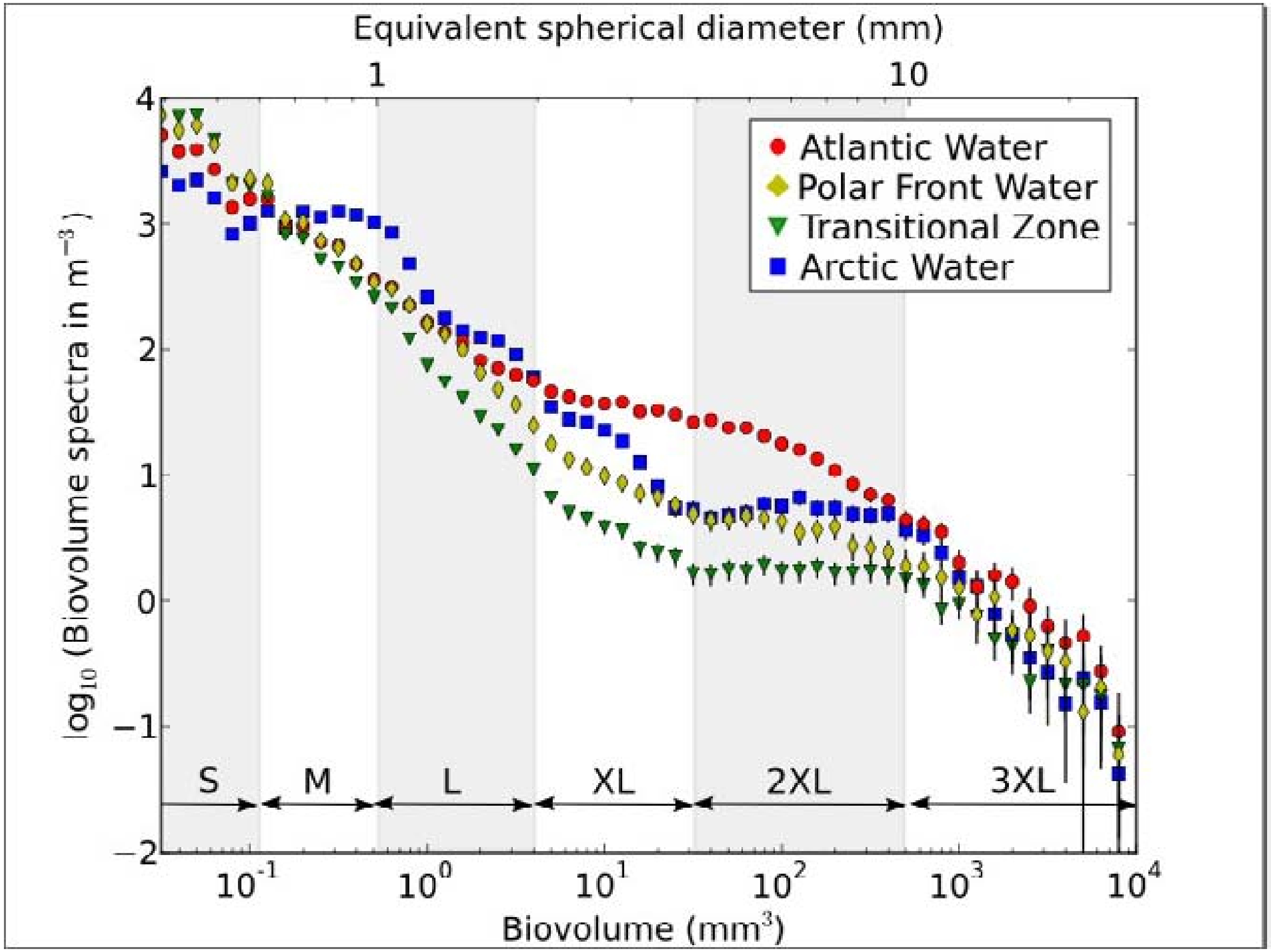
What are biovolume spectra?



- **The shape of a biovolume spectrum is defined by energy fluxes within aquatic systems.**

Biovolume spectrum theories

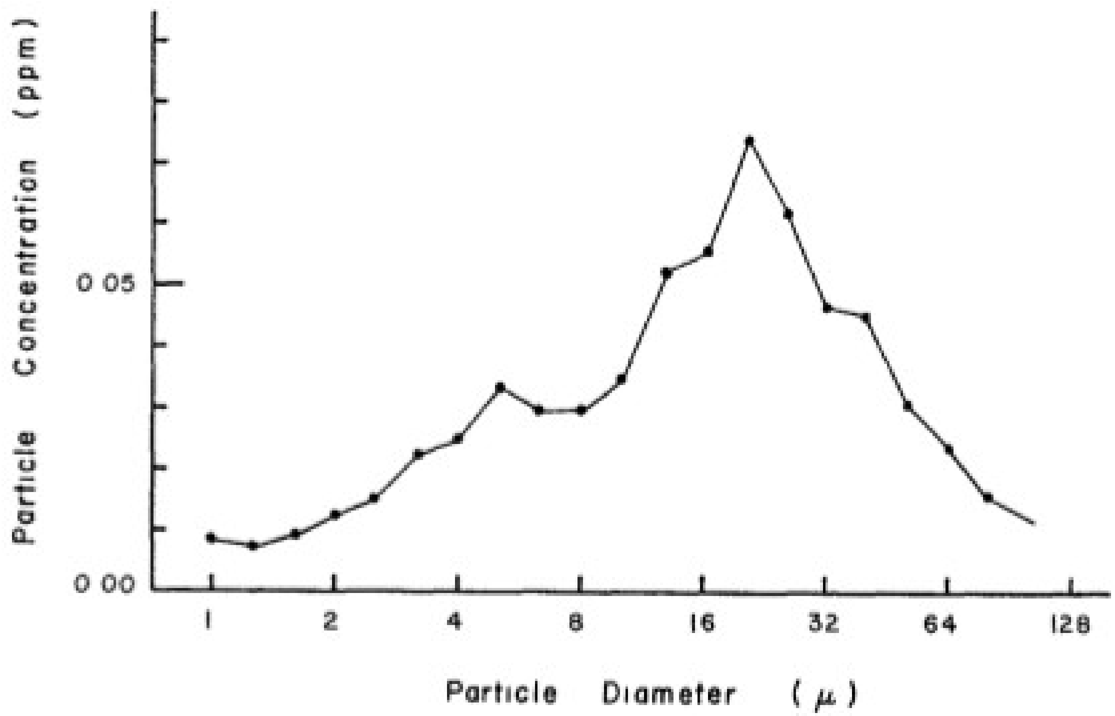
- Ecological theories that are tailored to optical instruments, which observe plankton distributions in size classes

- Proposed as a size-based alternative to the classical modelling of the planktonic food web

- Normalised biovolume spectrum (in m^{-3})
  b* = biovolume in size interval Δ*w* / size interval Δ*w

Historical background

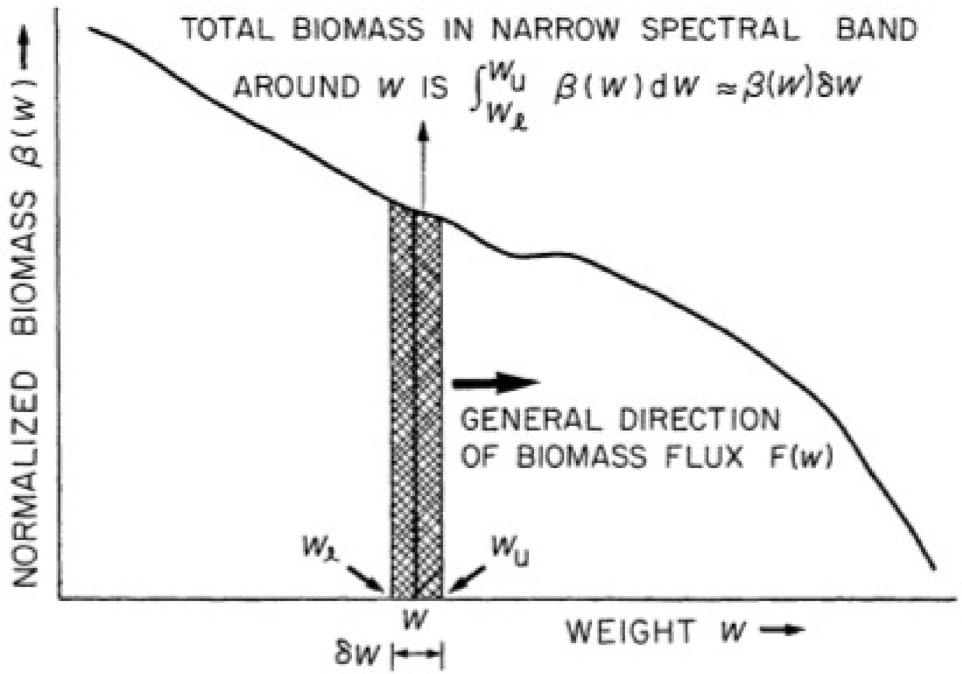
- **Observations of a systematic distribution of biomass of marine plankton by size**



Sheldon et al. 1972 Limnol Oceanogr 17

Historical background

- **Realisation that fluxes through the size spectrum can be described by size-dependent physiological and vital rates → biomass spectrum (Platt & Denman 1978, Silvert & Platt 1978)**



Silvert & Platt 1978 Limnol Oceanogr 23

Energy flow through system: Platt & Denman 1978

- Deduced from allometric equations
- Energy balance is between individual growth and respiration
- Slope of spectrum = $-1 + x - \alpha A$,
  where x, α and A are empirical constants in allometric equations that define respiration and individual growth
- Generalised by Silvert & Platt (1978)

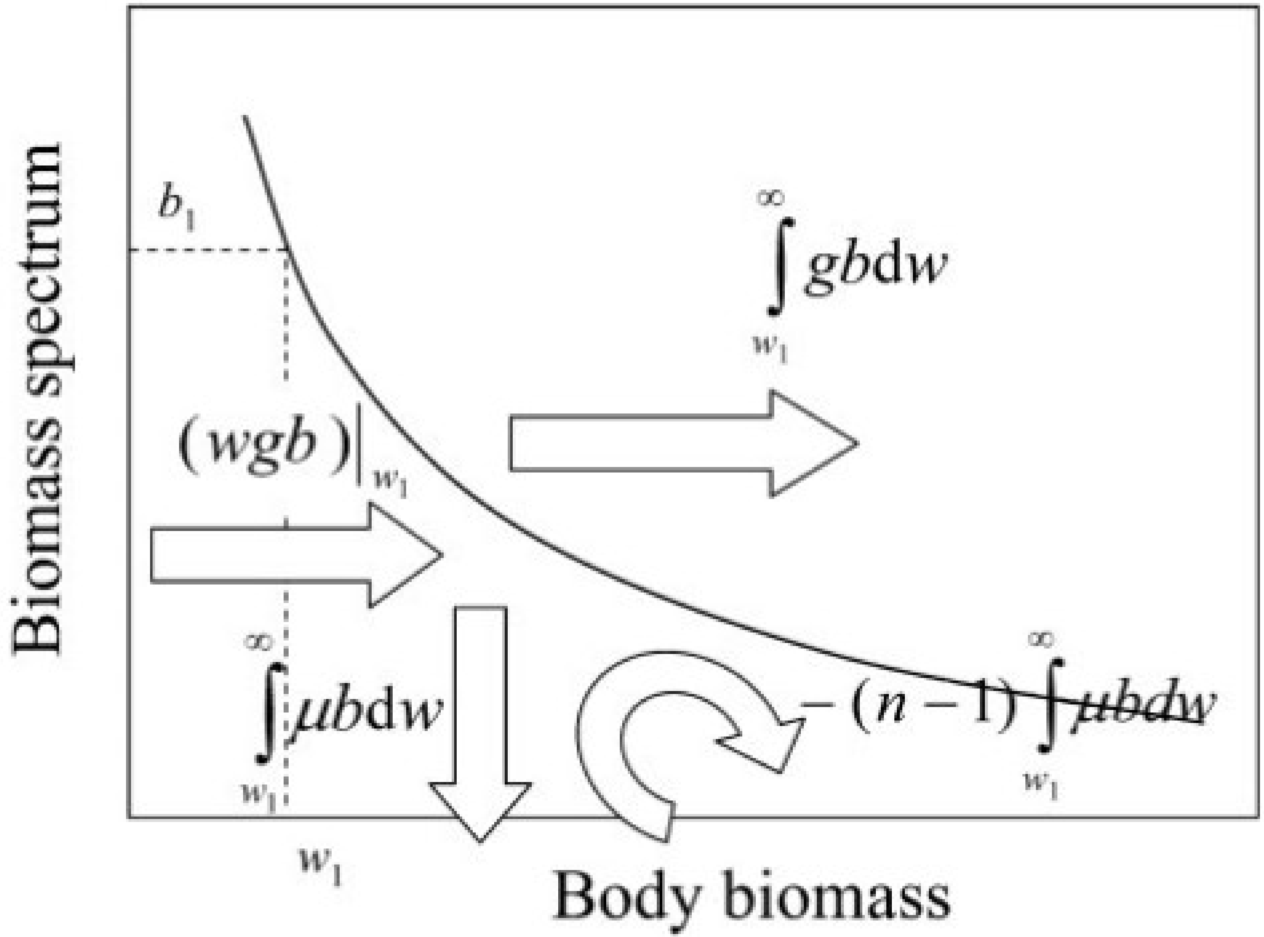
Energy flow through system: Heath 1995

- Deduced from seasonal observations of spectra in Loch Linnhe
- Energy balance is between growth and mortality
- Slope of spectrum = - z/g
  where g is the individual growth rate and z is the
    mortality rate

Energy flow through system: Zhou & Huntley 1997

- Unified models by Platt & Denman and Heath
- Energy balance is between growth and inflow on the one side and mortality and outflow on the other, all sinks and sources incorporated
- Basic equations for population growth and biomass production are deduced without empirical assumptions
- Based on distribution function of abundance and the law of conservation of mass
- Slope is determined by recycling within the system

Energy flow through the spectrum



Zhou 2006 J Plankton Res[1]

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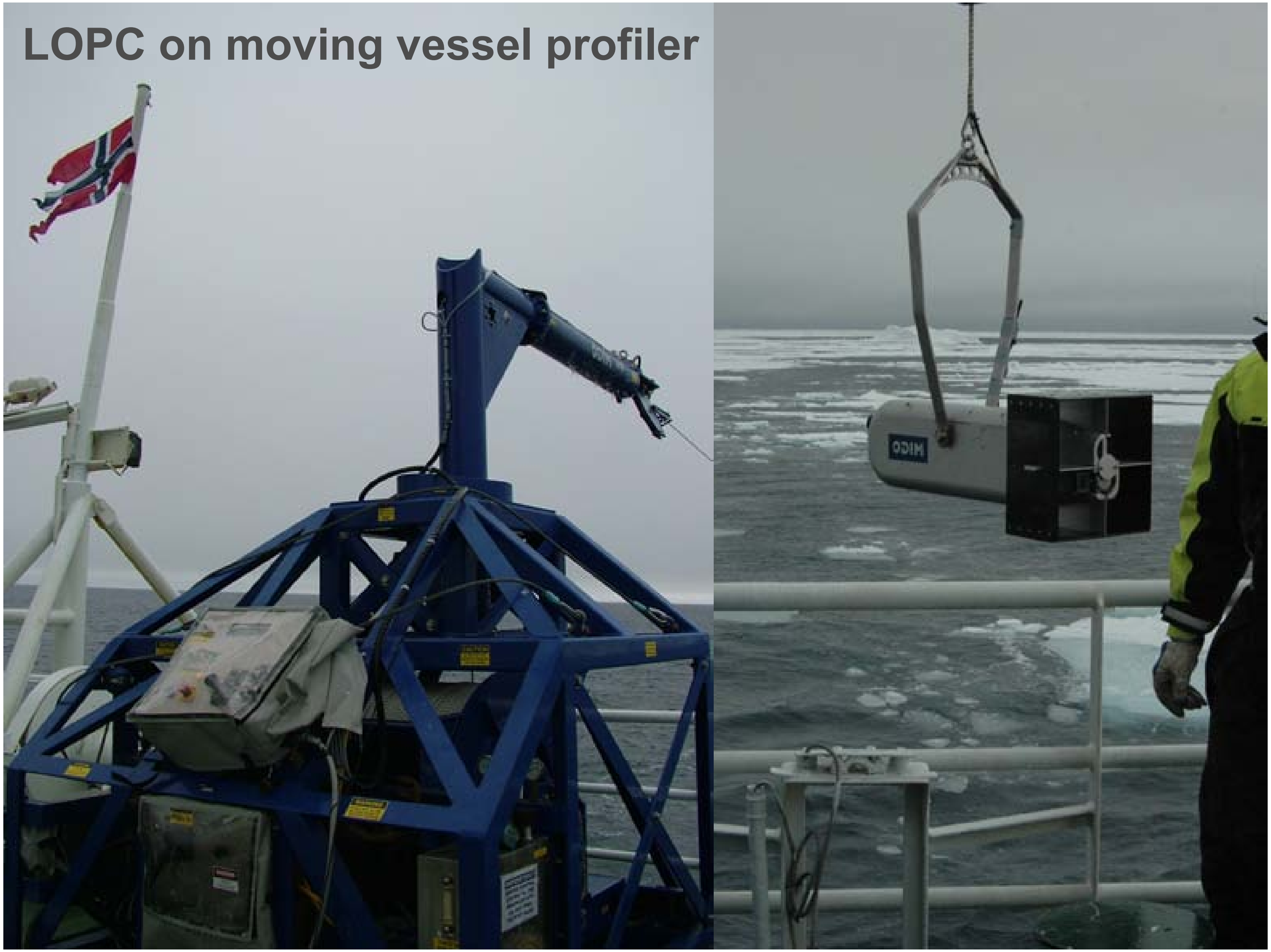
How do we measure spectra?



How do we measure spectra?

Deployment of towed VPR II

How do we measure spectra?

Example of processed LOPC data file

#idNr	year	mo	dy	hr	mi	se	latitude	longitude	dep	tem	sal	flu	1	2	3	4	5	6
#esd (mm) intervals:													0.100	0.112	0.126	0.141	0.159	0.178
#biovol (mm3) intervals:													5.248e-04	7.413e-04	1.047e-03	1.479e-03	2.089e-03	2.951e-03
10	2011	06	21	07	14	03	75.51035	29.98962	3.84	5.3660	35.0543	25.6429	105002.134	82092.577	71401.451	50782.850	50019.198	69492.321
11	2011	06	21	07	14	04	75.51036	29.98962	3.80	5.3710	35.0562	24.1900	92457.955	85228.732	66584.947	56692.326	46799.705	68487.374
12	2011	06	21	07	14	04	75.51037	29.98962	3.79	5.3747	35.0543	24.2900	108409.820	78530.081	74699.346	61674.844	37924.283	73550.125
13	2011	06	21	07	14	05	75.51038	29.98962	3.81	5.3717	35.0547	25.6333	101678.276	82400.982	68415.494	48760.214	34396.740	69927.439
14	2011	06	21	07	14	05	75.51039	29.98962	3.82	5.3693	35.0485	29.7800	108229.144	86888.186	64022.874	55638.926	44968.447	67071.582
15	2011	06	21	07	14	06	75.51040	29.98962	3.79	5.3642	35.0500	23.9133	98628.216	91826.270	75955.063	58572.312	41189.561	60083.856
16	2011	06	21	07	14	06	75.51040	29.98962	3.76	5.3659	35.0584	23.0231	105983.768	94122.769	83026.995	53183.191	41704.804	76522.576
17	2011	06	21	07	14	07	75.51041	29.98963	3.76	5.3687	35.0585	26.5846	99840.469	77952.367	71040.334	49536.233	44928.211	69888.329
18	2011	06	21	07	14	07	75.51043	29.98963	3.72	5.3738	35.0509	22.3692	108802.956	84197.340	75354.697	60360.650	41521.976	68818.831
19	2011	06	21	07	14	08	75.51044	29.98963	3.77	5.3699	35.0522	25.4812	87840.917	80584.494	53850.302	53086.467	42392.791	60342.891
20	2011	06	21	07	14	08	75.51045	29.98963	3.76	5.3659	35.0523	27.6600	93909.226	74975.914	71567.918	47333.279	42031.952	54527.938
21	2011	06	21	07	14	09	75.51046	29.98963	3.77	5.3666	35.0530	26.0647	100540.492	78618.129	65011.145	50270.246	38931.093	61231.428
22	2011	06	21	07	14	09	75.51047	29.98964	3.84	5.3662	35.0487	23.7083	87301.110	81481.036	66348.843	57424.730	33756.429	57812.735
23	2011	06	21	07	14	10	75.51049	29.98964	4.16	5.3605	35.0472	23.9615	89933.814	82180.899	66287.423	49618.656	40702.804	69776.235
24	2011	06	21	07	14	10	75.51050	29.98964	4.79	5.3613	35.0595	26.4417	97533.649	84529.163	65022.433	51635.461	38630.975	71907.161
25	2011	06	21	07	14	11	75.51051	29.98964	5.68	5.3755	35.0512	29.5846	95377.364	78036.025	66836.410	46604.848	44798.459	69004.077
26	2011	06	21	07	14	11	75.51052	29.98964	6.71	5.3697	35.0381	32.9750	93545.471	84513.494	75804.088	52901.576	37740.759	69997.818
27	2011	06	21	07	14	12	75.51053	29.98964	8.00	5.3162	34.9917	45.9154	76437.586	66565.573	50206.238	43154.800	33846.902	58667.963
28	2011	06	21	07	14	12	75.51054	29.98965	9.24	5.2071	34.9850	57.2727	30581.642	35528.672	29457.317	22486.501	20237.851	35978.402
29	2011	06	21	07	14	13	75.51055	29.98965	10.71	5.1763	35.0296	53.0286	26209.606	24291.830	23013.313	22160.968	17846.898	34093.797
30	2011	06	21	07	14	13	75.51056	29.98965	12.33	5.1405	34.9907	52.8917	44636.940	35752.889	32935.995	29685.732	23401.891	45720.361
31	2011	06	21	07	14	14	75.51057	29.98965	13.94	5.0427	35.0055	52.3231	43774.263	44177.713	33486.303	28644.910	22189.719	42967.365
32	2011	06	21	07	14	14	75.51058	29.98965	15.64	4.9687	34.9771	54.8250	31591.106	37006.724	32132.668	28522.256	22745.596	36826.204
33	2011	06	21	07	14	15	75.51059	29.98965	17.53	4.8262	34.9351	63.5846	61945.612	59704.159	49719.504	36067.017	31176.574	50330.818
34	2011	06	21	07	14	15	75.51060	29.98966	19.32	4.6422	34.9753	66.0333	54412.208	44695.742	41392.144	35173.606	25651.470	43918.425
35	2011	06	21	07	14	16	75.51061	29.98966	21.25	4.5047	34.9506	82.7615	76730.177	67774.931	54952.647	46811.514	31139.833	52917.364
36	2011	06	21	07	14	16	75.51063	29.98966	23.22	4.3374	34.8826	141.8417	49180.353	58209.559	44953.917	39959.037	31121.942	49564.575
37	2011	06	21	07	14	17	75.51064	29.98966	25.23	4.0762	34.8954	203.8000	31511.285	35069.011	33883.102	29986.546	21515.770	38287.906
38	2011	06	21	07	14	17	75.51065	29.98967	27.20	3.8829	34.9332	356.9500	36361.001	36181.883	36898.356	30987.454	24180.961	40659.838
39	2011	06	21	07	14	18	75.51066	29.98967	29.20	3.7790	34.9452	124.6385	33170.438	38288.163	34876.347	31085.439	29379.531	47765.431
40	2011	06	21	07	14	18	75.51067	29.98967	31.30	3.6706	34.9316	71.3167	48628.307	55178.242	51407.067	38505.680	35528.436	50017.687
41	2011	06	21	07	14	19	75.51068	29.98967	33.25	3.5346	34.9299	41.9167	67432.644	64384.841	60384.599	44955.096	32382.908	45907.535
42	2011	06	21	07	14	19	75.51069	29.98968	35.36	3.4980	35.0382	21.0583	67679.633	64852.286	45944.399	33751.462	21558.526	30217.278
43	2011	06	21	07	14	20	75.51070	29.98968	37.51	3.5320	34.9933	55.8846	36381.954	31961.717	23121.242	18360.986	11900.639	14620.785
44	2011	06	21	07	14	20	75.51071	29.98968	39.57	3.4810	35.0044	20.9750	32458.102	20639.119	18169.481	12524.594	7408.915	13053.802
45	2011	06	21	07	14	21	75.51072	29.98968	41.73	3.4396	34.9957	16.3462	22381.701	19160.092	14412.459	10682.175	8308.359	8477.917

Application 1: Trophic indices

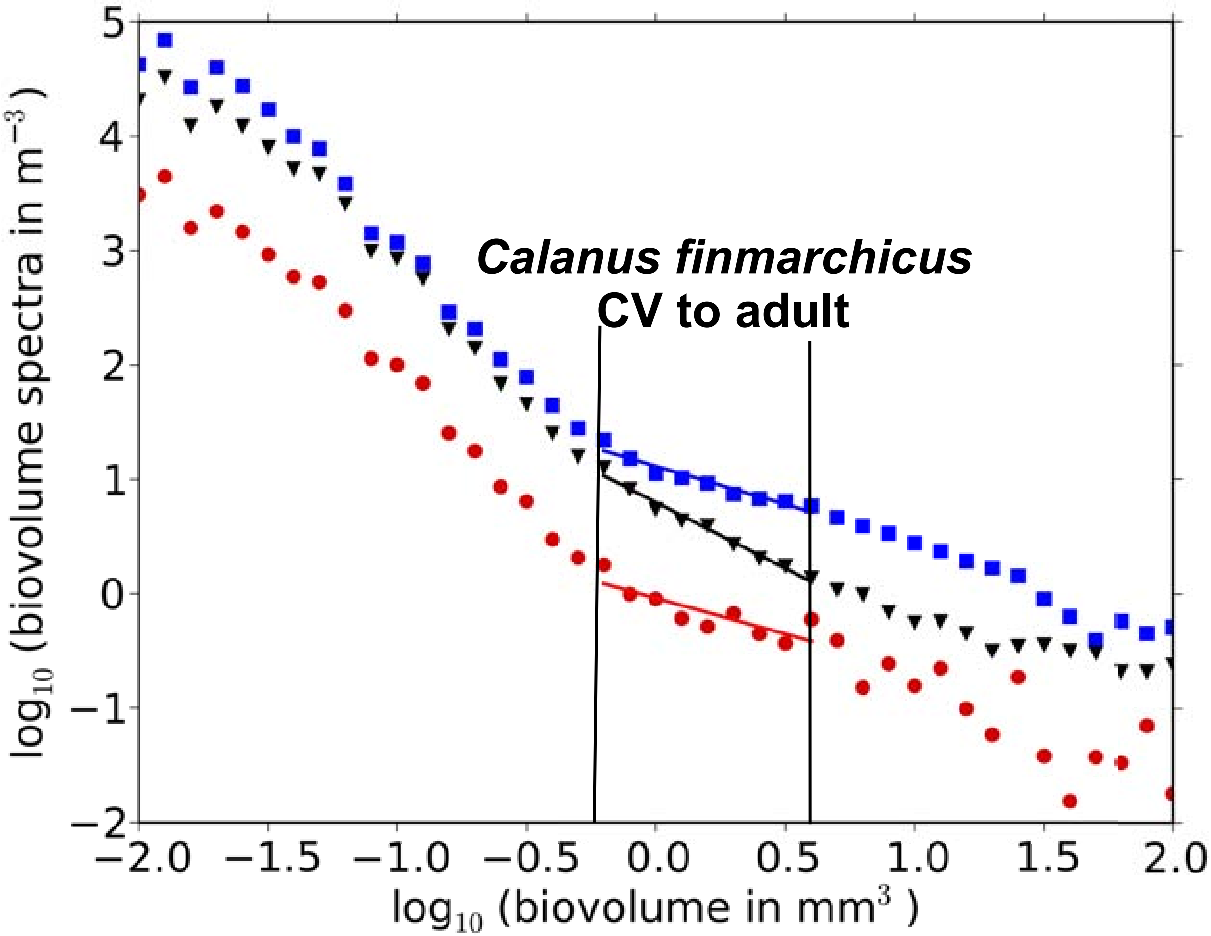
- **Assumption: significant fit of slope to spectrum**
- **Requires knowledge of assimilation efficiency**

- **Trophic index:**

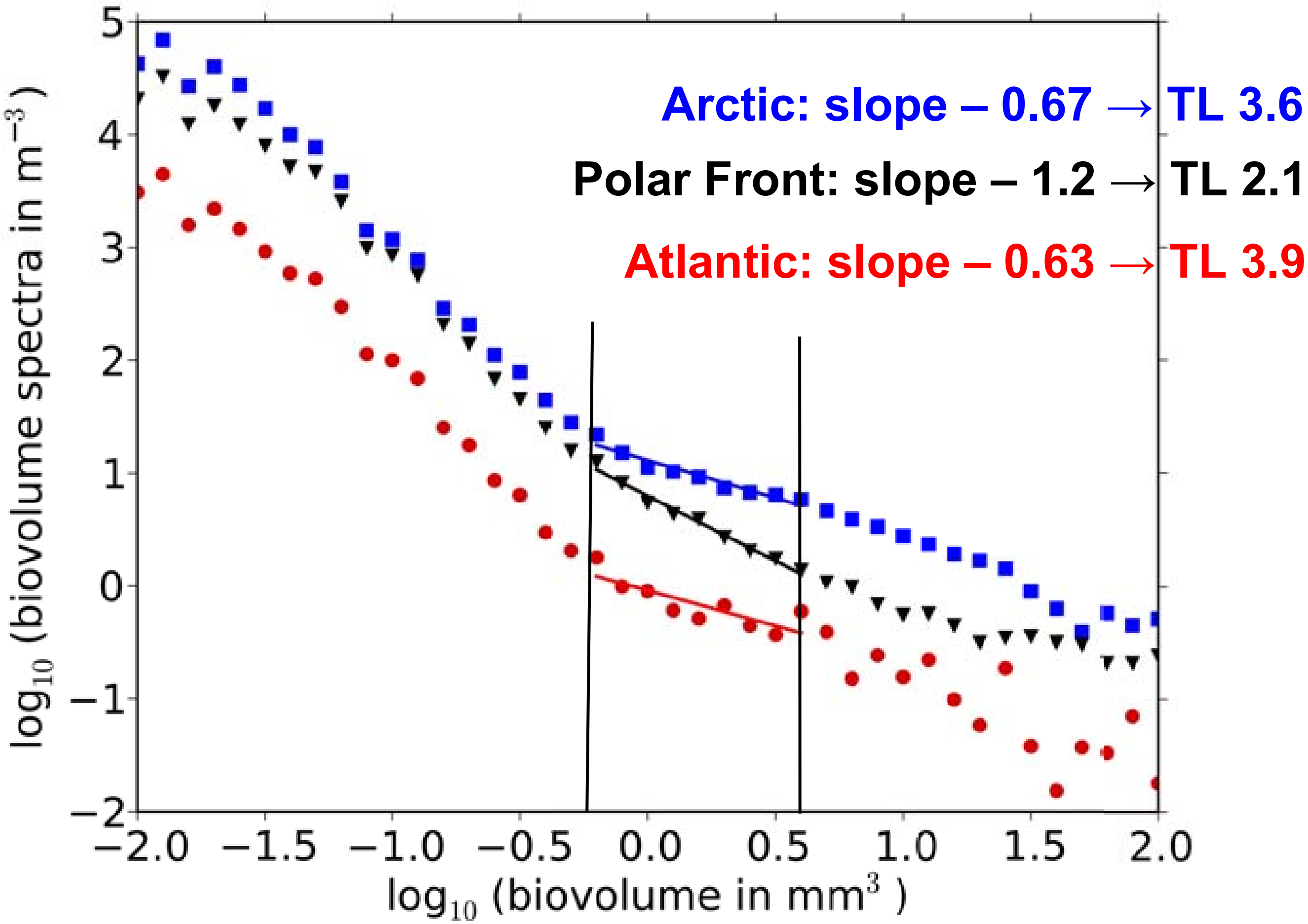
$$\mathbf{TI = - [(1 + \eta_n) / (\eta_n * \delta \log_{10} \mathit{b} / \delta \log_{10} \mathit{w})]}$$

Zhou 2006 J Plankton Res 28
Basedow et al. 2010 J Plankton Res 32

Application 1: Trophic indices



Application 1: Trophic indices



Application 1: Trophic indices

- Trophic levels estimated by biovolume spectrum theory

	Apr 30-May 2	10-12 May	14-15 May
Arctic	3.6	2.2	3.1
Polar Front	2.1	1.7	2.1
Atlantic	3.9	2.0	1.7

estimated by stable isotopes

spring	1.6 - 2.4
winter	2.6 - 3.1

Søreide et al. 2006 Prog Oceanogr 71

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Søreide et al. 2006 Prog Oceanogr 71

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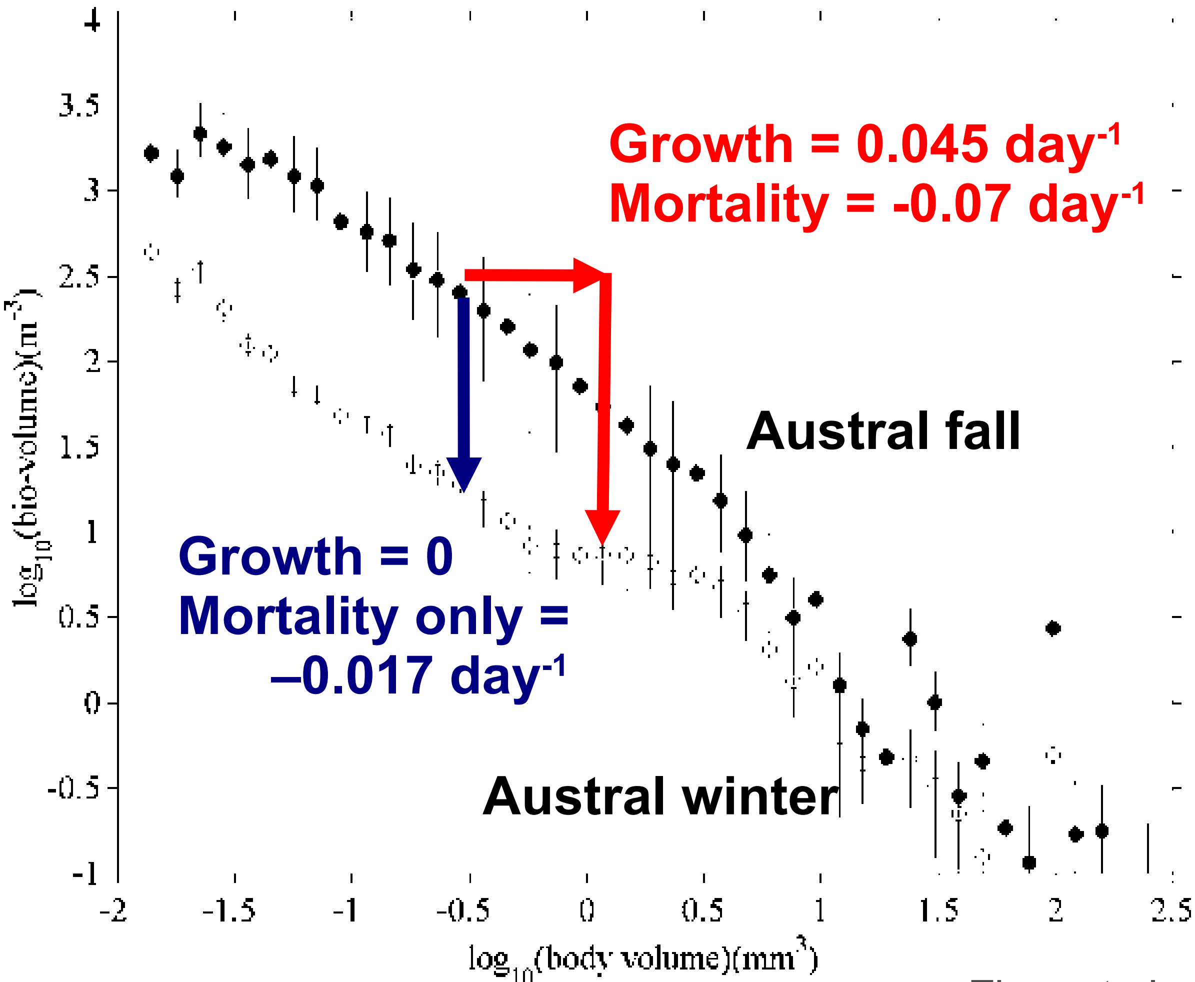
Growth, production and mortality: closure needed



Zhou et al.

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Application 2: Growth and production

A) Based on 2 or more consecutive biomass-spectra from non-advective areas (Edvardsen et al. 2002)

B) Using empirical fits of growth to bodyweight, chlorophyll concentration and temperature (Hirst & Bunker 2003)

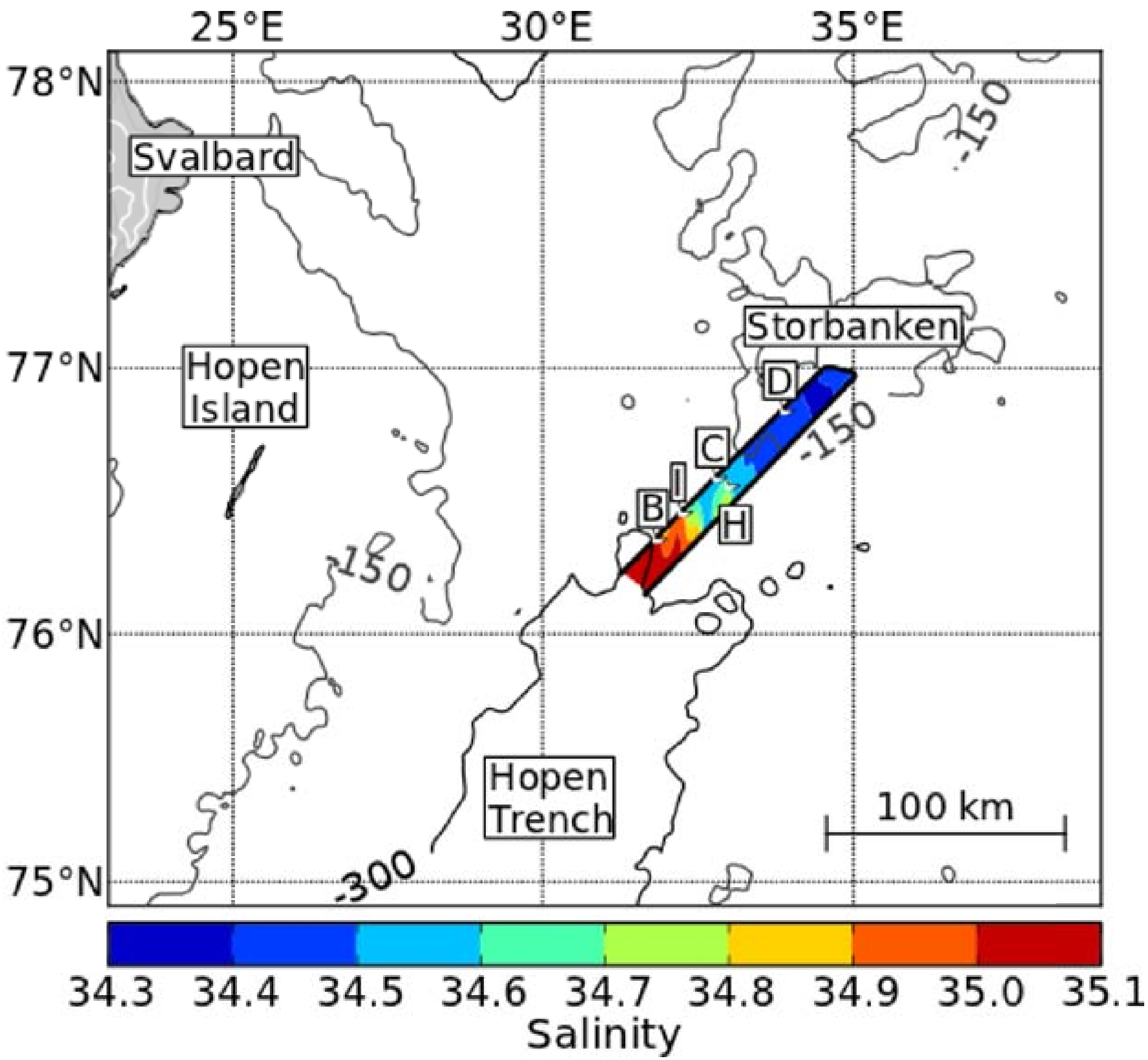
$$g(w, T, C_a) = 10^{aT} w^b C_a^{\,c}\, 10^d$$

C) Semiempirical fits (Zhou et al 2010)

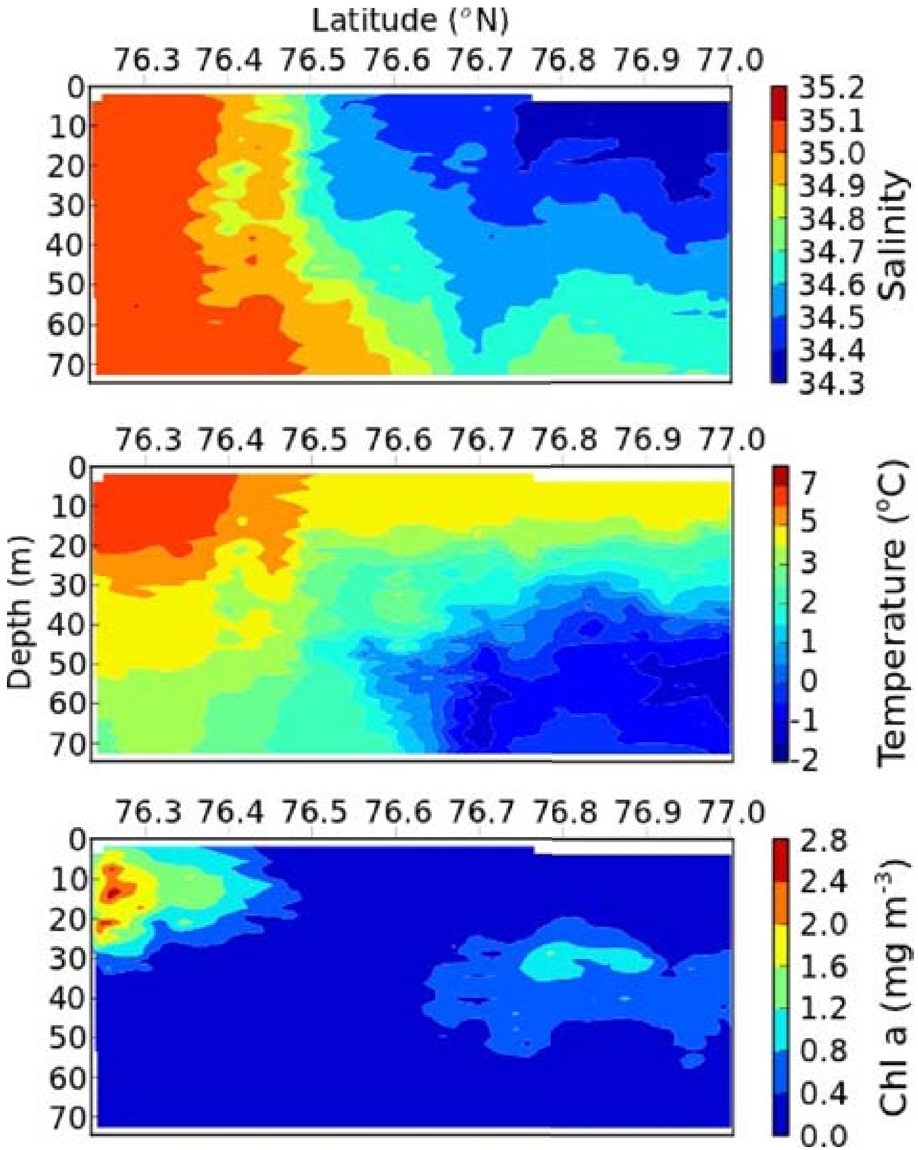
$$g(w, T, C_a) = 0.033(C_a / C_a + 205e^{-0.125T})e^{0.09T}w^{-0.06}$$

$$\text{Production} = g * w * N / dw$$

App. 2: Growth & production



App. 2: Growth & production



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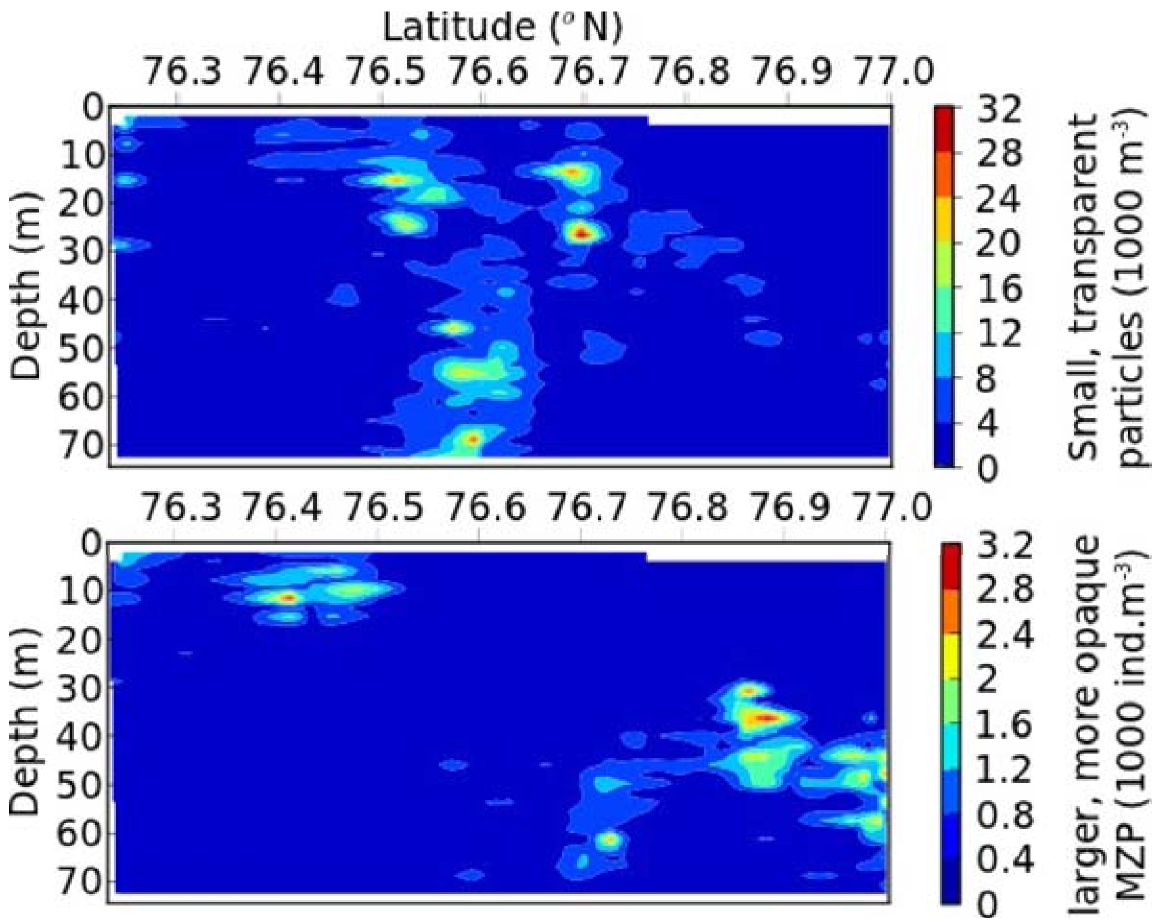
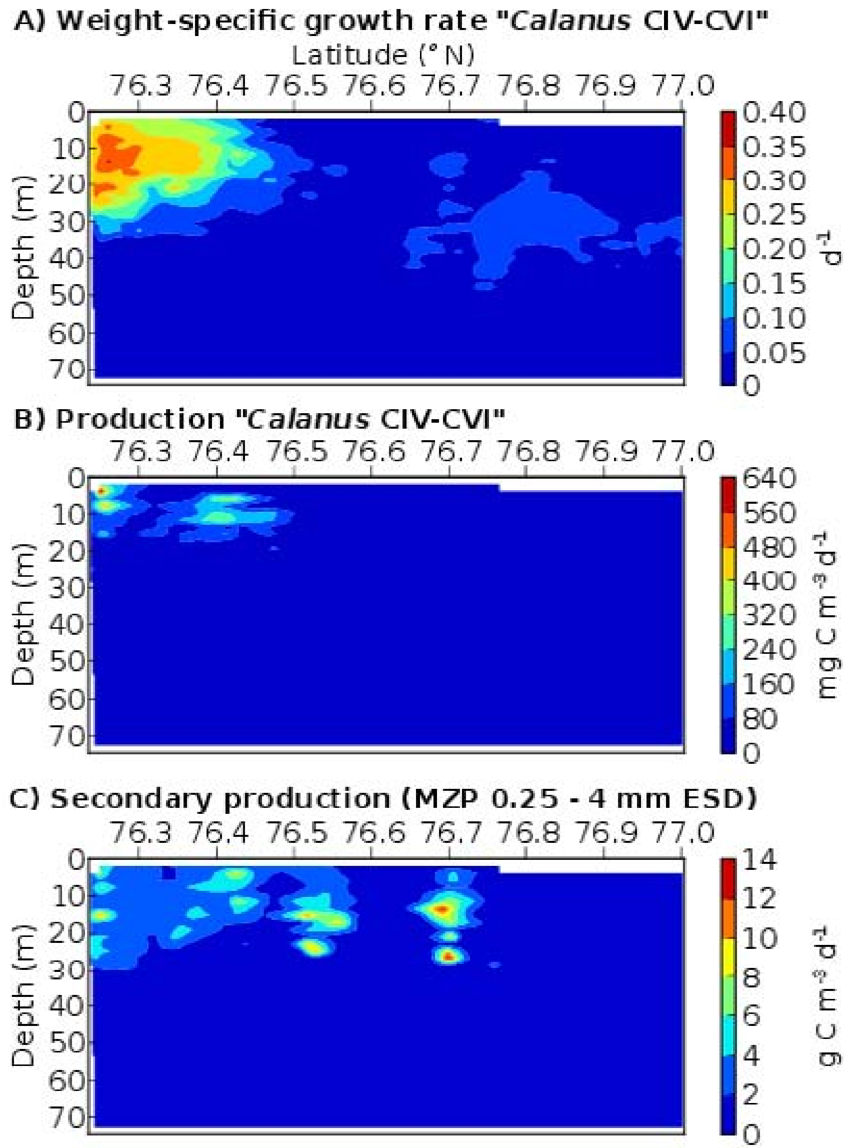


Basedow et al. in review J Mar Sys

App. 2: Growth & production



App. 2: Growth & production

in mg C d^{-1} m^{-3}

Production	AtW	PfW	TzW	ArW
S	1,388.5	973.8	1,084.3	76.1
M	94.2	41.9	27.0	16.6
L	23.4	11.5	3.2	4.3
XL	5.8	0.6	0.1	0.2
2XL	3.1	0.2	0.1	0.1
Loss				
S	-280.2	-165.8	-270.6	-14.0
M	-33.7	-21.4	-16.8	-0.1
L	-29.1	-29.8	-15.2	-5.3
XL	-6.9	-7.0	-4.8	-2.7
2XL	-22.7	-3.7	-0.3	-0.1
Population change				
S	133.6	35.1	-26.1	19.1
M	3.6	-5.3	-5.1	13.2
L	0.9	-1.7	-1.3	-1.0
XL	2.3	0.1	-	-
2XL	0.4	0.1	0.1	0.1

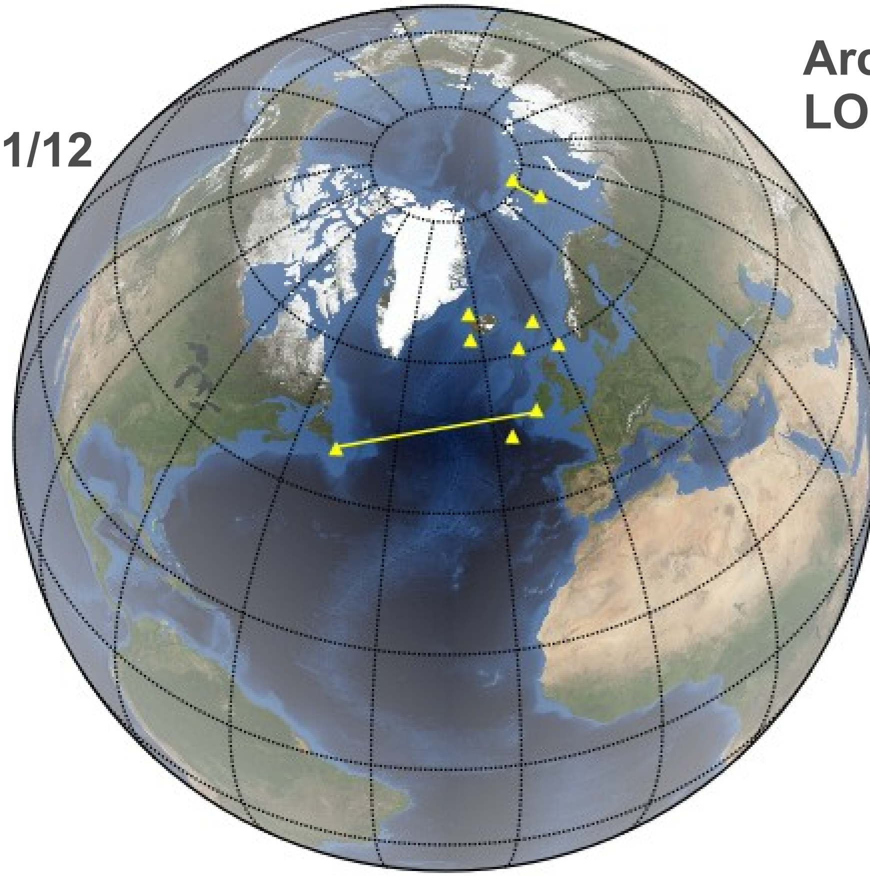
Approach within EURO-BASIN

- Study biomass flow, community structure and trophic interactions by computing growth, mortality and trophic state based on spectra from different seasons and areas
- Compare to data on vital rates from WP4
- Goal: develop an easy characterisation of pelagic habitats based on biovolume spectra (T3.2 Classification of different regimes by size spectra)
- Classification of different regimes by size spectra will also be important for T7.3 in the development of bio-economic modelling of fish communities
- Additional: estimate carbon flux based on optical data

Optical data collected during BASIN

Iceland:
Seasonal study 11/12
Annual 11/12/13
VPR

Transatlantic
2013
VPR and LOPC



Arctic habitat:
LOPC, summer 2011

Deep Convection
2012
LOPC and VPR

PAP site?

- Good coverage: seasonal/inter-annual, vertical/horizontal, small scale/large scale, basin/shelf, core/edges of North Atlantic
- Important: Intercalibraton of VPR and LOPC

Data analysis

- Optical workshop Hamburg September 2012
- Share expertise and develop best practice guidelines
- Train LOPC and VPR users to standardise analyses