PHOSPHORUS, NITROGEN, IRON AND MANGANESE IN MARINE ZOOPLANKTON

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In 1936 an investigation of the inorganic constituents of certain marine zooplankton organisms was started but had temporarily to be suspended. The results obtained are presented as an interim report.

Preparation of Material and Methods of Analysis

Nauplii of the cirripede crustacean *Balanus balanoides* (sample 2) were extracted from the mantle cavities of adults on February 20 1936, by Dr H. B. Moore. Only specimens able to swim towards the light were used for analysis. These were concentrated by centrifuging, placed on a no. 50 Whatman filter, washed with 1 ml. of sea water and dried under suction before transferring to a small tared porcelain crucible. Prepared in this way the sample must contain a little sea water which will slightly affect both wet and dry (105° C.) weights. The elementary analyses reported in Table I were all made on the same dried material and are comparable. Since parallel counts of the nauplii showed wide variations, the numbers of animals attributed to the sample and the wet and dry weights of single organisms are approximate only.

Samples 9–13, from a 2 m. ring-trawl catch taken two miles off Revelstoke Point on June 5 1936, were all picked out alive with stainless steel forceps, measured, and transferred to tared glass evaporating dishes by Mr F. S. Russell. The post-larvae of the fish *Callionymus lyra* and the mature chaetognath, *Sagitta elegans*, had the following measurements:

	C. lyra	*S. elegans*
No. of animals ...	32	125
Length (mm.):		
Range	5–9	9–18
Median	7	14

Fifty ctenophores, *Pleurobrachia* (sample 11), all lay between 7 and 10 mm. in height. A further 225 animals (sample 16*a*) were taken from another catch on September 28 1936, for manganese analysis.

After removal of excess sea water by filter paper, the samples were weighed wet and then dried to constant weight at 105–110° C. Aliquot parts of dried material were weighed out on a Kuhlmann micro-balance for carbon analysis by Pregl's method, for micro-Kjeldahl nitrogen determinations by the method of Parnas and Wagner and for wet digestion for analyses of phosphorus and

TABLE I

Sample no.	Organism	Date of capture 1936	No. of animals analysed	Wet weight of one animal mg.	Dry weight of one animal mg.	Dry weight / Wet weight %	Percentage composition based on dry weight: P	N	Fe	Mn
2	*Balanus balanoides* nauplii*	20. ii	102,000	0·0161	0·000915	5·67	1·7	9·7	0·12	<0·00003
9	*Callionymus lyra* post-larvae	5. vi	32	8·72	1·23	14·1	1·60	8·24	0·031	..
10	*Sagitta elegans* mature	5. vi	125	5·71	0·530	9·29	0·945	9·24	0·042	..
11	*Pleurobrachia pileus*†	5. vi	50	115	5·09	4·43	0·230	1·34	0·0050	..
11	,, ,, (ash free)	5. vi	50	..	..	..	0·630	3·68	0·0137	..
16*a*	,, ,,	2. x	225	481	19·6	4·07	..	..	..	<0·00005
12	Portunid megalopas	5. vi	15	4·47	0·784	17·5	1·14	6·32	0·077	..
13	Portunid zoeas and Crangonid larvae	5. vi	34	3·27	0·519	17·5	1·16	7·22	0·035	..
14	Portunid zoeas and Crangonid larvae	5. vi	20	1·77	0·301	17·0	..	..	0·093	..

* C 43·1 %, H 9·2 %, ash 16·3 %, chitin <2 % on dry weight.

† Ash at dull red heat 63·57 %.

Sample no.	Organism	Content of one animal μg.: P	N	Fe	Mn	Ratios in mg.-atoms: N/P	Fe/P
2	*Balanus balanoides* nauplii	0·016	0·89	0·0011	<0·00003	12·6	0·039
9	*Callionymus lyra* post-larvae	19·6	101	0·38	..	11·4	0·012
10	*Sagitta elegans* mature	5·02	49·0	0·22	..	21·6	0·025
11 and 16*a*	*Pleurobrachia pileus*	11·7	68·0	0·25	<0·009	12·8	0·012
12	Portunid megalopas	8·93	49·5	0·60	..	12·2	0·038
13	Portunid zoeas and Crangonid larvae	6·05	37·4	0·18	..	13·7	0·017
14	Portunid zoeas and Crangonid larvae	..	..	0·28	..	..	..

iron (Cooper, 1935*a*, *b*). In all the samples copper was determined by the diethyldithiocarbamate method. The amounts found were always greater than records for similar animals in the literature. The detailed results are withheld until the method can be re-examined.

Manganese determinations, requiring a large amount of material, were made only on *Pleurobrachia* and on *Balanus* nauplii. *Pleurobrachia* (225 animals; 108 g. wet weight) were digested with 5 ml. conc. sulphuric acid and perhydrol drop by drop. Some green matter remaining was destroyed with potassium persulphate. The solution was diluted and filtered through sintered glass and the manganese determined by the method of Willard and Greathouse (Yoe, 1928, p. 273) in which potassium periodate is employed to oxidize manganese to permanganate.

Discussion of Results

The presence of iron and copper in all the samples (Table I) confirms Fox & Ramage's report (1931) of their ubiquity in marine invertebrates and suggests further that the occurrence of both in sea water ought to show considerable seasonal fluctuations. The analyses of iron in the plankton indicator, *Sagitta elegans*, differ strikingly from those made two years earlier on *S. setosa* (Cooper, 1935*b*).

	Date of capture	No. in sample	Average length mm.	Content of one animal (μg.) P	Content of one animal (μg.) Fe	Ratio Fe/P mg.-atoms
*Sagitta setosa**	24. v. 34	6	15	5·3	6·8	0·72
Sagitta elegans	5. vi. 36	125	13·9	5·02	0·22	0·025

* No record has been kept of the condition of the forceps used for picking out *S. setosa* from the 1934 catch. These might have been rusty.

The contents of phosphorus, nitrogen and iron in *Pleurobrachia*, even after recalculation to an ash-free basis, are all considerably lower than those of other animals examined, suggesting that its gelatinous structure must consist of carbohydrate or fatty material and not of protein. *Pleurobrachia* contained less than 2×10^{-6} % of their wet weight as manganese ($< 5 \times 10^{-5}$ %

Table II. Seasonal Changes in Iron and Phosphorus Content of Plankton

Catches taken with the quantitative net in the English Channel at Station L 4 between the surface and 45 m.

Date 1935	Content in plankton from a cubic metre of sea water mg. Fe	mg. P	Ratio Fe/P wt./wt.	mg.-atoms
April 3	0·73	0·602	1·20	0·68
April 23	0·96	1·16	0·82	0·46
May 8	0·85	0·64	1·33	0·74

of dry weight). Since sea water contains from 0·1 to 1 × 10^{-6} % Mn (Thompson & Wilson, 1935), this animal evidently effects no considerable concentration of manganese from sea water. *Balanus* nauplii yielded a similar result.

Table II records some analyses of iron and phosphorus in mixed plankton in the spring of 1935 which confirm the picture already found in 1934 (Cooper, 1935*b*, table IV).

I wish to express my indebtedness to Mr F. S. Russell, who provided all but one of the zooplankton samples and measured them for me, and to Dr H. B. Moore, who prepared a very clean sample consisting only of lively *Balanus* nauplii.

Summary

Analyses of phosphorus, nitrogen, iron and manganese are recorded for *Balanus* nauplii (a cirripede crustacean), post-larval *Callionymus* (a teleostean fish), mature *Sagitta elegans* (a chaetognath), *Pleurobrachia* (a ctenophore) and for crab zoeas and megalopas (Table I). A sample of *Sagitta setosa* in 1934 contained much more iron than that in *S. elegans* here reported. The ctenophore, *Pleurobrachia*, is relatively poor in phosphorus, nitrogen and iron and its ash-free protoplasm must evidently be rich in either fats or carbohydrates. Neither *Pleurobrachia* nor *Balanus* nauplii effect any appreciable concentration of manganese from sea water.

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