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HANDBOOK FOR MARINE BIOLOGY

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## FOREWORD

This handbook represents an attempt to bring together a variety of conversion tables, drawings of representative marine and freshwater organisms, drawings of sampling gear used in aquatic biological research and terminology into a single volume. The material included should aid the beginning student in acquainting himself with the aquatic sciences and should be of use to professionals who may find the conversion tables and definitions in the glossary of some value.

The glossary of oceanographic and limnological terms is composed mainly of terms which we have found useful. Omissions are unavoidable, and some definitions may not be acceptable to individuals of disciplines other than biology. We have tried to define terms in a way which will gain the widest possible acceptance and avoid ambiguity.

The line drawings of organisms included in this handbook were selected largely from organisms commonly found in the southeastern United States, since this is the area with which we are most familiar and it is the area most accessible to us for sampling. Each of the drawings was made from preserved or fresh material or was redrawn as indicated.

The diversity of sampling gear utilized by aquatic biologists has grown rapidly in recent years. We have attempted to include at least one example of equipment used to sample each of the various aquatic communities. In general, oceanographers and limnologists utilize the same types of sampling gear, but the size and weight of oceanographic gear is often much

greater than a similar piece of equipment used by a limnologist.

This handbook is a revision of a previous manual: "Handbook for Marine Biology," which appeared as Georgia Marine Science Center Technical Report Series Number 72-5, August, 1972. Much of the material is the same in the two editions; however, deletions from and additions to the previous edition have been made. We have attempted to correct the several errors we noted in the first edition, and wish to thank those who pointed out some of these errors to us.

UNITS OF WEIGHT AND MEASUREMENT  
AND CONVERSION TABLES

TABLE 1

Conversion tables for units of measurement between the English  
and metric systems

Unit of measurement	Conversion factors
Acre-foot	43,560 cubic feet 1233.51 cubic meters
Acre	43,560 square feet 4,840 square yards 0.0016 square mile 0.4047 hectare
Angstrom	$10^{-10}$ meters $10^{-8}$ centimeters 0.1 millimicron
Centiliter	10 cubic centimeters
Centimeter	0.3937 inch 0.0328 foot 0.01 meter 10 millimeters
Cubic Cubic centimeter	0.0610 cubic inch 1 milliliter
Cubic foot	7.4805 gallons (U.S. liquid) 0.0283 cubic meter 28.3161 liters
Cubic inch	16.387 cubic centimeters
Cubic meter	35.314 cubic feet 264.172 gallons (U.S. liquid) 1.308 cubic yards 1,000 liters
Foot Foot	0.3048 meter
Gallon (U.S. liquid)	231.0 cubic inches 0.13368 cubic foot 0.0038 cubic meter 3.7853 liters

TABLE 1 (continued)

Unit of measurement	Conversion factors
Gram	0.0022 pound (avoir.) 0.0353 ounce (avoir.)
Hectare	2.471 acres 10,000 square meters
Inch	2.54 centimeters
Kilogram	2.2046 pounds (avoir.)
Kilometer	0.6214 mile (statute)
Liter	0.2642 gallon (U.S. liquid) 1.0567 quarts (U.S. liquid) 0.9080 quarts (wet measure) 0.0353 cubic foot
Meter	39.37 inches 3.2808 feet 1.0936 yards 1,000 millimeters 100 centimeters 0.001 kilometers
Micron	$10^{-6}$ meters $10^{-4}$ centimeters
Millimeter	0.0394 inch 0.001 meter
Mile (statute)	5,280 feet 1,760 yards 1.6093 kilometers
Mile (nautical)	6,080.27 feet (U.S. Navy)
Millimicron	0.001 micron $10^{-9}$ meters

TABLE 1 (continued)

Unit of measurement	Conversion factors
Ounce (U. S. fluid)	1.8047 cubic inches 29.5737 cubic centimeters
Ounce (apoth.)	31.1035 grams
Ounce (Avoir.)	28.3495 grams
Pint (U. S. liquid)	0.4732 liter 473.1765 cubic centimeters
Pound (Avoir.)	453.5924 grams
Pound (apoth.)	373.2417 grams
Quart (U. S. dry)	1.1012 liters
Quart (liquid)	0.9463 liter
Rod	5.5 yards 5.0292 meters
Square centimeter	0.1550 square inch
Square foot	0.0929 square meter
Square inch	645.16 square millimeters
Square meter	10.7639 square feet
Square yard	0.8361 square meter
Ton (metric)	1,000 kilograms
Ton (short)	2,000 pounds 907.1847 kilograms

TABLE 1 (continued)

Unit of measurement	Conversion factors
Ton (long)	2,240 pounds 1016.064 kilograms
Yard	0.9144 meter 3.0 feet

Source: Handbook of Chemistry and Physics. 1964. Forty-fifth ed. Chemical Rubber Co., Cleveland, Ohio.

TABLE 2

## Miscellaneous constants and conversion factors

Terminology	Constant or Conversion Factor
<b>Earth Dimensions</b>	
Equatorial radius	6378.388 kilometers 3963.34 statute miles
Polar radius	6356.912 kilometers 3949.99 statute miles
Seas	cover approximately 70 percent of the total surface area
<b>Physical Constants &amp; Conversions</b>	
Avogadro's number	$6.023 \times 10^{23}$ the number of molecules in one mole of an element
Calorie	gram calorie - amount of heat needed to raise the temperature of one gram of water one degree Celsius from 15 to 16  kilocalorie - 1,000 calories
Dyne	the force required to accelerate a one gram mass at $1 \text{ cm sec}^{-2}$
Gravity	the acceleration due to gravity at sea level ( $45^\circ$ latitude) = $980.621 \text{ cm sec}^{-2}$ = $32.1171 \text{ ft sec}^{-2}$
Temperature	Fahrenheit = F Celsius (replaces Centigrade) = C  $F = 1.8 C + 32$ $C = \frac{F - 32}{1.8}$  Water freezes: 32 F; 0 C (1 atmosphere pressure)

TABLE 2 (continued)

Terminology	Constant or Conversion Factor
	Water boils: 212 F; 100 C (1 atmosphere pressure)
	Kelvin or Absolute temperature scale: K
	Absolute zero = 0 K = -273 C
	Water freezes: 273 K
	Water boils: 373 K
Sverdrup	One Sverdrup is equivalent to the passage of $1 \times 10^6 \text{ m}^3$ of water past a point in one second
Water	Maximum density at 3.98 C ( $0.999973 \text{ g cm}^{-3}$ )
	Heat of fusion (0 C): $79.71 \text{ cal g}^{-1}$
	Heat of vaporization (100 C): $539.55 \text{ cal g}^{-1}$

TABLE 3

Salinity values from 2.0 to 38.0 parts per thousand and corresponding densities at 15 C

Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
1.0007	2.0	1.0027	4.6	1.0047	7.2	1.0067	9.8	1.0087	12.4
1.0008	2.1	1.0028	4.7	1.0048	7.3	1.0068	9.9	1.0088	12.6
1.0009	2.2	1.0029	4.8	1.0049	7.5	1.0069	10.1	1.0089	12.7
1.0010	2.4	1.0030	5.0	1.0050	7.6	1.0070	10.2	1.0090	12.8
1.0011	2.5	1.0031	5.1	1.0051	7.7	1.0071	10.3	1.0091	12.9
1.0012	2.6	1.0032	5.2	1.0052	7.9	1.0072	10.5	1.0092	13.1
1.0013	2.8	1.0033	5.4	1.0053	8.0	1.0073	10.6	1.0093	13.2
1.0014	2.9	1.0034	5.5	1.0054	8.1	1.0074	10.7	1.0094	13.3
1.0015	3.0	1.0035	5.6	1.0055	8.2	1.0075	10.8	1.0095	13.5
1.0016	3.2	1.0036	5.8	1.0056	8.4	1.0076	11.0	1.0096	13.6
1.0017	3.3	1.0037	5.9	1.0057	8.5	1.0077	11.1	1.0097	13.7
1.0018	3.4	1.0038	6.0	1.0058	8.6	1.0078	11.2	1.0098	13.9
1.0019	3.5	1.0039	6.2	1.0059	8.8	1.0079	11.4	1.0099	14.0
1.0020	3.7	1.0040	6.3	1.0060	8.9	1.0080	11.5	1.0100	14.1
1.0021	3.8	1.0041	6.4	1.0061	9.0	1.0081	11.6	1.0101	14.2
1.0022	3.9	1.0042	6.6	1.0062	9.2	1.0082	11.8	1.0102	14.4
1.0023	4.1	1.0043	6.7	1.0063	9.3	1.0083	11.9	1.0103	14.5
1.0024	4.2	1.0044	6.8	1.0064	9.4	1.0084	12.0	1.0104	14.6
1.0025	4.3	1.0045	7.0	1.0065	9.6	1.0085	12.2	1.0105	14.8
1.0026	4.5	1.0046	7.1	1.0066	9.7	1.0086	12.3	1.0106	14.9

TABLE 3 (continued)

Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
1.0107	15.0	1.0127	17.6	1.0147	20.3	1.0167	22.9	1.0187	25.5
1.0108	15.2	1.0128	17.8	1.0148	20.4	1.0168	23.0	1.0188	25.6
1.0109	15.3	1.0129	17.9	1.0149	20.5	1.0169	23.1	1.0189	25.8
1.0110	15.4	1.0130	18.0	1.0150	20.6	1.0170	23.3	1.0190	25.9
1.0111	15.6	1.0131	18.2	1.0151	20.8	1.0171	23.4	1.0191	26.0
1.0112	15.7	1.0132	18.3	1.0152	20.9	1.0172	23.5	1.0192	26.1
1.0113	15.8	1.0133	18.4	1.0153	21.0	1.0173	23.7	1.0193	26.3
1.0114	16.0	1.0134	18.6	1.0154	21.2	1.0174	23.8	1.0194	26.4
1.0115	16.1	1.0135	18.7	1.0155	21.3	1.0175	23.9	1.0195	26.5
1.0116	16.2	1.0136	18.8	1.0156	21.4	1.0176	24.0	1.0196	26.7
1.0117	16.3	1.0137	19.0	1.0157	21.6	1.0177	24.2	1.0197	26.8
1.0118	16.5	1.0138	19.1	1.0158	21.7	1.0178	24.3	1.0198	26.9
1.0119	16.6	1.0139	19.2	1.0159	21.8	1.0179	24.4	1.0199	27.1
1.0120	16.7	1.0140	19.4	1.0160	22.0	1.0180	24.6	1.0200	27.2
1.0121	16.9	1.0141	19.5	1.0161	22.1	1.0181	24.7	1.0201	27.3
1.0122	17.0	1.0142	19.6	1.0162	22.2	1.0182	24.8	1.0202	27.4
1.0123	17.1	1.0143	19.7	1.0163	22.4	1.0183	25.0	1.0203	27.6
1.0124	17.3	1.0144	19.9	1.0164	22.5	1.0184	25.1	1.0204	27.7
1.0125	17.4	1.0145	20.0	1.0165	22.6	1.0185	25.2	1.0205	27.8
1.0126	17.5	1.0146	20.1	1.0166	22.7	1.0186	25.4	1.0206	28.0

TABLE 3 (continued)

Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
1.0207	28.1	1.0227	30.7	1.0247	33.3	1.0267	35.9
1.0208	28.2	1.0228	30.8	1.0248	33.4	1.0268	36.0
1.0209	28.4	1.0229	31.0	1.0249	33.6	1.0269	36.2
1.0210	28.5	1.0230	31.1	1.0250	33.7	1.0270	36.3
1.0211	28.6	1.0231	31.2	1.0251	33.8	1.0271	36.4
1.0212	28.8	1.0232	31.4	1.0252	34.0	1.0272	36.6
1.0213	28.9	1.0233	31.5	1.0253	34.1	1.0273	36.7
1.0214	29.0	1.0234	31.6	1.0254	34.2	1.0274	36.8
1.0215	29.1	1.0235	31.8	1.0255	34.4	1.0275	37.0
1.0216	29.3	1.0236	31.9	1.0256	34.5	1.0276	37.1
1.0217	29.4	1.0237	32.0	1.0257	34.6	1.0277	37.2
1.0218	29.5	1.0238	32.1	1.0258	34.7	1.0278	37.3
1.0219	29.7	1.0239	32.3	1.0259	34.9	1.0279	37.5
1.0220	29.8	1.0240	32.4	1.0260	35.0	1.0280	37.6
1.0221	29.9	1.0241	32.5	1.0261	35.1	1.0281	37.7
1.0222	30.0	1.0242	32.7	1.0262	35.3	1.0282	37.9
1.0223	30.2	1.0243	32.8	1.0263	35.4	1.0283	38.0
1.0224	30.3	1.0244	32.9	1.0264	35.5		
1.0225	30.4	1.0245	33.0	1.0265	35.6		
1.0226	30.6	1.0246	33.2	1.0266	35.8		

Notes: One of the many ways in which salinity can be determined is by use of a hydrometer.

Many hydrometers are calibrated for 15 C, thus the above table may be used to calculate salinity directly from the density reading on the hydrometer. The table

may be calculated from values of sigma-t. A complete table of these values for intervals of 0.1 C and 0.1 part per thousand salinity is available (Keala 1965), and was used for the derivation of the data presented in the above density table.

Density is defined as mass per unit volume. For distilled water at 4 C the density at sea level is 1.0000. The density of distilled water decreases at temperatures above and below this maximum density. However, as the amount of dissolved salts in the water is increased, the density also increases. Thus, as can be seen from this table, at 15 C and 35 parts per thousand salinity the density of water is 1.0260.

Sigma-t values are utilized by physical oceanographers and others as a shorthand notation for density (see Table 4). Sigma-t is derived from the following formula:

$$\text{Sigma } t = (\text{Density} - 1) \times 1000 .$$

The following example will serve to demonstrate how the values in this table were derived. A glance at Table 4 will reveal that the sigma-t of water at 15 C and 20 parts per thousand salinity is 14.496. Rounding to 14.50 and substituting in the equation above:

$$\begin{aligned} 14.50 &= (\text{Density} - 1) \times 1000 \\ 14.50/1000 &= \text{Density} - 1 \\ .01450 &= \text{Density} - 1 \\ 1.01450 &= \text{Density} \end{aligned}$$

Confirmation may be obtained from this table as to the value derived for density in the example. In some cases, for example at a salinity of 30.0 parts per thousand in Table 3, an increase in density from 1.0222 to 1.0223 results in a 0.2 parts per thousand salinity jump (in this case from 30.0 to 30.2 parts per thousand). At 30 parts per thousand salinity the sigma-t value is 22.150, resulting in a calculated density of 1.02215, which rounds off to 1.0222. At 30.1 and 30.2 parts per thousand salinity the sigma-t values are 22.227 and 22.303, respectively, with resulting densities of 1.02227 at 30.1 parts salinity and 1.02230 at 30.2 parts salinity; both of which round off to 1.0223. In cases of this nature the same density appears in the table for both salinities. For biological purposes, salinity precision of  $\pm 0.5$  parts per thousand is usually adequate, and since this table is designed for use with hydrometers, which cannot be read are trusted beyond a limited degree of accuracy, the rounding of densities described above appears justified.

References:

Keala, B. A. L. 1965. Table of sigma-t with intervals of 0.1 for temperature and salinity. U.S. Department of the Interior Special Scientific Report-Fisheries No. 506. 106 p.

Other sources of information:

Bialek, E. L. (compiler). 1966. Handbook of oceanographic tables. U.S. Naval Oceanographic Office Special Publication-68. Washington, D. C. 427 p.

LaFond, E. C. 1951. Processing oceanographic data. U.S. Navy Hydrographic Office Publication Number 614. Washington, D. C. 114 p.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming. 1942. The oceans. Prentice-Hall, Inc. Englewood Cliffs, N. J. 1087 p.

TABLE 4

Sigma-t values for salinity from 2.0 through 38 parts per thousand  
and temperature from 0 through 30 C

Temperature (C)	Salinity (‰)									
	2	3	4	5	6	7	8	9	10	11
0	1.534	2.347	3.159	3.970	4.780	5.589	6.398	7.206	8.014	8.821
1	1.586	2.395	3.203	4.010	4.816	5.622	6.427	7.232	8.036	8.839
2	1.620	2.425	3.229	4.033	4.836	5.638	6.440	7.241	8.041	8.841
3	1.637	2.438	3.239	4.040	4.839	5.638	6.437	7.234	8.031	8.828
4	1.638	2.436	3.234	4.031	4.827	5.623	6.418	7.212	8.006	8.800
5	1.623	2.418	3.213	4.006	4.800	5.592	6.384	7.176	7.967	8.757
6	1.593	2.385	3.176	3.967	4.757	5.547	6.336	7.124	7.912	8.700
7	1.548	2.337	3.126	3.914	4.701	5.488	6.274	7.059	7.845	8.629
8	1.489	2.275	3.061	3.846	4.631	5.414	6.198	6.981	7.763	8.545
9	1.416	2.199	2.982	3.765	4.547	5.328	6.109	6.889	7.669	8.448
10	1.329	2.110	2.891	3.670	4.450	5.229	6.007	6.785	7.562	8.339
11	1.229	2.008	2.786	3.563	4.340	5.116	5.892	6.668	7.443	8.217
12	1.116	1.893	2.668	3.443	4.218	4.992	5.765	6.538	7.311	8.083
13	0.991	1.765	2.539	3.311	4.084	4.855	5.627	6.397	7.168	7.938
14	0.854	1.626	2.397	3.167	3.937	4.707	5.476	6.245	7.013	7.781
15	0.705	1.474	2.243	3.012	3.780	4.547	5.314	6.081	6.847	7.613
16	0.544	1.311	2.078	2.845	3.611	4.376	5.141	5.906	6.670	7.434
17	0.371	1.137	1.902	2.667	3.431	4.194	4.957	5.720	6.482	7.244
18	0.188	0.952	1.715	2.478	3.240	4.002	4.763	5.524	6.284	7.044
19	-0.006	0.756	1.517	2.278	3.038	3.798	4.558	5.317	6.075	6.834
20	-0.211	0.549	1.309	2.068	2.826	3.585	4.342	5.100	5.857	6.613
21	-0.426	0.332	1.090	1.848	2.604	3.361	4.117	4.873	5.628	6.383
22	-0.652	0.105	0.861	1.617	2.372	3.127	3.882	4.636	5.390	6.143
23	-0.887	-0.132	0.623	1.377	2.131	2.884	3.637	4.389	5.141	5.893
24	-1.132	-0.379	0.374	1.127	1.879	2.631	3.382	4.133	4.884	5.634
25	-1.387	-0.635	0.116	0.867	1.618	2.368	3.118	3.868	4.617	5.366
26	-1.652	-0.901	-0.151	0.599	1.348	2.097	2.845	3.593	4.341	5.089
27	-1.925	-1.176	-0.428	0.321	1.068	1.816	2.563	3.309	4.056	4.802
28	-2.208	-1.460	-0.713	0.034	0.780	1.526	2.271	3.017	3.762	4.507
29	-2.500	-1.753	-1.008	-0.262	0.482	1.227	1.971	2.715	3.459	4.203
30	-2.800	-2.055	-1.311	-0.567	0.176	0.919	1.662	2.405	3.147	3.890

TABLE 4 (cont'd)

Temperature (C)	Salinity (‰)						
	12	13	14	15	16	17	18
0	9.627	10.433	11.239	12.044	12.849	13.653	14.458
1	9.642	10.445	11.247	12.048	12.850	13.651	14.452
2	9.641	10.440	11.239	12.037	12.835	13.633	14.431
3	9.624	10.420	11.216	12.011	12.806	13.601	14.395
4	9.593	10.386	11.178	11.970	12.762	13.554	14.345
5	9.547	10.337	11.126	11.915	12.704	13.493	14.281
6	9.487	10.274	11.061	11.847	12.633	13.419	14.204
7	9.414	10.198	10.982	11.765	12.548	13.331	14.114
8	9.327	10.108	10.890	11.670	12.451	13.231	14.012
9	9.228	10.006	10.785	11.563	12.341	13.119	13.897
10	9.116	9.892	10.668	11.444	12.219	12.995	13.770
11	8.991	9.765	10.539	11.312	12.086	12.859	13.632
12	8.855	9.627	10.398	11.169	11.940	12.711	13.482
13	8.708	9.477	10.246	11.015	11.784	12.533	13.321
14	8.549	9.316	10.083	10.850	11.617	12.383	13.150
15	8.378	9.144	9.909	10.674	11.438	12.203	12.967
16	8.198	8.961	9.724	10.487	11.250	12.012	12.775
17	8.006	8.767	9.529	10.290	11.051	11.811	12.572
18	7.804	8.564	9.323	10.082	10.842	11.601	12.360
19	7.592	8.350	9.108	9.865	10.622	11.380	12.137
20	7.370	8.126	8.882	9.638	10.394	11.149	11.905
21	7.138	7.892	8.647	9.401	10.155	10.909	11.663
22	6.896	7.649	8.402	9.155	9.907	10.660	11.412
23	6.645	7.397	8.148	8.899	9.650	10.401	11.152
24	6.385	7.135	7.884	8.634	9.384	10.133	10.883
25	6.115	6.863	7.612	8.360	9.108	9.857	10.605
26	5.836	6.583	7.330	8.077	8.824	9.571	10.318
27	5.548	6.294	7.040	7.785	8.531	9.277	10.022
28	5.251	5.996	6.740	7.485	8.229	8.974	9.718
29	4.946	5.689	6.432	7.176	7.919	8.662	9.405
30	4.632	5.374	6.116	6.858	7.600	8.342	9.084

TABLE 4 (cont'd)

Temperature (C)	Salinity (‰)						
	19	20	21	22	23	24	25
0	15.261	16.065	16.869	17.672	18.476	19.279	20.083
1	15.252	16.053	16.853	17.653	18.453	19.254	20.054
2	15.228	16.025	16.822	17.619	18.416	19.213	20.011
3	15.189	14.983	16.777	17.571	18.365	19.159	19.953
4	15.136	15.927	16.718	17.509	18.300	19.091	19.883
5	15.070	15.858	16.646	17.434	18.222	19.011	19.799
6	14.990	15.775	16.561	17.346	18.131	18.917	19.702
7	14.897	15.680	16.462	17.245	18.028	18.811	19.594
8	14.792	15.572	16.352	17.132	17.912	18.693	19.473
9	14.675	15.452	16.230	17.007	17.785	18.563	19.341
10	14.545	15.321	16.096	16.871	17.646	18.422	19.198
11	14.405	15.178	15.951	16.723	17.497	18.270	19.043
12	14.253	15.023	15.794	16.565	17.336	18.107	18.878
13	14.090	14.858	15.627	16.396	17.164	17.933	18.702
14	13.916	14.683	15.449	16.216	16.982	17.749	18.516
15	13.732	14.496	15.261	16.026	16.790	17.555	18.320
16	13.538	14.300	15.063	15.825	16.588	17.351	18.114
17	13.333	14.094	14.854	15.615	16.376	17.138	17.899
18	13.118	13.877	14.636	15.396	16.155	16.914	17.674
19	12.894	13.652	14.409	15.166	15.924	16.682	17.440
20	12.660	13.416	14.172	14.928	15.684	16.440	17.196
21	12.417	13.171	13.926	14.680	15.434	16.189	16.944
22	12.165	12.917	13.670	14.423	15.176	15.929	16.682
23	11.903	12.654	13.406	14.157	14.908	15.660	16.412
24	11.633	12.382	13.132	13.882	14.632	15.383	16.133
25	11.353	12.102	12.850	13.599	14.348	15.097	15.846
26	11.065	11.812	12.559	13.307	14.054	14.802	15.550
27	10.768	11.514	12.260	13.006	13.752	14.499	15.246
28	10.462	11.207	11.952	12.697	13.442	14.187	14.933
29	10.148	10.892	11.635	12.379	13.123	13.868	14.612
30	9.826	10.568	11.311	12.053	12.796	13.540	14.283

TABLE 4 (cont'd)

Temperature (C)	Salinity (‰)						
	26	27	28	29	30	31	32
0	20.886	21.690	22.493	23.297	24.101	24.906	25.710
1	20.854	21.654	22.455	23.256	24.057	24.858	25.660
2	20.808	21.605	22.402	23.200	23.998	24.796	25.595
3	20.747	21.542	22.336	23.131	23.926	24.721	25.517
4	20.674	21.465	22.257	23.049	23.841	24.634	25.426
5	20.587	21.376	22.165	22.954	23.743	24.533	25.323
6	20.488	21.274	22.060	22.847	23.634	24.421	25.208
7	20.377	21.160	21.944	22.728	23.512	24.297	25.082
8	20.254	21.035	21.816	22.597	23.379	24.161	24.943
9	20.119	20.898	21.676	22.455	23.235	24.014	24.794
10	19.973	20.749	21.526	22.302	23.079	23.857	24.635
11	19.817	20.590	21.365	22.139	22.914	23.689	24.465
12	19.649	20.421	21.193	21.965	22.738	23.511	24.284
13	19.471	20.241	21.011	21.781	22.552	23.323	24.094
14	19.283	20.051	20.819	21.587	22.356	23.124	23.894
15	19.086	19.851	20.617	21.383	22.150	22.917	23.684
16	18.878	19.642	20.406	21.170	21.935	22.700	23.466
17	18.661	19.422	20.185	20.947	21.710	22.474	23.238
18	18.434	19.194	19.955	20.715	21.477	22.238	23.001
19	18.198	18.956	19.715	20.475	21.234	21.994	22.755
20	17.953	18.710	19.467	20.225	20.983	21.741	22.500
21	17.699	18.454	19.210	19.966	20.723	21.480	22.237
22	17.436	18.190	18.944	19.699	20.454	21.210	21.966
23	17.164	17.917	18.670	19.423	20.177	20.931	21.686
24	16.884	17.635	18.387	19.139	19.892	20.645	21.398
25	16.596	17.345	18.096	18.847	19.598	20.350	21.102
26	16.298	17.047	17.796	18.546	19.296	20.047	20.798
27	15.993	16.741	17.489	18.237	18.986	19.735	20.485
28	15.679	16.426	17.173	17.920	18.668	19.416	20.165
29	15.357	16.103	16.849	17.595	18.342	19.089	19.837
30	15.027	15.772	16.517	17.262	18.008	18.754	19.501

TABLE 4 (cont'd)

Temperature (C)	Salinity (‰)					
	33	34	35	36	37	38
0	26.515	27.321	28.126	28.933	29.739	30.547
1	26.461	27.264	28.066	28.870	29.673	30.478
2	26.394	27.193	27.993	28.793	29.594	30.396
3	26.313	27.110	27.907	28.704	29.502	30.301
4	26.220	27.013	27.808	28.602	29.398	30.194
5	26.114	26.905	27.697	28.489	29.281	30.075
6	25.996	26.785	27.574	28.363	29.153	29.944
7	25.867	26.653	27.439	28.226	29.014	29.802
8	25.726	26.510	27.294	28.079	28.864	29.650
9	25.575	26.356	27.138	27.920	28.703	29.486
10	25.413	26.192	26.971	27.751	28.532	29.313
11	25.241	26.017	26.794	27.572	28.351	29.130
12	15.058	25.833	26.608	27.383	28.160	28.937
13	24.866	25.638	26.411	27.185	27.959	28.734
14	24.664	25.434	26.205	26.977	27.749	28.522
15	24.452	25.221	25.990	26.760	27.530	28.301
16	24.232	24.999	25.766	26.534	27.302	28.072
17	24.002	24.767	25.533	26.299	27.066	27.833
18	23.763	24.527	25.291	26.055	26.820	27.586
19	23.516	24.278	25.040	25.803	26.567	27.331
20	23.260	24.020	24.781	25.542	26.304	27.067
21	22.995	23.754	24.513	25.273	26.034	26.795
22	22.723	23.480	24.238	24.996	25.756	26.516
23	22.441	23.197	23.954	24.711	25.469	26.228
24	22.152	22.907	23.662	24.418	25.175	25.932
25	21.855	22.608	23.362	24.117	24.873	25.629
26	21.549	22.302	23.055	23.808	24.563	25.318
27	21.236	21.987	22.739	23.492	24.245	24.999
28	20.915	21.665	22.416	23.168	23.920	24.673
29	20.586	21.335	22.085	22.836	23.587	24.340
30	20.249	20.997	21.747	22.496	23.247	23.999

## References:

- Bialek, E. L., (compiler). 1966. Handbook of oceanographic tables. U.S. Naval Oceanographic Office Special Publication 68. Washington, D. C. 427 p.

Keala, B.A.L. 1965. Table of sigma-t with intervals of 0.1 for temperature and salinity. U.S. Department of the Interior Special Scientific Report-Fisheries No. 506. 186 p.

LaFond, E.C. 1951. Processing oceanographic data. U.S. Naval Hydrographic Office Publication No. 614. Washington, D.C. 114 p.

TABLE 5

Solubility of oxygen in water in  $\text{ml l}^{-1}$  from moist air at one atmosphere

Temperature (C)	Salinity (parts per thousand)				
	0	10	20	30	35
0	10.21	9.54	8.91	8.33	8.05
2	9.67	9.04	8.45	7.90	7.64
4	9.16	8.57	8.02	7.51	7.26
6	8.70	8.15	7.64	7.15	6.92
8	8.28	7.76	7.28	6.82	6.61
10	7.89	7.41	6.95	6.52	6.32
12	7.53	7.08	6.65	6.24	6.05
14	7.20	6.77	6.37	5.99	5.81
16	6.90	6.49	6.11	5.75	5.58
18	6.62	6.23	5.87	5.53	5.36
20	6.35	5.99	5.64	5.32	5.17
22	6.11	5.76	5.44	5.13	4.98
24	5.88	5.55	5.24	4.95	4.81
26	5.66	5.35	5.06	4.78	4.65
28	5.46	5.17	4.89	4.62	4.50
30	5.28	4.99	4.73	4.47	4.35
32	5.10	4.83	4.58	4.34	4.22
34	4.93	4.68	4.33	4.20	4.09

Reference: Weiss, R.F. 1970. The solubility of nitrogen, oxygen and argon in water and seawater. Deep-Sea Research, 17:721-735.

Notes: The amount of dissolved oxygen that can be contained at saturation by water decreases with both increasing temperature and salinity as indicated in this table. Supersaturation may occur during periods of phytoplankton blooms. Values upwards of 200% saturation have been reported during daylight hours from natural waters.

Supersaturation not only implies high levels of primary production, but also implies the possibility of an eventual oxygen depletion if the plankton bloom fails or during the pre-dawn hours due to the high levels of respiration which result at night when both plants and animals respire, but there is no active photosynthesis taking place. Oxygen depletions often occur during the summer after a period of warm weather when the water temperature is high and often after a period of overcast skies which reduce the amount of photosynthetic activity. If an oxygen depletion occurs, the animal population may be severely affected. Fish kills often occur under these conditions. By the time an investigator appears on the scene of such a fish kill, it is usually several hours after dawn and the dissolved oxygen will have increased to safe levels due to a resumption of photosynthesis. Fish kills are a problem in many aquaculture operations where standing ponds are used, or where lakes are heavily stocked and the fish supplementally fed with artificial diets. This supplemental feeding allows the fish farmer to culture more animals per unit area of water, but increases the chance of oxygen depletion. Summer fish kills also occur in natural waters, such as ponds and lakes and have been known to occur in semi-enclosed coastal waters, such as lagoons.

Dissolved oxygen is often reported by fishery biologists and other aquatic scientists in terms of the concentration in milligrams per liter ( $\text{mg l}^{-1}$ ), although the standard for sea water adhered to by physical oceanographers is milliliters per liter ( $\text{ml l}^{-1}$ ). To convert  $\text{ml l}^{-1}$  to  $\text{mg l}^{-1}$  the following formula may be used:

$$1 \text{ mg l}^{-1} = 0.6998 \text{ ml l}^{-1} = 0.7 \text{ ml l}^{-1} .$$

For purposes of most biological work dissolved oxygen to the nearest 0.1 whole unit is adequate. A biologist is usually interested in whether the dissolved oxygen is 5.0 or 5.5  $\text{mg l}^{-1}$ , not whether it is 5.001 or 5.002  $\text{ml l}^{-1}$ . The latter determination might be critical to a physical oceanographer.

As an additional aid in determining saturation of oxygen in water, Table 6 has been included. Table 6 presents oxygen saturation in  $\text{mg l}^{-1}$  calculated from the data presented in this table according to the above conversion factor.

TABLE 6

Solubility of oxygen in water in  $\text{mg l}^{-1}$  from moist air at one atmosphere

Temperature (C)	Salinity (parts per thousand)				
	0	10	20	30	35
0	14.59	13.63	12.73	11.90	11.50
2	13.81	12.92	12.07	11.29	10.91
4	13.08	12.25	11.46	10.73	10.37
6	12.43	11.65	10.92	10.22	9.89
8	11.83	11.09	10.40	9.75	9.45
10	11.27	10.59	9.93	9.32	9.03
12	10.76	10.12	9.50	8.92	8.65
14	10.29	9.67	9.10	8.56	8.30
16	9.86	9.27	8.73	8.22	7.97
18	9.46	8.90	8.39	7.90	7.66
20	9.07	8.56	8.06	7.60	7.39
22	8.73	8.23	7.77	7.33	7.12
24	8.40	7.93	7.49	7.07	6.87
26	8.09	7.65	7.23	6.83	6.64
28	7.80	7.39	6.99	6.60	6.43
30	7.55	7.13	6.76	6.39	6.22
32	7.29	6.90	6.54	6.20	6.03
34	7.04	6.69	6.19	6.00	5.84

Notes: This table was derived from Table 5 using the following relationship:

$$1 \text{ mg l}^{-1} = 0.6998 \text{ ml l}^{-1} \quad .$$

Fisheries biologists generally agree that a dissolved oxygen level of  $5.0 \text{ mg l}^{-1}$  is adequate for the normal activities of fishes. Information provided in this table indicates that even at the highest temperature and salinity presented, sufficient oxygen for aquatic life is provided if the water is saturated with oxygen.

The temperature of natural waters rarely climbs above 34 C, and salinity only goes above 35 parts per thousand to any significant extent in hypersaline lagoons or in other special circumstances. The variation in dissolved oxygen concentration with salinity does not vary to an extent which is biologically significant over the increments between salinity shown, except in studies designed to investigate very small changes on the physiology of an organism, and similar studies. In these cases it might be necessary to know the saturation within smaller increments.

TABLE 7

Conversion table for temperature from Celsius (Centigrade) to Fahrenheit degrees in 0.5 degree increments from 0 to 40 C

C	F	C	F	C	F	C	F
0.0	32.0	10.0	50.0	20.0	68.0	30.0	86.0
0.5	32.9	10.5	50.9	20.5	68.9	30.5	86.9
1.0	33.8	11.0	51.8	21.0	69.8	31.0	87.8
1.5	34.7	11.5	52.7	21.5	70.7	31.5	88.7
2.0	35.6	12.0	53.6	22.0	71.6	32.0	89.6
2.5	36.5	12.5	54.5	22.5	72.5	32.5	90.5
3.0	37.4	13.0	55.4	23.0	73.4	33.0	91.4
3.5	38.3	13.5	56.3	23.5	74.3	33.5	92.3
4.0	39.2	14.0	57.2	24.0	75.2	34.0	93.2
4.5	40.1	14.5	58.1	24.5	76.1	34.5	94.1
5.0	41.0	15.0	59.0	25.0	77.0	35.0	95.0
5.5	41.9	15.5	59.9	25.5	77.9	35.5	95.9
6.0	42.8	16.0	60.8	26.0	78.8	36.0	96.8
6.5	43.7	16.5	61.7	26.5	79.7	36.5	97.7
7.0	44.6	17.0	62.6	27.0	80.6	37.0	96.8
7.5	45.5	17.5	63.5	27.5	81.5	37.5	99.5
8.0	46.4	18.0	64.4	28.0	82.4	38.0	100.4
8.5	47.3	18.5	65.3	28.5	83.3	38.5	101.3
9.0	48.2	19.0	66.2	29.0	84.2	39.0	102.2
9.5	49.1	19.5	67.1	29.5	85.1	39.5	103.1
						40.0	104.0

Note: This table was derived from the formula:

$$F = 1.8 C + 32.$$

In unusual cases, temperatures outside the above range may be encountered. In those cases the above formula may be used for a rapid calculation of the conversion. To go from

To go from Fahrenheit to Celsius use the formula:

$$C = (F - 32) / 1.8.$$

TABLE 8

Conversion table for barometric pressure from inches to mm Hg

Inches	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
27.0	685.8	686.1	686.3	686.6	686.8	687.1	687.3	687.6	687.8	688.1
27.1	688.3	688.6	688.9	689.1	689.4	689.6	689.9	690.1	690.4	690.6
27.2	690.9	691.1	691.4	691.6	691.9	692.2	692.4	692.7	692.9	693.2
27.3	693.4	693.7	693.9	694.2	694.4	694.7	695.0	695.2	695.5	695.7
27.4	696.0	696.2	696.5	696.7	697.0	697.2	697.5	697.7	698.0	698.3
27.5	698.5	698.8	699.0	699.3	699.5	699.8	700.0	700.3	700.5	700.8
27.6	701.0	701.3	701.6	701.8	702.1	702.3	702.6	702.8	703.1	703.3
27.7	703.6	703.8	704.1	704.3	704.6	704.9	705.1	705.4	705.6	705.9
27.8	706.1	706.4	706.6	706.9	707.1	707.4	707.9	708.2	708.2	708.4
27.9	708.7	708.9	709.2	709.4	709.7	709.9	710.2	710.4	710.7	711.0
28.0	711.2	711.5	711.7	712.0	712.2	712.5	712.7	713.0	713.2	713.5
28.1	713.7	714.0	714.3	714.5	714.8	715.0	715.3	715.5	715.8	716.0
28.2	716.3	716.5	716.8	717.0	717.3	717.6	717.8	718.1	718.3	718.6
28.3	718.8	719.1	719.3	719.6	719.8	720.1	720.4	720.6	720.9	721.1
28.4	721.4	721.6	721.9	722.1	722.4	722.6	722.9	723.1	723.4	723.7
28.5	723.9	724.2	724.4	724.7	724.9	725.2	725.4	725.7	725.9	726.2
28.6	726.4	726.7	727.0	727.2	727.5	727.7	728.0	728.2	728.5	728.7
28.7	729.0	729.2	729.5	729.7	730.0	730.3	730.5	730.8	731.0	731.3
28.8	731.5	731.8	732.0	732.3	732.5	732.8	733.1	733.3	733.6	733.8
28.9	734.1	734.3	734.6	734.8	735.1	735.3	735.6	735.8	736.1	736.4
29.0	736.6	736.9	737.1	737.4	737.6	737.9	738.1	738.4	738.6	738.9
29.1	739.1	739.4	739.7	739.9	740.2	740.4	740.7	740.9	741.2	741.4
29.2	741.7	741.9	742.2	742.4	742.7	743.0	743.2	743.5	743.7	744.0
29.3	744.2	744.5	744.7	745.0	745.2	745.5	745.8	746.0	746.3	746.5
29.4	746.8	747.0	747.3	747.5	747.8	748.0	748.3	748.5	748.8	749.1
29.5	749.3	749.6	749.8	750.1	750.3	750.6	750.8	751.1	751.3	751.6
29.6	751.8	752.1	752.4	752.6	752.9	753.1	753.4	753.6	753.9	754.1
29.7	754.4	754.6	754.9	755.1	755.4	755.7	755.9	756.2	756.4	756.7
29.8	756.9	757.2	757.4	757.7	757.9	758.2	758.5	758.7	759.0	759.2
29.9	759.5	759.7	760.0	760.2	760.5	760.7	761.0	761.2	761.5	761.8
30.0	762.0	762.3	762.5	762.8	763.0	763.3	763.5	763.8	764.0	764.3
30.1	764.5	764.8	765.1	765.3	765.6	765.8	766.1	766.3	766.6	766.8
30.2	767.1	767.3	767.6	767.9	768.1	768.4	768.6	768.9	769.1	769.4
30.3	769.6	769.9	770.1	770.4	770.6	770.9	771.2	771.4	771.7	771.9
30.4	772.2	772.4	772.7	772.9	773.2	773.4	773.7	773.9	774.2	774.5

TABLE 8 (continued)

Inches	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
30.5	774.7	775.0	775.2	775.5	775.7	776.0	776.2	776.5	776.7	777.0
30.6	777.2	777.5	777.8	778.0	778.3	778.5	778.8	779.0	779.3	779.5
30.7	779.8	780.0	780.3	780.6	780.8	781.1	781.3	781.6	781.8	782.1
30.8	782.3	782.6	782.8	783.1	783.3	783.6	783.9	784.1	784.4	784.6
30.9	784.9	785.1	785.4	785.6	785.9	786.1	786.4	786.6	786.9	787.2

Notes: The conversions from inches to millimeters were made utilizing the conversion factor:

$$1 \text{ inch} = 25.4 \text{ mm}$$

If barometric pressure data is not measured in the field, but is obtained from the U.S. Weather Bureau or some local agency, the data will probably be expressed in inches of mercury. For scientific publication the metric system is generally used, thus the conversion of inches to millimeters is necessary.

The measurement of barometric pressure may seem irrelevant to many studies, and in some cases this is undoubtedly true. There have been correlations found between barometric pressure and such things as spawning or movement in fishes, even though a vertical change of position in the water column by a fish would seem to counteract even a large change in barometric pressure, even if the fish were to swim up or down only a few millimeters. The apparent correlation between barometric pressure and some type of physiological response in fishes, then, may actually relate to other weather conditions associated with changes in barometric pressure, such as light intensity due to the passage of frontal systems, etc. In any case, barometric pressure measurements are not always irrelevant and should be recorded if there is a chance that the data will have some bearing on a particular study.

TABLE 9

Conversion table for particles expressed in diameters in phi and millimeters, with descriptive terminology

Classification	Phi equivalent	Millimeter equivalent
Boulder	-12	4096.0
	-11	2048.0
	-10	1024.0
	- 9	512.0
Cobble*	- 8	256.0
	- 7	128.0
Pebble*	- 6	64.0
	- 5	32.0
	- 4	16.0
	- 3	8.0
	- 2	4.0
Granules*	- 1	2.0
Sand	0	1.0
	+ 1	0.50
	+ 2	0.25
	+ 3	0.125
	+ 4	0.0625
Silt	+ 5	0.0313
	+ 6	0.0156
	+ 7	0.0078
	+ 8	0.0039
Clay	+ 9	0.00195
	+10	0.00098
	+11	0.00049
	+12	0.00024
Colloids	> +12	<0.00024

Notes: Cobbles, pebbles and granules (followed by an asterisk in this table) may be placed in the general classification of gravel sized particles.

The phi scale is related to millimeters by the equation:

$$\phi = -\log_2 \text{ x diameter (mm) } .$$

This scale was derived as a more convenient means of describing sediment particle size than writing out the millimeter equivalent which requires numerous numerals in some cases, whereas no more than two digits appear in the phi scale.

Animals living within or in relatively close proximity to the bottom of lakes, rivers and the ocean are often limited by the type of substrate available. While some animals are able to live over or within a variety of sediment types, many animals are limited to sand substrates, or to mud substrates. The characterization of the sediments (by grain size analysis) along with analysis of the animal population is often important in benthic studies.

References: Further information on this subject may be found in the following.

Bialek, E. L. (compiler). 1966. Handbook of oceanographic tables. U.S. Naval Oceanographic Office Special Publication 68. Washington, D. C. 427 p.

Baker, B. B., Jr., W. R. Deebel and R. D. Geisenderfer (eds.). 1966. Glossary of oceanographic terms, 2nd ed. U.S. Naval Oceanographic Office Special Publication 35. Washington, D. C. 204 p.

Shepard, F. P. 1963. Submarine geology, 2nd ed. Harper & Row, New York. 557 p.

TABLE 10

Conversion table of fathoms (fms) to meters (m) in the depth range 1 to 10,000 fms. (1 fathom = 6 feet = 1.8285 m).

fms	m	fms	m	fms	m	fms	m
1	1.83	36	65.83	71	129.82	200	365.70
2	3.66	37	67.65	72	131.65	300	548.55
3	5.49	38	69.48	73	133.48	400	731.40
4	7.31	39	71.31	74	135.31	500	914.25
5	9.14	40	73.14	75	137.14	600	1097.10
6	10.97	41	74.97	76	138.97	700	1279.95
7	12.80	42	76.80	77	140.79	800	1462.80
8	14.63	43	78.63	78	142.62	900	1645.65
9	16.46	44	80.45	79	144.45	1000	1828.50
10	18.29	45	82.28	80	146.28	1100	2011.35
11	20.11	46	84.11	81	148.11	1200	2194.20
12	21.94	47	85.94	82	149.94	1300	2377.05
13	23.77	48	87.77	83	151.77	1400	2559.90
14	25.60	49	89.60	84	153.59	1500	2742.75
15	27.43	50	91.43	85	155.42	1600	2925.60
16	29.26	51	93.25	86	157.25	1700	3108.45
17	31.08	52	95.08	87	159.08	1800	3291.30
18	32.91	53	96.91	88	160.91	1900	3474.15
19	34.74	54	98.74	89	162.74	2000	3657.00
20	36.57	55	100.57	90	164.57	2100	3839.85
21	38.40	56	102.40	91	166.39	2200	4022.70
22	40.23	57	104.22	92	168.22	2300	4205.55
23	42.06	58	106.05	93	170.05	2400	4388.40
24	43.88	59	107.88	94	171.88	2500	4571.25
25	45.71	60	109.71	95	173.71	2600	4754.10
26	47.54	61	111.54	96	175.54	2700	4936.95
27	49.37	62	113.37	97	177.36	2800	5119.80
28	51.20	63	115.20	98	179.19	2900	5302.65
29	53.03	64	117.02	99	181.02	3000	5485.50
30	54.86	65	118.85	100	182.85	3100	5668.35
31	56.68	66	120.68	110	201.14	3200	5851.20
32	58.51	67	122.51	120	219.42	3300	6034.05
33	60.34	68	124.34	130	237.71	3400	6216.90
34	62.17	69	126.17	140	255.99	3500	6399.75
35	64.00	70	128.00	150	274.28	3600	6582.60

TABLE 10 (continued)

fms	m	fms	m	fms	m	fms	m
3700	6765.45	5300	9691.05	6900	12616.65	8500	15542.25
3800	6948.30	5400	9873.90	7000	12799.50	8600	15725.10
3900	7131.15	5500	10056.75	7100	12982.35	8700	15907.95
4000	7314.00	5600	10239.60	7200	13165.20	8800	16090.80
4100	7496.85	5700	10422.45	7300	13348.05	8900	16273.65
4200	7679.70	5800	10605.30	7400	13530.90	9000	16456.50
4300	7862.55	5900	10788.15	7500	13713.75	9100	16639.35
4400	8045.40	6000	10971.00	7600	13896.60	9200	16822.20
4500	8228.25	6100	11153.85	7700	14079.45	9300	17005.05
4600	8411.10	6200	11336.70	7800	14262.30	9400	17187.90
4700	8593.95	6300	11519.55	7900	14445.15	9500	17370.75
4800	8776.80	6400	11702.40	8000	14628.00	9600	17553.60
4900	8959.65	6500	11885.25	8100	14810.85	9700	17736.45
5000	9142.50	6600	12068.10	8200	14993.70	9800	17919.30
5100	9325.35	6700	12250.95	8300	15176.55	9900	18102.15
5200	9508.2	6800	12433.80	8400	15359.40	10000	18285.00

Notes: Calculations of values between those listed in table 10 may be readily found by adding together values given in the table which total the value sought.

Example: Find the depth in meters when the depth is 4217 fms.

$$\begin{array}{r}
 4200 \text{ fms} = 7679.70 \text{ m} \\
 17 \text{ fms} = 31.08 \text{ m} \\
 \hline
 4217 \text{ fms} = 7710.78 \text{ m} \\
 \hline
 \hline
 \end{array}$$

TABLE 11

Conversion table of meters (m) to fathoms (fms) in the depth range 1 to  
15,000 meters. (1 m = 0.54681 fathoms)

m	fms	m	fms	m	fms	m	fms
1	0.55	36	19.69	71	38.82	200	109.36
2	1.09	37	20.23	72	39.37	300	164.04
3	1.64	38	20.78	73	39.92	400	218.72
4	2.19	39	21.33	74	40.46	500	273.41
5	2.73	40	21.87	75	41.01	600	328.09
6	3.28	41	22.42	76	41.56	700	382.77
7	3.83	42	22.97	77	42.10	800	437.45
8	4.37	43	23.51	78	42.65	900	492.13
9	4.92	44	24.06	79	43.20	1000	546.81
10	5.47	45	24.61	80	43.74	1100	601.49
11	6.01	46	25.15	81	44.29	1200	656.17
12	6.56	47	25.70	82	44.84	1300	710.85
13	7.11	48	26.25	83	45.39	1400	765.53
14	7.66	49	26.79	84	45.93	1500	820.22
15	8.20	50	27.34	85	46.48	1600	874.90
16	8.75	51	27.89	86	47.03	1700	929.58
17	9.30	52	28.43	87	47.57	1800	984.26
18	9.84	53	28.98	88	48.12	1900	1038.94
19	10.39	54	29.53	89	48.67	2000	1093.62
20	10.94	55	30.07	90	49.21	2100	1148.30
21	11.48	56	30.62	91	49.76	2200	1202.98
22	12.03	57	31.17	92	50.31	2300	1257.66
23	12.58	58	31.71	93	50.85	2400	1312.34
24	13.12	59	32.26	94	51.40	2500	1367.03
25	13.67	60	32.81	95	51.95	2600	1421.71
26	14.22	61	33.36	96	52.49	2700	1476.39
27	14.76	62	33.90	97	53.04	2800	1531.07
28	15.31	63	34.45	98	53.59	2900	1585.75
29	15.86	64	35.00	99	54.13	3000	1640.43
30	16.40	65	35.54	100	54.68	3100	1695.11
31	16.95	66	36.09	110	60.15	3200	1749.79
32	17.50	67	36.64	120	65.62	3300	1804.47
33	18.04	68	37.18	130	71.09	3400	1859.15
34	18.59	69	37.73	140	76.55	3500	1913.84
35	19.14	70	38.28	150	82.02	3600	1968.52

TABLE 11 (continued)

m	fms	m	fms	m	fms	m	fms
3700	2023.20	6600	3608.95	9500	5194.70	12400	6780.44
3800	2077.88	6700	3663.63	9600	5249.38	12500	6835.13
3900	2132.56	6800	3718.31	9700	5304.06	12600	6889.81
4000	2187.24	6900	3772.99	9800	5358.74	12700	6944.49
4100	2241.92	7000	3827.67	9900	5413.42	12800	6999.17
4200	2296.60	7100	3882.35	10000	5468.1	12900	7053.85
4300	2351.28	7200	3937.03	10100	5522.78	13000	7108.53
4400	2405.96	7300	3991.71	10200	5577.46	13100	7163.21
4500	2460.65	7400	4046.39	10300	5632.14	13200	7217.89
4600	2515.33	7500	4101.08	10400	5686.82	13300	7272.57
4700	2570.01	7600	4155.76	10500	5741.51	13400	7327.25
4800	2624.69	7700	4210.44	10600	5796.19	13500	7381.94
4900	2679.37	7800	4265.12	10700	5850.87	13600	7436.62
5000	2734.05	7900	4319.80	10800	5905.55	13700	7491.30
5100	2788.73	8000	4374.48	10900	5960.23	13800	7545.98
5200	2843.41	8100	4429.16	11000	6014.91	13900	7600.66
5300	2898.09	8200	4483.84	11100	6069.59	14000	7655.34
5400	2952.77	8300	4538.52	11200	6124.27	14100	7710.02
5500	3007.46	8400	4593.20	11300	6178.95	14200	7764.70
5600	3062.14	8500	4647.89	11400	6233.63	14300	7819.38
5700	3116.82	8600	4702.57	11500	6288.32	14400	7874.06
5800	3171.50	8700	4757.25	11600	6343.00	14500	7928.75
5900	3226.18	8800	4811.93	11700	6397.68	14600	7983.43
6000	3280.86	8900	4866.61	11800	6452.36	14700	8038.11
6100	3335.54	9000	4921.29	11900	6507.04	14800	8092.79
6200	3390.22	9100	4975.97	12000	6561.72	14900	8147.47
6300	3444.90	9200	5030.65	12100	6616.40	15000	8202.15
6400	3499.58	9300	5085.33	12200	6671.08		
6500	3554.27	9400	5140.01	12300	6725.76		

Notes: Calculations of values between those listed in table 11 may be readily found by adding together values given in the table which total the value sought.

Example: Find the depth in fathoms when the depth in meters is 11213.

$$\begin{array}{r}
 11200 \text{ m} = 6124.27 \text{ fms} \\
 \underline{13 \text{ m} = 7.11 \text{ fms}} \\
 11213 \text{ m} = \underline{\underline{6131.38 \text{ fms}}}
 \end{array}$$

MISCELLANEOUS TABLES

TABLE 12

Characters of the Greek alphabet with corresponding English spelling

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Α	α	Alpha
Β	β	Beta
Γ	γ	Gamma
Δ	δ	Delta
Ε	ε	Epsilon
Ζ	ζ	Zeta
Η	η	Eta
Θ	θ ϑ	Theta
Ι	ι	Iota
Κ	κ	Kappa
Λ	λ	Lambda
Μ	μ	Mu
Ν	ν	Nu
Ξ	ξ	Xi
Ο	ο	Omicron
Π	π	Pi
Ρ	ρ	Rho
Σ	σ ς	Sigma

TABLE 12 (continued)

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$\tau$	Tau
$\upsilon$	Upsilon
$\phi$	Phi
$\chi$	Chi
$\psi$	Psi
$\omega$	Omega

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TABLE 13

Classification of Marine Environments

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Pelagic Classification (within the water column)

Neritic zone - Low water mark to 200 meters depth (essentially equivalent to the water lying over the continental shelves).

Oceanic zone - Water of depths greater than 200 meters

Epipelagic: surface to 200 meters

Mesopelagic: 200 meters to 1000 meters

Bathypelagic: 1000 meters to 4000 meters

Abyssopelagic: depths exceeding 4000 meters

Benthic Classification (associated with the substrate)

Supralittoral zone - above the mean high water mark

Littoral zone - intertidal zone (between the high and low tide extremes)

Sublittoral zone - 200 meters to 4000 meters

Abyssal zone - depths exceeding 4000 meters

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References:

Hedgpeth, J.W. 1957. Treatise on marine ecology and paleoecology. Volume I. Geological Society of America Memoir 67. Washington, D.C. 1296 p.

Baker, B.B., Jr., W. R. Deebel and R. D. Geisenderfer (eds.) 1966. Glossary of oceanographic terms, 2nd ed. U.S. Naval Oceanographic Office Special Publication 35. Washington, D.C. 204 p.

TABLE 14

Sea states and wind velocities associated with the Beaufort Number scale

Beaufort <sup>1</sup> Number	Explanatory Information	Wind Velocity (miles per hour)
0	calm	less than 1
1	light air	1 - 3
2	slight breeze	4 - 7
3	gentle breeze	8 - 12
4	moderate breeze	13 - 18
5	fresh breeze	19 - 24
6	strong breeze	25 - 31
7	high wind	32 - 38
8	gale	39 - 46
9	strong gale	47 - 54
10	whole gale	55 - 63
11	storm	64 - 75
12	hurricane	above 75

<sup>1</sup> The Beaufort Number scale is an arbitrary scale set up as defined above to standardize the measurement of wind forces. The use of the Beaufort Number eliminates the need for recording further description in logs, for instance.

TABLE 15

## Common shipboard terms and their definitions

Terminology	Definition
aft = after	toward the rear or stern of a vessel
below	any area within a vessel which is located beneath the main deck, e. g., the cargo hold and engine room
bow	the extreme front or foreward end of a vessel
bulkhead	a wall such as that which might separate two compartments or staterooms, or which might separate an individual from the exterior of the vessel
deck	the floor
fathom	a unit of measurement equal to six feet or two yards
fore = forward	toward the bow of a vessel
head	a bathroom on a large ship or the toilet facilities on a small boat
galley	the kitchen
knot (1 nautical mile/hr)	101.269 ft min <sup>-1</sup> 1.6878 ft sec <sup>-1</sup> 1.1508 statute miles hr <sup>-1</sup>
league	a unit of measurement equal to approximately three nautical miles
lee = leeward	toward the side of a vessel away from the wind
midships = amidships	the area located approximately midway between the bow and stern of the vessel

TABLE 15 (continued)

Terminology	Definition
overhead	the ceiling
port	toward the left as you face the bow of the vessel; also a harbor when used as in a "port of call"
starboard	toward the right as you face the bow of the vessel
stern	the extreme rear or aft end of the ship
windward	the side of the vessel facing the wind

Note: Many of the terms defined above are part of the casual speech of many limnologists and oceanographers. Experience has shown, however, that many persons are confused about various aspects of shipboard life. It is hoped that someone may be saved some embarrassment merely by familiarizing himself with some of the above terms.

**TABLE 16**  
**PERIODIC TABLE OF THE ELEMENTS**

40

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac															

LANTHANIDES	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
ACTINIDES	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw

TABLE 17

List of the elements in alphabetical order with symbol, atomic number and atomic weight

Element	Symbol	Atomic Number	Atomic Weight
Actinium	Ac	89	227*
Aluminum	Al	13	26.98
Americium	Am	95	243*
Antimony	Sb	51	121.76
Argon	Ar	18	39.944
Arsenic	As	33	74.91
Astatine	At	85	210*
Barium	Ba	56	137.36
Berkelium	Bk	97	245*
Beryllium	Be	4	9.013
Bismuth	Bi	83	209.00
Boron	B	5	10.82
Bromine	Br	35	79.916
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Californium	Cf	98	248*
Carbon	C	6	12.011
Cerium	Ce	58	140.13
Cesium	Cs	55	132.91
Chlorine	Cl	17	35.457
Chromium	Cr	24	52.01
Cobalt	Co	27	58.94
Copper	Cu	29	63.54
Curium	Cm	96	245*
Dysprosium	Dy	66	162.51
Einsteinium	Es	99	254*
Erbium	Er	68	167.27
Europium	Eu	63	152.0
Fermium	Fm	100	252*
Fluorine	F	9	19.00
Francium	Fr	87	223*
Gadolinium	Gd	64	157.26
Gallium	Ga	31	69.72
Germanium	Ge	32	72.60

TABLE 17 (continued)

Element	Symbol	Atomic Number	Atomic Weight
Gold	Au	79	197.0
Hafnium	Hf	72	178.50
Helium	He	2	4.003
Holmium	Ho	67	164.94
Hydrogen	H	1	1.008
Indium	In	49	114.82
Iodine	I	53	126.91
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.92
Lawrencium	Lw	103	257*
Lead	Pb	82	207.21
Lithium	Li	3	6.94
Lutetium	Lu	71	174.99
Magnesium	Mg	12	24.32
Manganese	Mn	25	54.94
Mendelevium	Mv	101	256*
Mercury	Hg	80	200.61
Molybdenum	Mo	42	95.95
Neodymium	Nd	60	144.27
Neon	Ne	10	20.183
Neptunium	Np	93	237*
Nickel	Ni	28	58.71
Niobium	Nb	41	92.91
Nitrogen	N	7	14.008
Nobelium	No	102	254*
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.975
Platinum	Pt	78	195.09
Plutonium	Pu	94	242*
Polonium	Po	84	210*
Potassium	K	19	39.10
Praseodymium	Pr	59	140.92
Promethium	Pm	61	145*

TABLE 17 (continued)

Element	Symbol	Atomic Number	Atomic Weight
Protactinium	Pa	91	231*
Radium	Ra	88	226.05
Radon	Rn	86	222*
Rhenium	Re	75	186.22
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.48
Ruthenium	Ru	44	101.1
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Selenium	Se	34	78.96
Silicon	Si	14	28.09
Silver	Ag	47	107.88
Sodium	Na	11	22.991
Strontium	Sr	38	87.63
Sulfur	S	16	32.066
Tantalum	Ta	73	180.95
Technetium	Tc	43	99*
Tellurium	Te	52	127.61
Terbium	Tb	65	158.93
Thallium	Tl	81	204.39
Thorium	Th	90	232.05
Thulium	Tm	69	168.94
Tin	Sn	50	118.70
Titanium	Ti	22	47.90
Tungsten	W	74	183.86
Uranium	U	92	238.07
Vanadium	V	23	50.95
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.04
Yttrium	Y	30	88.92
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22

\* - indicates the atomic weight of the most stable isotope of the element indicated

TABLE 18

Plankton net silk numbers with corresponding diameters of mesh (mm)

Silk number	Diameter (mm)	Silk number	Diameter (mm)
0000	1.36	8	0.20
000	1.02	9	0.17
00	0.75	10	0.16
0	0.57	11	0.15
1	0.42	12	0.12
2	0.37	13	0.11
3	0.33	14	0.10
4	0.32	15	0.09
5	0.28	20	0.08
6	0.24	25	0.06
7	0.22		

Notes: While plankton netting comes in a variety of sizes, 000 is commonly used for sampling fish eggs and larvae, size 6 for zooplankton and size 25 for phytoplankton. As the size of the mesh decreases, the amount of drag exerted by the water when the net is being towed increases and the shock waves sent out by the approaching net are also increased. Thus, fish larvae and zooplankton can avoid a phytoplankton net both by actively swimming away and by being pushed out of the way due to the shock wave.

The original plankton nets were made of silk cloth, thus the silk number. Modern nets are usually fabricated of nylon.

The diameter of the mouth of a plankton net varies from as small as 10 cm for some limnological work to 1 m for much oceanographic

plankton collection. Mouth diameters of 40 cm and 50 cm are common. Experimental plankton nets with mouth diameters in excess of 1 m have been used.

The depth of any plankton net is largely at the discretion of the user, as is the mouth diameter. The depth of the net is usually some multiple of the mouth diameter, such as three or four times the diameter. Most plankton nets taper from the mouth to a small opening at the rear (often five cm diameter or larger). A collecting container of some type is attached to the small end of the net. The container is often fixed in such a manner that it can be quickly removed and replaced. The sample is concentrated in the collection container during the course of the tow, with supplemental washing down of the net after it is brought out of the water.

Plankton nets are towed for various periods of time depending upon the size of the net (both mesh size and mouth diameter) and the type of plankton sought. The background concentration of the plankton is important too, since a longer tow is required when the plankton is sparse than would be the case during periods when plankton is concentrated. Tows generally vary from five to 30 minutes in duration.

Some nets are equipped with apparatus which allows them to be opened and closed at some kind of signal from the surface. This allows the investigator to select a specific depth at which he would like the plankton to be sampled and be sure that the sample is not contaminated by plankton from other depths which might enter an open net while it is being lowered and raised.

TABLE 19  
Geological time scale

Era	Period	Epoch	Time from beginning of period to present (millions of years)
Cenozoic (Age of mammals)	Quaternary	Recent	0.01 - 0.025
		Pleistocene	1
		Pliocene	12-13
		Miocene	25
		Oligocene	34-36
		Eocene	55-58
		Paleocene	63-75
Mesozoic (Age of reptiles)	Cretaceous		130-135
		Jurassic	180-181
		Triassic	230
Paleozoic	Permian		260-280
		Pennsylvanian (Age of amphibians)	310-320
		Mississippian	345-350
		Devonian (Age of fishes)	400-405
		Silurian	425-430
		Ordovician	475-500
		Cambrian (Age of invertebrates)	550-600
Proterozoic (Precambrian)			1600-2000
Archeozoic (Precambrian)			3600-4500

GLOSSARY

TABLE 20

## Glossary of terms useful to biological oceanographers and limnologists

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Abyssal - depths in the ocean in excess of 4000 meters.

Acid - a proton donor.

Adsorption - the process by which molecules or ions are retained on the surface of a solid.

Aerobe - an organism which can live only in the presence of oxygen. Most commonly used in conjunction with bacteria (aerobic vs. anaerobic).

Age of the tide - the time interval between the new or full moon and the appearance of the spring tide maximum.

Alkalinity - Alkalinity in freshwater has been defined as the capacity of water containing other compounds for neutralizing strong acid to pH 4.5. In seawater total alkalinity is the number of milliequivalents of hydrogen ion that are neutralized by 1 kg of seawater when an excess of acid is added, while carbonate alkalinity is the number of milliequivalents of hydrogen ion that are neutralized by 1 kg of seawater in converting the contained carbonate and bicarbonate to carbon dioxide.

Allochthonous - material which arises from an area other than the one in which it is found (e.g., leaf detritus deposited in a lake, stream or estuary, but originating on land).

Amphidromic point - a nodal point (or area) at which no tide can be detected. At such places the various tide generating forces cancel one another out.

Amplitude - the magnitude of displacement of a wave from its mean value, or one-half of the wave height measured from trough to crest vertically.

Anadromous - a type of fish such as salmon and some clupeids which mature and spend an appreciable amount of their lives in the sea but return to freshwater rivers and streams to spawn.

Anaerobe - an organism which can survive only in an environment lacking free oxygen. Such organisms may be obligate or facultative. Facultative anaerobes can adapt at least temporarily to aerobic conditions.

TABLE 20 (continued)

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- Aphotic zone - depths below which natural light does not penetrate. The aphotic zone varies with turbidity, water color, time of day, atmospheric conditions and season of the year.
- Aqua regia - a mixture of one part nitric acid and three parts hydrochloric acid. Aqua regia is a strong oxidizing agent.
- Aquaculture - the rearing of organisms (plants or animals) in water, either freshwater or salt water with the goal of producing a food product under controlled conditions.
- Aquatic - pertaining to water, either freshwater or salt water. Some authorities use aquatic in reference to freshwater only, and use marine when referring to salt water.
- Aquiculture - see aquaculture
- Ash weight - the weight of the material remaining after an organism, group of organisms, or part of an organism has been exposed to a temperature sufficient to oxidize all of its organic matter to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , leaving an inorganic residue, the ash.
- Astronomical tide - tidal activity due to forces generated by the sun, moon and other bodies in space.
- Atoll - a ring-shaped coral reef or series of reefs surrounded by the sea and enclosing a lagoon.
- Atom - the smallest particle of an element which is capable of existence.
- Aufwuchs - those aquatic organisms, both autotrophic and heterotrophic, which are found attached to, but not penetrating substrates. Some workers refer to this community as periphyton. Others have called it the benthic algae, although these terms tend to exclude the heterotrophic assemblage.
- Authigenic - pertaining to products of chemical and biochemical action which were formed in sediments during or after deposition but prior to the burial and consolidation of the sediments.
- Autochthonous - material which arises locally, such as deposits in the sediments of lakes, streams and the ocean which are the result of deposition of material formed in that water body; e.g. the settling of exoskeletal material to the floor of the sea.

TABLE 20 (continued)

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Autotrophic - the type of nutrition in which an organism manufactures its own food from inorganic constituents, often in the presence of light. Photosynthetic plants are autotrophic.

Azoic - abiotic, or without life.

Back reef - the region behind a reef; lying between the reef and the land or lagoon.

Backshore - pertaining to that part of a beach which is usually dry, being wetted only by the highest tides and during storms.

Barrier reef - a coral reef which lies parallel to a coast but is separated from the coast by a lagoon which is too deep to support massive reef building corals. The best example of this type of reef is the Great Barrier Reef off Australia.

Base - a proton acceptor.

Bathyal - the ocean depth zone between 200 and 4000 meters. Usually used in conjunction with bottom depth rather than that part of a water mass lying between 200 and 4000 meters. See table 13.

Bathypelagic - the depth zone within the water column lying between 1000 and 4000 meters. See table 13.

Bathypelagic fishes - marine fishes which spend all or part of their existence within the bathypelagic zone.

Bathyscaphe - a manned submersible vehicle which can be operated in the deep sea independently of the surface. This term has been largely replaced by the term "submersible."

Bathysphere - a manned spherical chamber which is lowered from a surface ship and cannot operate independent of the surface. Used in marine research and exploration.

TABLE 20 (continued)

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Bathythermograph (BT) - a torpedo shaped device which is used to obtain a record of temperature versus depth in the ocean. In bathythermographs which are lowered from ships and retrieved, the record is etched on a piece of glass as the BT is lowered. Expendable bathythermographs (XBT's), are allowed to free fall. A fine copper wire connecting the XBT with a recorder feeds out as the XBT falls. When the end of the wire is reached, the wire breaks and the XBT is not recovered.

Bay - a recess or inlet in a coastline between two capes or headlands. A bay is smaller than a gulf but larger than a cove. As with most terminology referring to coastal features, a certain amount of ambiguity exists in the exact definition.

Baymouth bar - a sand or mud shoal which extends partially or completely across the mouth of a bay. Such bars may shift seasonally depending upon the prevailing wind and currents. They may even disappear during certain periods of the year or under special conditions.

Bayou - a small creek or stream in an estuarine region. Bayous generally exhibit a slow flow rate and are located in coastal swamp and deltaic areas. In the U. S. the term bayou is used almost exclusively on the Gulf Coast, especially in and around Louisiana.

Beach - the shore zone extending from the low water line to either the permanent vegetation line or to an area where there is a physical change in the substrate present (for example, a change from sand to rock outcrops or cliffs).

Benthos - the community of organisms associated with the substrate. Benthic organisms may live within the substrate (benthic infauna) or may live on the surface of the substrate (benthic epifauna). Some animals, such as Penaeid shrimp, burrow during certain periods of the day and come to the surface of the sediment to feed. Many benthic organisms dig burrows in the sediment and expose various portions of their bodies in order to feed and respire (e. g. , mollusks and polychaetes). In freshwater environments the benthos is inhabited by mollusks, and other aquatic organisms, but is often dominated by insect larvae which often develop wings and leave the water when they become adults.

TABLE 20 (continued)

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Biochemical oxygen demand (BOD) - the decrease in dissolved oxygen over a period of time (the standard incubation period is five days) when the sample is incubated in the dark at 20 C. BOD is a measure of bacterial decomposition of organic material within the water at the time the collection was made. BOD is sometimes erroneously called "Biological Oxygen Demand."

Biocoenose - a community of organisms, the precise structure of which is dependent upon interrelationships among its members and the physical characteristics of the environment.

Bioluminescence - the production of light by living organisms by means of certain chemical reactions which may occur intracellularly, within specialized organs or extracellularly as the result of a secretion. Many phyla of animals inhabiting marine waters exhibit bioluminescence of one type or another. Certain species of fishes can often be identified only on the basis of the location of the photophores (light emitting areas) along their bodies. The extent of bioluminescence emitted by plankton appears to be a function of species composition and season of the year (related to water temperature).

Biomass - the total weight of organisms contained in a sample, or on the basis of weight of organic material present per unit volume or per unit area. Examples include the biomass of zooplankton per square meter in a lake and the biomass of fish captured per unit time with a particular type of sampling gear.

Biosphere - the zone of the earth which supports life. This includes, in general, the atmosphere to an altitude well above the upper limits of mountains and the sea to its greatest depths. Bacteria were found to survive on the moon for long periods of time during the recent Apollo program, so the definition of biosphere may have to be modified to include portions of the globe (including the atmosphere) wherein organisms are able to carry on an active existence. In that case the formation of spores by bacteria and certain types of protozoans would not necessarily fit the definition.

Biota - the flora and fauna existing within a specified area.

Biotope - a place where life can be found. A biotope includes the total environment in which a biocoenose exists.

TABLE 20 (continued)

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- Black bottle (= dark bottle)** - an opaque container used in conjunction with light bottles in primary productivity experiments of the type that measure such phenomena as oxygen evolution of a phytoplankton community per unit time or carbon-14 uptake of such a community per unit time. The black bottle is used to examine respiration in the case of oxygen production experiments and changes in carbon-14 in the dark in the case of carbon-14 uptake experiments. The black bottles are prepared by painting a light bottle black or wrapping it with electrical tape, although other techniques are possible. Black bottles are subjected to the same experimental conditions as light bottles and are used to correct for effects of respiration on community metabolism.
- Bloom** - a phenomenon associated with phytoplankton in which a rapid increase in the population of one or more species occurs allowing those species to become dominant. This usually occurs when conditions in the environment become extremely favorable for the growth of one particular species but are limiting to competitors. Phytoplankton blooms often occur as a result of the sudden availability of some nutrient in the water. Blooms are common in lakes and the ocean, occurring under natural conditions annually in some situations. Blooms can also be induced by pollution or excessive fertilization of a body of water by planned or accidental acts of man. A bloom will continue to thrive (often at levels of millions of cells per liter of water) until some factor in the environment becomes limiting. When this happens, the organisms responsible for the bloom begin to die, and if present in large enough quantities may create problems due to the noxious odors accompanying their decomposition and the possible release of toxins which may lead to fish kills (see Red Tide).
- Bottom sampler** - any instrument which is utilized to obtain a sediment sample. Various types of bottom samplers are illustrated in another section of this handbook.
- Bottom sediments** - sedimentary material of any origin (allochthonous or autochthonous) lying on the bottom of an ocean, lake, river or other body of water.
- Brownian movement** - the movement of colloidal particles caused by the bombardment of those particles by molecules of the solvent. Certain stains which are of colloidal sized particles demonstrate this phenomenon vividly when suspended in water and viewed through a microscope.

TABLE 20 (continued)

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Brine - sea water containing dissolved salts in excess of normal sea water concentrations.

BT - see Bathythermograph.

Buffer solution - a solution which tends to resist changes in pH when diluted or when acids or bases are added. Sea water is an excellent buffer solution, whereas the buffer capacity of freshwater varies depending upon water chemistry.

Caballing - the mixing of two water masses which have identical densities but different temperatures. The water mass which results is more dense than the water masses from which it was formed.

Calcareous - consisting of or containing calcium or calcium carbonate. Many sediments and the carapaces and shells of many marine and freshwater organisms are calcareous in nature.

Calorie - the amount of heat required to raise the temperature of one gram of water one degree C. The large calorie (kilogram-calorie) is equivalent to 1,000 calories.

Cape - a projection in the coastline such as a headland or promontory.

Capillary wave - a very small wave, the propagation of which is controlled primarily by surface tension. Capillary waves are also referred to as ripples.

Carapace - a calcareous, chitinous or bony covering associated with the external skeletal structure of an organism. The carapace is a common structure in the crustaceans and is also used to describe the shell of turtles.

Carbohydrate - one of the basic types of foods, comprising the sugars and starches. Carbohydrates are made up of carbon, hydrogen and oxygen in the ratio C:H:O = 1:2:1. For example, the chemical formula for glucose is  $C_6H_{12}O_6$ .

Carotene - a plant pigment

TABLE 20 (continued)

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- Catadromous - fish which mature in fresh water and migrate to the sea to spawn. A widely used example is the common American eel, Anguilla rostrata.
- Cathode - in an electrolytic or galvanic cell the cathode is the electrode at which reduction occurs.
- Celsius temperature scale (C) - the same as the centigrade temperature scale in which water freezes at 0 degrees and boils at 100 degrees. Celsius has been accepted as the term to replace Centigrade.
- Centigrade temperature scale (C) - the temperature scale under which water freezes at 0 degrees and boils at 100 degrees. Centigrade has been superceded by the term Celsius.
- Chelate - a coordination compound resulting from the reaction between a ligand and a metal ion. The ligand must contain two or more donor groups.
- Chelating agent - the ligand portion of a chelate. A chelating agent coordinates with the metal ions. For instance, a chelating agent may be used to scavenge metal ions from solutions.
- Chemocline - a layer containing a strong concentration gradient of dissolved substances. For example, in cases where rivers enter the sea a strong salinity gradient is established (the salt wedge) in which the salinity increases rapidly from the surface of the river to the bottom due to intrusion of salt water from the sea. This is a situation which gives rise to a type of chemocline.
- Chemotrophic = chemoautotrophic - that process by which certain organisms obtain their nutrition by using energy gained by oxidizing inorganic matter.
- Chemosynthesis - synthesis of organic matter from inorganic substances through the utilization of chemical energy.
- Chitin - a polysaccharide (large molecule formed by coupling many monosaccharide units) in which a derivative of glucosamine is the repeating unit. Chitin is used in the formation of the exoskeleton of many aquatic organisms.
- Chlorinity (Cl) - the weight of chlorine in grams contained in one kilogram of sea water after the bromides and iodides have been replaced by chloride, or 0.3285233 times the weight of silver equivalent to all the halides in a sea water sample.

TABLE 20 (continued)

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**Chlorophyll** - green plant pigments which can be identified from their spectral properties as chlorophylls a, b and c. Chlorophyll is important in the photosynthetic process which takes place in green plants.

**Chlorosity** - the chlorine content of one liter of sea water. Chlorosity is equal to the chlorinity of a water sample multiplied by its density at 20 C.

**Ciguatera** - a poisoning of humans resulting from the ingestion of various, often tropical fishes. A variety of symptoms may be manifested, with death resulting in some cases. Toxins may be stored in fish on a seasonal basis depending upon the diet of the affected fish species. A fish of a certain species may be safe to eat one week and toxic the next. Once fishes which pass toxins to man are identified, they are usually avoided at all times as a precautionary measure. The toxins usually originate at some lower level on the food chain than the fish which ultimately affects man.

**Clay** - a size fraction of sedimentary material ranging from 0.00195 to 0.00024 millimeters (see table 9).

**Clinograde** - a stratification curve of temperature or chemical entity in water which demonstrates uniform slope from surface into deep water.

**Coast** - the land area extending from the edge of the sea inland for an indefinite distance to the first major change in terrain.

**Coastal plain** - a flat expanse of land which extends from the edge of the sea to the nearest elevated land. May coincide with the coast.

**Coelom** - the body cavity of organisms having three germ layers. The coelom is lined with cells of the middle of the three germs layers, the mesoderm.

**Colligative property** - one of the four characteristic properties of a solution:  
1) vapor pressure, 2) osmotic pressure, 3) freezing point and  
4) boiling point.

**Colloid** - particles of small size intermediate between molecules and suspended particulates. Colloids are larger than molecules but smaller than 0.00024 millimeters in diameter.

**Commensalism** - a type of symbiotic relationship in which one species gains benefit while the other receives neither benefit nor harm. An example is the relationship between sharks and remoras. Remoras benefit by getting scraps from the shark's meals, while no benefit is gained by the shark.

TABLE 20 (continued)

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Community - the assemblage of organisms, plants and animals, inhabiting a natural physiographic area.

Compensation depth - the depth at which the production of oxygen by photosynthesis is just balanced out by the utilization of oxygen through respiration, giving no net gain or loss over a 24 hour period. The compensation depth is usually assumed to occur at a depth where the light intensity is one percent of its surface value.

Complex ion - a compound possessing an electrical charge and formed by covalent bonding of a metal ion and a ligand.

Conservative property - any property of sea water which is not under the influence of biological activity. Salinity is a conservative property; whereas, dissolved oxygen is non-conservative since it is affected by both photosynthesis and respiration.

Consumers - organisms which obtain their nutrition through the ingestion or other means of consumption of particulate organic matter.

Continental rise - a gentle slope, often of relatively smooth surface, on the sea bed which rises from the abyssal zone to the base of the continental slope.

Continental shelf - a zone on the sea floor adjacent to a continent and extending from the edge of the water to a depth of 200 meters or to where there is a rapid increase in the angle of slope of the bottom.

Continental slope - a zone of rapidly increasing depth of the ocean lying between the edge of the continental shelf (200 meters deep) and the upper limit of the continental rise where the angle of slope decreases dramatically.

Convergence - an area or zone at which two water masses meet. The water mass having the higher density of the two will sink at the zone of convergence.

Coordination compound - an electrically neutral compound formed by the covalent bonding of a metal ion and a ligand.

Coprecipitation - the process by which soluble substances are scavenged from a solution by an insoluble precipitate.

TABLE 20 (continued)

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Coral reef - a ridge or mass of calcareous material formed from detritus and skeletal structures of colonial coelenterates, mollusks and calcareous algae. Coral reefs are limited by temperature, salinity and other parameters to tropical waters.

Corange line - a line passing through places which exhibit the same tidal range.

Coriolis force - the apparent force acting on a particle which results from the rotation of the earth causing diversion of the particle to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. For example, if a cannon is fired toward the north from any point in the Northern Hemisphere, the trajectory of the projectile will appear to follow an arc moving toward the right (east in this case). The reason for the apparent movement toward the right is based on the fact that the earth is rotating beneath the projectile while it is in the air.

Cotidal line - a line passing through places which exhibit the same stage of the tide at the same time.

Counter current - a current which flows adjacent to a main current but in the opposite direction.

Cove - a small bay or small recess in a coastline.

Crest - the highest aspect of a wave.

Curie - the quantity of a radioactive nuclide which disintegrates at the rate of  $3.7 \times 10^{10}$  atoms per second.

Cycloidal wave - a steep symmetrical wave, the crest of which forms an angle of 120 degrees.

Cyclonic - rotational sense about the local vertical which is the same as the direction of the rotation of the earth; i. e., counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Cyclomorphosis - repeated changes in the body form of successive generations of plankton which follow a periodic pattern.

Cytoplasm - the material or protoplasm in an animal cell excluding the plasma membrane and the nucleus.

TABLE 20 (continued)

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Dark bottle - synonym for black bottle

Deep scattering layer - the wide reflective band of material which causes a distinct intermediate depth trace on a recording echo-sounder during some periods of the day. The layer is often absent during the daylight and can be seen forming as the sun sets in the evening. It is often present throughout the night and disperses as the sun rises. The deep scattering layer has been attributed to zooplankton and nekton which are apparently negatively phototaxic and rise toward the surface at night presumably to feed. Demonstration of this community has been difficult as plankton and midwater trawl samples taken while the deep scattering layer is both absent and present do not show distinctive communities or even numbers of organisms in many cases.

Delta - deposition of sediments at the mouth of a river, stream or tidal inlet. The extensive delta of the Mississippi River is an example of one of the largest extant.

Demersal - fishes which live on or near the bottom and the eggs of certain fishes which sink to the bottom after being broadcast into the water column.

Denitrification - the reduction of nitrate to nitrite and finally to elemental nitrogen. This process is undertaken by certain bacteria.

Density - the ratio of the mass of a substance to its volume. In aquatic science density is equivalent to specific gravity and represents the ratio of a given volume of water at atmospheric pressure to the same volume of distilled water at 4 C and atmospheric pressure. Density is often expressed in terms of sigma-t in oceanography.

Detritus - finely divided settleable material of organic and inorganic origin which is found suspended in water.

Diagenesis - the chemical and physical changes which sediments undergo following their deposition in the aquatic environment.

Diatomaceous ooze - sediments composed of siliceous material and containing in excess of 30 percent diatom tests.

Diffusion - the gradual complete mixing of two substances which are in contact with one another, the forces involved being molecular movement only.

TABLE 20 (continued)

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Diploid - the somatic number of chromosomes. Also equal to twice the number of chromosomes found in the gamete of a species.

Disphotic zone - a zone of dim light in which little or no primary production can occur, and what little that does occur is more than compensated for by respiration. Most of the plants present in the disphotic zone arrive there by sinking from the layer above (euphotic zone). This zone lies essentially between the compensation depth and the aphotic zone.

Dissimilation - the metabolic processes whereby more simple substances (down to the inorganic end products of bacterial decomposition) arise from complex organic compounds.

Dissociation - the splitting of a molecule existing in a solution into ions (cations having positive electrical charges, and anions, having negative electrical charges).

Diurnal - daily; pertaining to the activities or actions occurring in the environment which are completed within 24 hours or recur on a 24 hour basis. In certain areas of the world (e.g., the Gulf of Mexico) tides may occur with a frequency of only one high and one low tide per lunar day (about 24 hours 50 minutes) instead of the more normal occurrence of two high tides and two low tides occurring during that period of time. Such cases are referred to as diurnal tides.

Divergence - the horizontal flow of water in different directions from a common center line as exemplified in areas of upwelling.

Dorsal - pertaining to or lying on the back of an animal as in the case of the dorsal fin on a fish.

Dry weight - the weight of an organism, group of organisms, or part of an organism after all of the unbound water within that organism, group or part of an organism has been removed by heating for a period of time at up to 105 C (often 80 C) until constant weight is achieved.

Dysphotic zone - see disphotic zone

Dystrophic lake - a lake having brown water (associated with high concentrations of high molecular weight organic acids), low calcium carbonate and low nutrient levels. Dystrophy is one of the final stages in the aging process which occurs in all lakes.



TABLE 20 (continued)

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- Embryo - the stage in the development of an organism between zygote formation and the completion of formation of the body structure.
- Endoderm - the innermost of the germ layers formed during the formation of an embryo possessing a gastrula stage. In higher animals the endoderm forms the lining of the alimentary canal and respiratory passages, the urinary bladder and various glandular tissues.
- Endoplasm - the part of the cytoplasm of a cell which immediately surrounds the nucleus.
- Endostyle - a groove in the floor of the pharynx of protochordates which possesses cilia and is used in obtaining food for the animals.
- End point - that point in a titration where physical changes in the solution can be observed, usually with the aid of an indicator of some type.
- Entrainment - the transfer of fluid by friction from one water mass to another, or the suspension and movement of sediments by flowing water.
- Environment - the total of all internal and external conditions which may affect an organism or community of organisms.
- Enzyme - protein substance produced by living cells which acts as a catalyst to speed up certain chemical reactions. The enzyme is unaltered through its involvement with other chemical transformations.
- Epilimnion - the upper layer of a stratified lake, it is that portion lying above the thermocline and is usually well mixed.
- Epipelagic - the upper zone of the ocean, extending from the surface of the water to a depth of 200 meters.
- Epiphytic - those plants which are found attached to the surface of other plants as commensals, but which are not rooted or free floating. (See epizoite.)
- Epizoite - animals which are found living attached to the surface of plants in the aquatic environment. (Some confusion has been attached to this term and to the term epiphyte. Some authors think of epiphytes as plant species attached to any substrate and of epizoites as animals species attached to any aquatic substrate. A presentation of the operating definition should probably accompany the use of these terms. Also see Aufwuchs and periphyton.)

TABLE 20 (continued)

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**Equivalence point** - the theoretical point in any titration when the amount of standard solution added is chemically equal to the substance being reacted upon. The point at which this phenomenon can be observed is the end point. The end point and equivalence point should be identical, but in practice there is often a certain degree of difference between the two.

**Equivalent weight** - three types of reactions call for different definitions of equivalent weight according to Skoog and West (1963). These are:

- 1) Neutralization reaction - the equivalent weight is the weight of a substance which either contributes or reacts with one gram formula weight of hydrogen ions in the reaction.
- 2) Oxidation-reduction reaction - the equivalent weight is the weight of a participant in the reaction which consumes or produces one mole of electrons.
- 3) Precipitation or complex-formation reaction - the weight of a substance which reacts with or produces one gram formula weight of a univalent reacting cation, half of a formula weight of a divalent cation, etc.

For a more complete discussion of this concept see: Skoog, D.A., and D.M. West. 1963. Fundamentals of Analytical Chemistry. Holt, Reinhart and Winston. New York. 786 p.

**Establishment of the port** - the average period of time between the passage of the new or full moon and the occurrence of the next high water.

**Estuary** - Among the many definitions which have been proposed for this term, that of Pritchard (1967) is the most widely accepted. He stated: "an estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." (Pritchard, D.W. 1967. What is an estuary: physical viewpoint. In: G.H. Lauff, ed. Estuaries. American Association for the Advancement of Science Publication No. 83. Washington, D.C. 757 p.)

While that definition is adequate in most situations, at least three types of estuaries have been widely recognized, and not all adhere strictly to Pritchard's definition. These are:

- 1) Positive estuary - freshwater inflow from precipitation and river runoff exceeds evaporation and there is a net transport of diluted saltwater out of the estuary annually.

TABLE 20 (continued)

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- 2) Negative estuary - annual evaporation exceeds the input of rivers and precipitation and the salinity becomes higher than the adjacent sea. The net transport of water is from the sea into the estuary to replace evaporation losses.
  - 3) Neutral estuary - annual precipitation and freshwater input from rivers, etc. balances evaporation. There is no net transport of water from the sea into the estuary or from the estuary to the sea.

Eulittoral - in lakes it is that zone which extends over the area which is covered by annual fluctuations in water level. Some authorities say that in the sea this zone extends from the high tide mark to a depth of about 50 meters; however, this term is not often used by contemporary oceanographers.

Euphausiid - a small pelagic shrimp-like crustacean. Euphausiids make up the major food of certain cetaceans and are referred to as krill.

Euphotic zone - the layer of water in which active photosynthesis occurs. This zone lies between the water surface and the compensation depth.

Euryhaline - organisms which can adapt to wide variations in salinity.

Eurythermal - organisms which exhibit a wide tolerance for temperature.

Eurytopic - organisms which can be found throughout a wide geographical range.

Eustatic - pertaining to world-wide, simultaneous changes in sea level such as those which might occur as a result of large scale melting of polar ice, or large scale glaciation. Localized changes in coastal elevation are not considered to be eustatic.

Eutrophic - waters which contain abundant levels of nutrients resulting in high levels of organic production.

Eutrophication - the process by which lakes become nutrient rich. Eutrophication of lakes is often associated with noxious algae blooms, encroachment of shallow water areas by rooted aquatics and increases in dissolved organic material in the water. The process is a natural one; however, it can be, and has been in many instances, accelerated by the activities of man. Eutrophication can be used as a synonym for enrichment. The objection to eutrophication comes when man's addition of fertilizers, organic wastes and detergents to natural waters accelerates the process.

TABLE 20 (continued)

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- Euxinic basin - a marine basin in which lack of circulation results in oxygen depletion in the deep water leading to anaerobic conditions. Euxinic areas are characterized by the virtual absence of aerobic organisms and the presence of anaerobic sediments which produce hydrogen sulfide. Such areas are relatively rare in the world ocean.
- Fathom - a unit of depth in the English system of measurement equal to six feet (1.83 meters).
- Fetch - the distance traversed over water by a wind of constant direction and velocity. In general, the longer the fetch, the greater the wave generating power of the wind.
- Fiord - see fjord
- Fjord - a narrow, steep-walled, deep inlet from the sea which is often characterized by having a relatively shallow sill at its entrance.
- Flocculate - to aggregate in clumps. Colloidal clay particles transported in suspension in freshwater tend to flocculate and settle out when brought into contact with salt water due to changes in the electrolyte balance between the two solutions. Clay particles are usually negatively charged and don't form precipitates in most freshwaters because of a lack of positively charged particles. In salt water, on the other hand, there are abundant amounts of negative ions which stimulate flocculation.
- Flood tide - the period of the tidal cycle between dead low water and maximum high water. The period during which the tide is rising.
- Flushing time - the time required to remove or reduce to some specified concentration by natural current and/or tidal action a substance, such as a pollutant, which has been introduced into a harbor, bay or estuary.
- Food chain - the sequence of organisms, each of which provides a source of food for the next, from primary producer through the ultimate consumer. Simple food chains are rare in nature since most animals do not feed exclusively on one other species of organism. It is more realistic to speak of food webs rather than food chains.
- Food cycle - the production, consumption and decomposition of organic matter in aquatic ecosystems, along with the energy relationships involved in the transfer from one step in the cycle to another.

TABLE 20 (continued)

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Food web - the complex feeding relationships which exist within any community of organisms. (See food chain.)

Foraminiferal ooze - a type of marine sediment formed from calcium carbonate contributed by the tests of Foraminifera (an order of protozoa). To qualify the sediment must contain a minimum of 30 percent calcium carbonate attributable to this source.

Formality - The number of gram formula weights of a solute present in one liter of a solution.

Fouling organisms - those organisms which attach to manmade surfaces such as the hulls of ships, pilings and piers and which commonly result in either nuisance or permanent structural damage to the object to which they are attached.

Gamete - a mature reproductive (germ) cell, either male (sperm) or female (ova).

Gastrula - a stage in the development of an embryo in which indentation occurs in the wall of the hollow ball shaped blastula stage forming a cup shaped mass of cells two layers thick. The inner layer is known as the endoderm, the outer layer the ectoderm.

Gene - a part of a chromosome which carries a hereditary unit and can be transmitted from one generation to another. Chromosomes contain hundreds or thousands of genes, each responsible for a small part of the individual organism.

Genotype - the sum total of the genes possessed within the chromosomes of an individual organism, both those which are expressed as characteristics which can be readily observed and those which are latent within the individual.

Geostrophic current - a current defined by assuming that a balance exists between a horizontal pressure gradient and the coriolis force.

Geosyncline - areas in the earth's crust which have undergone long periods of subsidence and have been later compressed by tectonic forces. Mountains containing sedimentary rock are considered to be geosynclines which have been uplifted due to geophysical activities within the crust of the earth.

TABLE 20 (continued)

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- Germ layer - any of the three layers of cells which can be found in the embryo of higher organisms (two layers in lower animals) and which differentiate into various tissues as the embryo develops. The three types of germ layers are the ectoderm, endoderm and mesoderm.
- Gestation - the period of time during which a developing embryo is carried within the uterus, or the period of development from fertilization of an ovum to birth of the organism.
- Globigerina ooze - a marine sediment which consists of more than 30 percent calcium carbonate contributed by foraminiferal tests of which the genus Globigerina (a protozoan) is dominant.
- Grab sampler - a device equipped with jaws used to collect samples of bottom sediments from the aquatic environment.
- Gram formula weight - the summation of the atomic weights, in grams, of all of the atoms appearing in the chemical formula of a particular substance.
- Gram molecular weight - the formula weight of a single, real chemical species. Substances which ionize, such as sodium chloride (NaCl), have no gram molecular weight according to this definition, but do have a gram formula weight.
- Grazing - in the terminology of the aquatic sciences, grazing refers to the feeding of zooplankton organisms upon phytoplankton organisms, for the most part. Some marine animals do graze on submerged aquatic macrophytes and are thus similar to grazers in terrestrial environments.
- Green mud - see green ooze
- Green ooze - a fine-grained sediment of terrestrial origin found near the continental shelf edge and characterized by a greenish color.
- Gross production - the total amount of new organic material formed during a given period of time including that which was simultaneously utilized in metabolism.
- Gulf - a large embayment in a coast in which the width of the opening is greater than the depth of penetration inland. The Gulf of Mexico is a misnomer.

TABLE 20 (continued)

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Guyot - a flat-topped seamount.

Gyre - a closed system of circulation on a large scale, i. e., a large eddy.  
Gyres in the oceans may cover many degrees of latitude and longitude.  
The whole North Atlantic ocean is one large gyre in which the Gulf Stream makes up the western side.

Gyttja - the type of sedimentary material typical of aerated lake bottoms.

Hadal - pertaining to the deepest portions of the oceans, those areas lying in depths in excess of 6,000 meters.

Halogen - a substance, which by interacting chemically with a metal, forms a compound of a saline nature. The halogens include chlorine, iodine, bromine and fluorine. When in the presence of metals, they form chlorides, iodides, bromides and fluorides, all of which are present to greater or lesser extents in seawater.

Haploid - the total number of chromosomes present in germ cells (sperm and ova). The haploid number is equal to one-half of the diploid (somatic) chromosome number.

Heterotroph - an organism which obtains its nourishment only from preformed organic matter.

High tide - the highest vertical limit of the water surface reached by the rising tide.

High water - see high tide.

High water mark - an established reference point which indicates the highest elevation along the shoreline reached by the high tide. A discoloration of pilings, breakwaters and other structures located intertidally may occur at a level approximately equal to the high water mark.

Holomictic - lakes which are completely mixed from surface to bottom during the period of winter cooling when stratification occurs in many lakes.

Holophytic - the process by which an organism manufactures its food through photosynthesis. This is the most common type of autotrophic nutrition.

Holoplankton - organisms which spend their whole lives as members of the planktonic community.

TABLE 20 (continued)

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Holozoic - organisms which obtain their nutrition by ingesting particulate organic materials and which digest them internally.

Homology - the similarity among different species of organisms having similar embryology and adult structure based on the fact that the species share a common ancestor somewhere in their evolution.

Horizontal tow - the pulling of a net at a predetermined depth for a specific length of time. The net may be equipped with opening and closing devices to insure that the total catch came from the desired sampling depth.

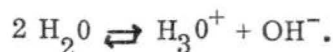
Humic acids - see humic substances

Humic substances - a group of high molecular weight organic substances (often organic acids) which dissolve in water and are a product of the decay of vegetable matter. Humic substances are often responsible for the tea-colored water found in areas like the southeastern coastal areas of the United States.

Hydrography - the science which deals with the measurement and description of the physical features of bodies of water.

Hydrology - the science which deals with the cycling and character of water.

Hydronium ion - The positively charged ion which results from the dissociation of a water molecule:  $H_3O^+$ ,



The other ion formed is called the hydroxyl ion ( $OH^-$ ).

Hydroxyl ion - see hydronium ion.

Hypertonic - refers to a solution which has an osmotic pressure greater than that of a solution with which it is being compared due to the presence of more dissolved substances within it as compared with the other solution.

Hypolimnion - the deep water of a lake underlying the thermocline. The hypolimnion is present only when a lake is stratified.

TABLE 20 (continued)

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**Hypotonic** - refers to a solution which has an osmotic pressure less than that of a solution with which it is being compared due to the presence of less dissolved substances within it as compared with the other solution. Particles will pass through a semi-permeable membrane from a hypertonic solution and into a hypotonic solution until the osmotic pressure of the two solutions is the same.

**Ice floe** - a single piece of sea ice.

**Ice point** - the true freezing point temperature of water. Varies with salinity and other physical and chemical considerations.

**Indicator** - a chemical substance which changes color dependent upon the pH of a solution in which it is placed. Indicators are used to determine end points in titrations.

**Indicator species** - species which are characteristic of a certain type of environment; e.g., a particular species of zooplankton may be indicative of a certain water mass, or a species of benthic invertebrate may be indicative of a certain sediment type. Indicator species have been sought as a means of determining the extent of pollution, but, in general, few good indicators of that nature have been identified.

**Inquilinism** - a special type of commensalism in which one organism lives within another (often within the digestive tract) without causing harm to the host organism, although the internally living organism gains benefit from the association.

**in situ** - latin for "in place." Refers to events which occur in their natural locations as opposed to **in vitro**, which refers to events occurring under other than natural conditions, e.g., in the laboratory.

**Interface** - a boundary separating two media and across which there exists a discontinuity in some property such as density. The air-sea and water-sediment interfaces are among the most important and dynamic in the marine realm.

**Interstitial water** - water contained within the pore spaces present between the particles which make up a sediment.

**in vitro** - see **in situ**.

**Ion** - an electrically charged atom or group of atoms.

TABLE 20 (continued)

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- Isobath - a contour line connecting points of equal depth on a chart.
- Isobathytherm - a line showing ocean depths or lake depths which have the same temperature.
- Isohaline - a line on a chart connecting points which have the same salinity.
- Isopleth - a line on a chart which connects points having equal or constant values of a given parameter, such as temperature, salinity or density with respect to space or time.
- Isopycnic - a line on a chart which connects points which have the same density.
- Isotherm - a line on a chart which connects points which have the same temperature.
- Isotonic - a solution which exhibits the same osmotic pressure as a solution with which it is being compared. When two solutions which are isotonic are separated by a semi-permeable membrane there is no net transport of particles through the membrane in either direction.
- Isotope - atoms which have the same atomic number but different atomic weights.
- Juvenile water - water which enters the hydrologic cycle for the first time, having been released into the ground or surface waters from igneous rock through volcanic activity.
- Knoll - a projection which rises less than 1,000 meters above the surrounding sea floor and is of limited areal extent across the summit.
- Krill - a general term used in describing the plankton community dominated by euphausiids and utilized as a major food source by certain cetaceans.
- Lagging of the tide - the periodic retardation in the time of occurrence of high tide and low tide following the passage of the moon overhead due to changes in the relative positions of the sun and moon.
- Lagoon - a shallow sound, pond or lake generally separated from the open sea. The separation is often caused by the presence of a coral reef.
- Laminar flow - a nonturbulent flow in which a fluid moves smoothly in streamlines, parallel layers or sheets.
- Land breeze - a light wind blowing from the land toward the sea caused by unequal cooling of land and water masses.

TABLE 20 (continued)

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- Law of constancy of relative proportions - this law states that regardless of the absolute concentrations of total dissolved solids in sea water, the ratios between the more abundant substances are virtually constant throughout the world ocean.
- Layer of no motion - a layer in the sea which is assumed to be at rest. The detection of such a layer is often theorized rather than actually detected.
- LeChatelier's principle - this principle states that a chemical equilibrium will react to a stress by a shift in the direction which counteracts the stress.
- Lee - toward the sheltered side or in shelter; away from the wind.
- Lentic - flowing water (e.g., a stream) as opposed to lotic (standing water).
- Level of no motion - the depth at which the layer of no motion occurs.
- Ligand - the species in a coordination compound or complex ion which donates one or more electron pairs to the compound or ion. A metal ion serves as the acceptor in such a reaction.
- Light bottle - the transparent container used in primary productivity experiments which measure some aspect of photosynthetic activity such as carbon-14 uptake or oxygen evolution. Light is allowed to penetrate the bottles which are incubated for various periods of time either in situ or under controlled environmental conditions in the laboratory or aboard ship. Dark bottles are used in conjunction with light bottles to determine respiration and/or dark fixation of carbon.
- Limnology - the branch of aquatic science which deals with the study of inland waters, both lotic and lentic. Limnology covers all aspects of freshwater science, with the exception that freshwater fishery science is often considered as being outside of limnology, although the fields are closely interrelated and workers in either field must interact and be aware of the contributions made in both areas. Limnologists who study animal communities usually work at a level below the fishes. Historically, most limnologists have been biologically trained, but in recent years more physicists, geologists, and especially chemists have begun entering the field. Limnology, like oceanography is an interdisciplinary field of science.
- Lipid - any portion of plant or animal tissue which can be dissolved in the so-called "fat solvents," such as, ether, benzene, petroleum and chloroform. Included in the general category are fatty acids, triglycerides, phosphatides, steroids, derivatives of glycerol and waxes. One of the three main classes of foods: lipids, carbohydrates and protein.

TABLE 20 (continued)

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**Lithification** - the process by which loose sedimentary material is transformed into rock.

**Littoral** - the zone in the ocean existing between the high and low water marks.

**Littoral current** - a current which is caused by the action of waves and which runs parallel to the shore. Also called a longshore current. Such currents occur close to the beach.

**Littoral drift** - the material which is moved in conjunction with longshore currents and nearshore wave action.

**Littoral transport** - the movement of material in the littoral drift. If littoral transport brings in more material than is being removed there will be beach building and/or bar formation. If more material is being removed annually than is brought in by the littoral drift, erosion will occur.

**Longshore current** - see littoral current.

**Lotic** - standing water, such as a lake or pond, as opposed to lentic (flowing water).

**Low tide** - the lowest level reached by the falling tide.

**Macrophytes** - large plants. In aquatic science, macrophytes generally refer to rooted aquatic plants and do not include kelps which are algae.

**Macroplankton** - planktonic organisms within the size range of one millimeter to one centimeter.

**Marine borer** - any organism which excavates tunnels, holes or depressions by abrasion, chewing or chemical activity. Such organisms become economically destructive when they attack manmade structures such as ship hulls and pilings.

**Marl** - a calcareous clay or mixture of clay particles, calcium carbonate particles and shell fragments (the latter being also composed of calcium carbonate). Marly sediments occur in the sea as well as in lakes under certain conditions.

**Marsh** - an area of soft wet land. Salt marshes occur when areas are periodically wetted by tidal action.

TABLE 20 (continued)

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- Maxilla** - one of the head appendages in crustaceans, and one of the upper jawbones in vertebrates.
- Maxilliped** - One of the three pairs of appendages occurring on the head just posterior to the maxilla in crustaceans.
- Mean sea level** - the mean surface water level as determined by averaging the levels of the water at all tidal stages over a period of 19 years.
- Megaloplankton** - planktonic organisms larger than one centimeter.
- Meiosis** - the nuclear change which occurs when the chromosome number is reduced from the diploid to the haploid value. Also referred to as reduction division in cells.
- Meromictic lake** - a lake which during the period in fall and winter when cooling occurs undergoes only partial circulation. Circulation occurs to a depth determined by a density gradient.
- Meroplankton** - the planktonic stages (eggs and larvae) of organisms which in later life become members of the benthos or nekton.
- Mesoderm** - one of the three germ layers, it arises within the internal space of the gastrula embryonic stage. The mesoderm gives rise to the skeleton and muscles, connective tissue and circulatory system in higher animals.
- Mesopelagic** - the depths in the ocean encompassing that zone which occurs between 200 meters and 1,000 meters.
- Mesoplankton** - plankton within the size range from 0.5 centimeters to one centimeter. This term is most often used to indicate planktonic organisms of all sizes which are found at middepths, thus, some care in defining the term should be associated with its use.
- Messenger** - a cylindrical metal (or other type of material) device which can be clipped on a hydrographic wire and allowed to slide freely down the wire to trigger some device being used to collect a sample such as a water bottle or closing plankton net which has been lowered to a predetermined depth.

TABLE 20 (continued)

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Metabolism - a group of processes which occur in living organisms by which nutrition, synthesis of new tissue and respiration are achieved.

Metalimnion - see thermocline.

Microplankton - planktonic organisms within the size range between 60 microns and one millimeter.

Millequivalent - one-thousandth of an equivalent weight.

Mitochondria - a type of organelle which occurs within cells.

Mitosis - somatic cell division, wherein the diploid number of chromosomes is reproduced.

Mixed layer - the layer of water in the ocean or a lake which is mixed by the wind and wave action and lies above the thermocline. In lakes this layer is referred to as the epilimnion.

Mixotrophic - that type of nutrition whereby an organism is able to obtain its food either by autotrophic or heterotrophic modes.

Mole - one gram molecular weight of any molecule. Equal to Avogadro's number of molecules ( $6.023 \times 10^{23}$ ).

Molecule - the smallest particle of an element or compound which can have a stable independent existence.

Molarity - the number of moles of a species in one liter of a solution.

Monimolimnion - the deep water of a meromictic lake which is not involved in the annual circulation.

Monosaccharide - a simple sugar which cannot be dissociated into smaller sugar molecules.

Mutualism - a symbiotic relationship under which both species benefit and neither is harmed.

Nannoplankton - small planktonic organisms in the size range between five and 60 microns. Animals of this size are collected by centrifugation as they pass through the finest plankton nets.

TABLE 20 (continued)

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- Neap tide - the series of tides associated with the moon in its first and third quarter during which high low tides and low high tides occur.
- Negative estuary - an estuary in which evaporation exceeds freshwater inflow from all sources and the net flow of water is from the sea into the estuary.
- Nekton - those animals which are active swimmers and occupy the pelagic water zone, including most fishes, squids, marine mammals and some other animals.
- Neritic - the zone in the ocean which includes all of the water over the bottom between the shore and the shelf edge. The other major marine province is the oceanic zone.
- Net plankton - same as microplankton.
- Net production - the total amount of organic matter elaborated over a specified period of time minus the amount utilized in metabolism.
- Neuston - the community of organisms associated with the surface film of the water. This community is often better established in freshwater than in salt water since the surface of the ocean is often disturbed and limits the community.
- Neutral estuary - an estuary in which neither freshwater inflow or evaporation dominates and there is no net flow of water either into or out of the system.
- Nitrification - The oxidation of nitrogen from ammonia through nitrite to nitrate.
- Normality - the number of equivalents of solute dissolved in one liter of a solution.
- Nutrient - any of a number of organic and inorganic compounds or ions which are necessary for the proper nutrition of one or more primary producers in the aquatic realm. Notable examples are nitrates, phosphates, vitamins and silicates.
- Oblique tow - the retrieval of an open net from a certain depth to the surface at a constant rate while the ship is underway.

TABLE 20 (continued)

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Oceanography - the study of the world ocean including the coastal boundary areas. Oceanography encompasses marine aspects of biology, geology, chemistry and physics. Oceanographers should be trained in each of these fields to some extent, with emphasis in their education in one of the four specialties.

Oceanology - synonymous with oceanography, oceanology is used as the preferred term in the U.S.S.R., and is gaining in worldwide popularity. Either term is accepted in the United States.

Oligo-aerobe - an organism which can thrive at low oxygen tensions.

Oligohaline - confined to a narrow range of salinity.

Oligothermal - confined to a narrow range of temperature.

Oligotrophic - water bodies (especially lakes) which contain low supplies of nutrients and thus low levels of organic production.

Ontogeny - the development of an individual organism from fertilization of the egg by the sperm through senescence.

Operculum - the gill cover on a fish; also the cover on the end of certain parasite eggs.

Organism - any individual plant or animal, either unicellular or multicellular.

Osmosis - the process by which liquids migrate through a semi-permeable membrane from a solution containing a lesser concentration of dissolved particles into a solution containing a greater concentration of dissolved particles. Once the concentration of the two solutions is balanced, migration of the water will cease. (It is possible that other solvents besides water can exhibit this phenomenon, but for our purposes, water is by far the most important.)

Overturn - the complete mixing which occurs in lakes after thermal stratification is broken due to the cooling of the surface waters to the temperature of the water in the hypolimnion in the fall, or warming of the surface waters to that of the hypolimnion water temperature in the spring (hypolimnetic waters generally remain at 4 C during the winter, whereas in temperate climates the surface waters may be colder). This is generally a phenomenon of temperate areas.

TABLE 20 (continued)

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Oviparous - the type of reproduction in which the eggs are released into the environment by the female and develop outside the body of the female.

Ovoviviparous - the type of reproduction in which the eggs develop within the body of the female, but the eggs receive no nutrition during their development other than that provided by stores of nutrients within the eggs themselves.

Oxidation - any one of a number of processes which increases the acid-forming portion or the oxygen proportion in a compound. Electron loss.

Oxygen minimum layer - the layer in the ocean where the oxygen concentration drops to its lowest level (often approaching zero ml l<sup>-1</sup>). This layer may be at intermediate depths with higher values in dissolved oxygen occurring above and below.

Parapodium - an appendage located on the segments of polychaete worms. In most polychaetes each segment has one pair of parapodia. These function in respiration, movement of water and locomotion.

Parasitism - the relationships which may exist between two organisms in which one organism lives on or within its host and obtains its nourishment at the expense of the host. A "good" parasite shouldn't kill its host, but it may weaken the host to the point that it becomes subject to predation or disease.

Parthenogenesis - the type of sexual reproduction by which an individual organism develops from an unfertilized egg.

Parts per thousand - equal to 10<sup>-3</sup> in the same way as 10<sup>-2</sup> is equal to percent. Parts per thousand is the unit in which salinity is usually recorded. Distilled water has a salinity of 0.0 parts per thousand, while the salinity of the open ocean is usually around 35 parts per thousand. The abbreviation for parts per thousand is ‰.

Pelagic - organisms which inhabit the water column. The pelagic zone or division of the ocean includes all of the water column as opposed to the benthic zone which refers to provinces along the bottom.

Per mille - equivalent to parts per thousand.

Periphyton - the autotrophic component of the Aufwuchs community. Also sometimes called benthic algae.

TABLE 20 (continued)

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Peritoneum - The membrane in higher animals that covers the visceral organs and lines the abdominal cavity.

pH - the negative logarithm of the hydrogen ion concentration expressed in gram equivalents. The pH scale is based on increasing hydrogen ion concentration from pH = 1 through pH = 14, with a pH of 7 being neutral. Values of pH less than 7 are acidic, and values above 7 are basic. A change in pH of one full pH unit is an order of magnitude change in hydrogen ion concentration. Thus, a solution at pH = 8 is ten times more basic (less acid) than a solution of pH = 7.

Phenotype - the characteristics inherited by an individual which are visible as opposed to the genotype. Hair and eye color are traits which are expressed in an individual and are, thus, phenotypic.

Photosynthesis - the elaboration of organic matter from carbon dioxide and water utilizing light as the source of energy. The formation of organic matter through photosynthesis is usually accomplished in the presence of chlorophyll. The process results in the release of molecular oxygen as a byproduct.

Phototropism - an orientation or movement of an organism in response to light stimulus.

Phylum - the first level of classification of organisms in the binomial system of nomenclature below the level of kingdom.

Phytoplankton - the plant constituents of the plankton community.

Plankter - a single planktonic organism.

Plankton - organisms which exist in the aquatic realm and which are at the mercy of the currents. These animals drift passively or swim weakly. Some planktonic organisms can traverse rather great distances vertically, but cannot overcome horizontal currents. They range in size from a few microns in the case of some phytoplankters to many centimeters. Some, such as the Portuguese man-o-war (Physalia physalia) are also moved by winds.

Plasma membrane - the thin membrane that surrounds and encloses the internal structures of animal cells.

Pleopod - one of the swimming appendages of crustaceans.

TABLE 20 (continued)

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- Pleuston - the community of organisms which may be found floating at the surface of the water.
- Polymorphism - the presence within a species of various types of structurally different individuals.
- Polyp - the coelenterate life cycle stage exhibited by the sessile form of the organism. Some coelenterates are polyps throughout their lives.
- Polyploid - genetic change involving the gaining of an additional set or sets of chromosomes in excess of the diploid number.
- Polysaccharide - carbohydrate formed by the polymerization of numerous monosaccharide units. Cellulose, starch and glycogen are examples.
- Polythermal - confined to a high range of temperature, such as certain species of algae which are found only in geothermally heated springs.
- Port - the left side of a ship as observed when facing the bow. Also: a place where a ship ties up to load or unload cargo.
- Potamoplankton - the plankton of large rivers which forms its own community independent of contributions from tributaries and other water input sources.
- Positive estuary - an estuary in which the inflowing freshwater is present in excess of evaporation and there is a measurable dilution of the sea water by freshwater.
- Precipitate - a solid, formed from solution, which will eventually drop out of solution by means of gravity unless agitation prohibits its settling.
- Primary production - the elaboration of organic matter from inorganic materials by autotrophic organisms which use light as their source of energy.
- Priming of the tide - the periodic acceleration in the time of occurrence of high tide and low tide after the passage overhead of the moon due to changes in the relative positions of the sun and the moon.
- Production - the elaboration of organic matter by the organisms within a specific area over a specified period of time.

TABLE 20 (continued)

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- Productivity - the rate at which production occurs.
- Protein - any member of a class of chemical compounds containing the elements carbon, hydrogen, oxygen and nitrogen (and sometimes sulfur), and composed of a series of amino acids. Protein is one of the classes of food vital in the nutrition of all organisms.
- Psammon - the community which is found within the interstitial spaces of sand deposits associated with the shores of lakes and rivers.
- Pteropod ooze - a type of marine sediment which is made up of at least 30 percent calcium carbonate contributed by the tests of marine organisms dominated by pteropods (a type of free-swimming gastropod).
- Pycnocline - a vertical gradient in density.
- Radiolarian ooze - a type of marine sediment which is made up of siliceous material characterized by large percentages of radiolarian algal tests.
- Red tide - a reddish or reddish-brown discoloration of surface waters caused by high concentrations of certain species of dinoflagellates which produce toxins and may lead to massive fish and invertebrate kills or to the contamination of fish and invertebrates to such an extent that a public health hazard is created. Red tides have occurred at intervals in many areas, predominantly in the Gulf of Mexico in the United States. One of the organisms which may be responsible for a Red Tide outbreak is Gymnodinium breve. The exact nature of the toxin and its detoxification have not been elaborated. The toxins are generally released when the organisms responsible become senescent. Such organisms may be present in the phytoplankton throughout the year but become toxic only after conditions allow them to bloom.
- Reduction - any of a number of processes which increased the base-forming portion in a compound. Electron gain by an atom, ion or element.
- Rostrum - a projection on the head of an animal.
- Salinity - a measure of the total amount of dissolved salts present in a sample of sea water, in parts per thousand by weight, when all the carbonate has been converted to oxide, the bromide and iodide have been replaced by chloride, and all organic matter is completely oxidized. In practice, salinity is obtained by titration from chlorinity, by electrical conductivity, specific gravity or refractometry.

TABLE 20 (continued)

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- Sapropel - a type of sediment generally associated with lakes which is characterized by a high content of organic matter and a foul odor caused by the emission of hydrogen sulfide ( $H_2S$ ) gas.
- Saprophyte - an organism which obtains its nutrition by absorbing food which, in most cases, has been digested externally.
- Saturation - the point reached in the preparation of a solution when no more solute can be dissolved in the solvent. Also, a chemical compound is said to be saturated when it contains no double or triple bonds.
- Seamount - an elevation on the seafloor which rises a minimum of 1,000 feet (about 300 meters) above the surrounding seafloor and is of limited surface areal extent. Seamounts which protrude above the surface of the sea form islands.
- Secchi disc - a white, black or combination of white and black panelled disc of variable diameter (generally larger diameter Secchi discs are used in the ocean than in freshwater) used to measure the transparency of water. The disc is lowered until a point is reached when it is just barely visible and that depth is recorded as the Secchi disc reading under the conditions and at the location when the reading was taken.
- Sediment - particulate or dissolved organic and inorganic matter of allochthonous and/or autochthonous origin.
- Seiche - the standing wave oscillation of an enclosed or semienclosed body of water or the ocean analogous to the sloshing of water within a basin or bath tub but with much longer period. The phenomenon continues long after the generating force has dissipated. This phenomenon occurs most often in oceans and seas, but may also occur in large bodies of fresh water such as the Great Lakes.
- Semidiurnal tide - the type of tide common to most coastal areas in which two high tides and two low tides occur during a lunar day with small inequalities existing between the two highs and the two lows.
- Seston - living and nonliving bodies which float or swim in water. This includes all particulate suspended matter. Abioseston refers to seston particles of an inorganic nature as opposed to bioseston which includes particles made up of organic matter.

TABLE 20 (continued)

**Shelf break** - analogous to the edge of the continental shelf, or that area where a significant increase in the rate of slope begins as the continental shelf gives way to the continental slope.

**Shoal** - a submerged object (such as a sand bar or coral platform) which is near enough to the surface to create a hazard to navigation. Shoal is also used for any areas in which the water becomes less deep. In addition, large schools of fish are often called shoals.

**Sigma-t ( $\sigma_t$ )** - an abbreviation for the value of the density of sea water of temperature  $t$  and salinity  $S$  based on the relationship:

$$\sigma_t = (\alpha - 1) \times 10^3$$

where  $\alpha$  = the density at standard atmospheric pressure and in situ temperature. If, for example the density ( $\alpha$ ) under the conditions outlined were 1.02739, then  $\sigma_t$  would be 27.39.

**Siliceous ooze** - a type of marine sediment which contains a minimum of 30 percent siliceous skeletons of pelagic algae and/or animals.

**Sill** - a low ridge or rise which separates ocean basins or fjords from the open sea. An example is the sill which lies across the straits of Gibraltar separating the Mediterranean Sea from the Atlantic Ocean.

**Slack tide** - also referred to as slack water, this refers to that part of the tidal cycle which occurs following both flood and ebb tide when the tidal current is absent or very weak.

**Slack water** - see slack tide.

**Solute** - that component of a solution comprising the substance which is being placed into solution. E.g., in a solution of sodium chloride and water, the sodium chloride is the solute.

**Solvent** - that component of a solution comprising the substance into which the solute is being dissolved. E.g., in a solution of sodium chloride and water, the water is the solvent.

**Somatic** - refers to the body of an organism. Somatic cells are tissue cells as opposed to reproductive or germ cells.

TABLE 20 (continued)

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Specific heat - the amount of heat that must be added to a substance (in calories) to raise its temperature 1 degree C. The specific heat of pure water at 17.5 C is 1.0000 calorie per gram.

Specific volume - the volume per unit mass of a substance. In the case of water specific volume is the reciprocal of density or specific gravity.

Specific volume anomaly - in oceanography the specific volume anomaly is the excess of the actual specific volume of a sea water sample over the specific volume of sea water at 0 C and 35 parts per thousand at the same pressure. This concept is important mainly to physical oceanographers.

Spermatheca - a sac located in the female reproductive organs of certain invertebrate organisms and used for the storage of sperm which have been transferred from the male of the species. The sperm may be stored for periods of up to several months before being used to fertilize eggs.

Spring tide - the portion of the lunar tidal cycle which occurs during the period of new and full moon and results in tides which exhibit higher high tide levels and lower low tide levels than during any other portion of the normal lunar cycle. Occurs every two weeks regardless of the season of the year.

Standing crop - the biomass present per unit area or per unit volume in the water body of interest or portion of a large water body at the point in time during which a sample was taken.

Starboard - the right side of a ship as observed when facing the bow.

Station - an area or geographic location where a sample or series of samples are collected or where oceanographic or limnological observations are made.

Stenohaline - organisms which can exist only within a narrow range of salinity.

Stenothermal - organisms which can exist only within a narrow range of temperature.

Stenotopic - organisms which are restricted to a small geographic range.

TABLE 20 (continued)

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Steroid - a type of compound under the general group called lipids. Important in certain hormones.

Stratification - the physical state of a fluid in which two or more horizontal layers are arranged from the top in order of increasing density. Thermal stratification (wherein the density layers are dependent upon differences in temperature) is an important phenomenon in lakes and occurs in the ocean as well.

Sublittoral - the benthic zone extending from mean low water (the seaward extent of the littoral zone) to 200 meters or the actual edge of the continental shelf.

Supersaturation - a solution in which more of the solute is dissolved in the solvent than can ordinarily be held under equilibrium conditions.

Supralittoral - the benthic zone extending from the high tide mark (upper limit of the littoral zone) to a point at which there occurs a definite break in topography. This area would be wetted only during storms or when unusually high tides occurred.

Sverdrup - a unit of volume transport equivalent to the passage of one million cubic meters of water per second. This unit is most often used when depicting the volume transport of major ocean currents.

Symbiosis - a relationship between two species. Some authors restrict this term to commensalism, mutualism and inquilinism, while others also include parasitism. If parasitism is excluded, the definition must include the statement that neither species is harmed by the relationship.

Tablemount - see guyot.

Temperature-salinity diagram (T-S diagram) - a plot of temperature versus salinity for a given water column.

Test - the exoskeleton or shell of certain organisms including many protozoans.

Tetrapod - any four-legged vertebrate animal.

Thermocline - a vertical negative temperature gradient which may be found in the ocean and many lakes, seasonally, and leads to stratification of the water body. The thermocline is an area of rapidly decreasing temperature bounded above and below by areas of slowly decreasing temperature.

TABLE 20 (continued)

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Multiple thermoclines often occur when they are initially established in lakes after the winter overturn. These usually merge into one well defined thermocline with **time**.

Thermotaxis - an orientation or movement of an animal in response to thermal stimulus.

Thigmotaxis - an orientation or movement of an animal in response to touch stimulus.

Tidal bore - the rapidly flowing inflow of water, often to great depth, when the flooding tide is funneled into a narrow inlet, such as a steep-sided river channel. The force of the tidal pressure causes an upstream flow of water which may cause reversal in the whole net flow of the river.

Tidal wave - the wave motion of the tides. In popular usage tidal wave is often used erroneously when speaking of a tsunami.

Tide - the periodic rising and falling of the earth's oceans in response to forces generated by celestial bodies, especially the earth's moon and sun.

Tideland - land which is under water at high tide and exposed to the atmosphere at low tide (equal to the littoral zone).

Titer - the weight of a substance which is chemically equivalent to one milliliter of a solution.

Titration - the quantitative measure of the capacity of a substance to combine with a reagent.

Tow - a single net haul, usually made at some specified depth and for a specified period of time.

Transparency - the property of water which allows light to be transmitted through it. Various wavelengths travel various distances in water depending upon the nature of the water. Transparency is reduced, for instance, by suspended and dissolved materials.

Trench - a long, relatively narrow and deep depression in the floor of the ocean often associated with island arcs and areas of volcanic activity.

Tripton - the non-living suspended particulate matter or detritus present in water.

TABLE 20 (continued)

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- Trochophore - a type of free-swimming ciliated larva common in marine invertebrates of many phyla.
- Tropism - a movement or orientation of a plant in response to a stimulus.
- Trophic level - the position which an organism occupies in a food chain or food web. Some trophic levels are: primary producer, herbivore, and carnivore.
- Tsunami - a long-period sea wave generated by a submarine earthquake or volcanic eruption. While not noticeable at sea, a tsunami may build up to heights of over 15 meters when it approaches land, thus leading to devastation along coastal areas in its path. Tsunamis generally occur in groups, with the first wave to hit the beach not necessarily being the one of greatest height.
- Turbidity current - a usually short-lived highly turbulent current which carries loads of sediment down a submarine slope through the less dense sea water. Turbidity currents have been indicated as being responsible, at least in part, for the formation of submarine canyons.
- Tychoplankton - organisms which have become members of the plankton community on a temporary or accidental basis. They may be normally benthic forms which have been displaced into the plankton by unusual turbulence, etc.
- Tyndall effect - the phenomenon by which the path of a light beam through a colloidal suspension can be observed due to the light scattering caused by the colloidal particles.
- Ultraplankton - plankton in the size range less than five microns.
- Upwelling - the process by which water is brought to the surface from the depths of the sea due to the actions of certain types of coastal currents and divergence of water masses. Upwelling areas are often extremely productive since the upwelling water is often high in nutrients.
- Van't Hoff's law - states that the rate of a chemical reaction approximately doubles with a 10 C temperature increase.
- Vertical tow - the lifting of an open net from a stationary ship through the water column from a specified depth in the vertical direction. The sample should be quantitatively representative of the whole water column sampled.

TABLE 20 (continued)

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- Ventral - pertaining to or associated with the lower or abdominal surface of an organism.
- Virus - probably the most simple organism in existence; a virus is a non-cellular particle made up of nucleic acid surrounded by a protein shell.
- Viscera - any organ which lies within the body cavity of an organism.
- Vitamin - an organic substance vital for the functioning of an organism's biochemistry by contributing to the formation or action of enzymes.
- Viviparous - the type of reproduction in which the eggs develop within the body of the female and the developing embryo obtains nutrition from the mother.
- Water mass - a discrete body of water within an ocean which can be identified by its temperature and salinity characteristics.
- Wave height - the vertical distance between the crest of a wave and the preceding wave trough.
- Wavelength - the distance between corresponding points on two successive periodic waves. Often measured between crests or troughs.
- Wave period - the time in seconds required for a wave crest to travel the distance of one wavelength.
- Wet weight - a quantitative measure of whole organisms or parts of organisms based on the fresh weight of the tissue. Dry and ash weights are often used as less error is involved.
- Windward - the direction from which the wind is blowing.
- Xanthophyll - a plant pigment.
- XBT (expendable BT) - see Bathythermograph
- Zooplankton - the animal components of the plankton community.
- Zygote - the cell formed from the union of a male and a female gamete, or a fertilized egg.

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TABLE 22

## Classification of Organisms

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Major classification groups:      Kingdom  
  Phylum  
  Class  
  Order  
  Family  
  Genus  
  Species

Selected minor classification groups:  
  Subphylum  
  Subclass  
  Superorder  
  Suborder  
  Superfamily  
  Subfamily  
  Subspecies

---

Notes: All organisms can be classified according to the major classification groups listed above. Each organism is separated from all others by a system of binomial nomenclature developed by Linnaeus in the Sixteenth Century in which each organism has a generic and specific name unlike any other organism. Several plants or animals can be classified within a genus, but all the organisms within a species are identical. E.g., all dogs, wolves, and coyotes share the same genus, but each has its own species name.

Generic and specific names are always italicized (underlined when italics type are not available or in handwritten instances), with the generic name being capitalized and the specific name being uncapitalized. For example the generic and specific name for man appears as follows:

Homo sapiens

Kingdom, phylum, class, order and family names always appear in regular type, not italics.

Traditionally, the biota of the earth has been separated into two kingdoms, those of the plant and animal worlds. At the most primitive level of both plants and animals there exist organisms which cannot be conveniently placed in either kingdom, the Protozoa. Many of these simple organisms

TABLE 22 (continued)

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contain chlorophyll and would normally be placed in the plant kingdom, while others, lacking chlorophyll, are more likely to be thought of as animals. To confuse matters, certain organisms contain chlorophyll and function as autotrophic forms under some environmental conditions and lose their chlorophyll to function as heterotrophs under another set of circumstances. Largely because of the uncertainty which reigns, a third group, the Protista, has been established at the kingdom level and is recognized by many authors. Under most circumstances, confusion should be avoidable, and the following two tables present the classic picture of phylogeny in which all organisms belong to one of two kingdoms: the plants or the animals. Under this system, those organisms which may be plants under some circumstances and animals under others are not considered separately, but are included in both kingdoms. The bacteria are included in the plant kingdom, although there is reason to believe that they also should be placed in a separate kingdom. The phylogeny considered in Tables 23 and 24 considers classifications which have aquatic members and ignores those in which no aquatic forms are known, or in which all the members are parasitic.

While the bacteria and fungi groups are well represented in the marine environment, these have been excluded from consideration in the plant kingdom presented in Table 23. Most of the work on plants which has been done in the aquatic environment has been devoted to algae, especially phytoplankton. Because of this, our consideration of the plant kingdom will begin with the algae and include the vascular plants found in aquatic ecosystems.

TABLE 23

Classification within the plant kingdom

Division or Phylum	Subclassification	Common name
Cyanophyta	Class Cyanophyceae	Blue-green algae
Pyrrophyta	Class Dinophyceae	Dinoflagellates
	Class Cryptophyceae	Cryptomonads
	Class Desmokyontae	--
Chrysophyta	Class Chrysophyceae	Golden-brown algae
	Class Xanthophyceae	Yellow-green algae
	Class Bacillariophyceae	Diatoms
Phaeophyta	Class Phaeophyceae	Brown algae
Rhodophyta	Class Rhodophyceae	Red algae
Euglenophyta	Class Euglenophyceae	Euglenas
Chlorophyta	Class Chlorophyceae	Green algae
	Class Charophyceae	Stoneworts
Spermatophyta	Class Angiospermae	Macrophytic plants
	Family Lemnaceae	Duckweeds
	Family Najadaceae	Pondweeds
	Family Typhaceae	Cat-tails
	Family Alismaceae	Water-plantains
	Family Juncaceae	Rushes
	Family Xyridaceae	Yellow-eyed grasses
	Family Eriocaulaceae	Pipeworts
	Family Pontederiaceae	Pickereel-weeds
	Family Hydrocharitaceae	Frog's bit family
	Family Callitrichaceae	Water starworts
	Family Ceratophyllaceae	Hornworts
	Family Podostemaceae	River weeds
	Family Nymphaeaceae	Water lilies
	Family Elatinaceae	Waterworts
Family Haloragidaceae	Water-milfoils	

TABLE 23 (continued)

Division or Phylum	Subclassification	Example
Spermatophyta	Class Angiospermae	
	Family Lentibulariaceae	Bladderworts
	Family Gramineae	Grasses
	Family Haemodoraceae	Bloodworts
	Family Myricaceae	Bayberry family
	Family Limnanthaceae	False mermaids

Note: An attempt has been made to list those families of spermatophytes which have notable aquatic species, or are restricted to the aquatic environment. Grasses, for instance, are best known as land plants, but many aquatic species exist. Plants which predominately grow in bogs or wet places are not considered in this light to be truly aquatic and have been excluded for the most part. Undoubtedly, some families which should have been included have been overlooked.

TABLE 24

## Classification within the animal kingdom

Phylum	Subclassification	Example
Protozoa (Unicellular animals)	Class Mastigophora (=Flagellata)	Flagellates ( <u>Euglena</u> )
	Class Ciliata	Ciliates ( <u>Paramecium</u> )
	Class Sarcodina	Amoebas ( <u>Globigerina</u> )
Porifera (Sponges)	Class Calcarea	Calcareous sponges ( <u>Sycon</u> )
	Class Hexactinellida	Glass sponges ( <u>Euplectella</u> )
	Class Demospongia	Includes bath sponges ( <u>Cliona</u> )
Ctenophora (Comb jellies)	Class Tentaculata	<u>Pleurobrachia</u>
	Class Nuda	<u>Beroe</u>
Coelenterata (Polyps and medusae)	Class Hydrozoa	Medusae and polyp stages in life cycle. ( <u>Velella</u> <u>Obelia</u> , <u>Physalia</u> )
	Class Scyphozoa	Medusa as adult. Jellyfish. ( <u>Aurelia</u> , <u>Stomalophus</u> )
	Class Anthozoa	Corals, Sea anemones. ( <u>Leptogorgia</u> , <u>Metridium</u> )
Platyhelminthes (Flatworms)	Class Turbellaria	Free-living flatworms. ( <u>Planaria</u> , <u>Dugesia</u> ).
Nemertinea (Ribbon worms)	Class Anopla	<u>Cerebratulus</u>
	Class Enoplia	<u>Prostoma</u>

TABLE 24 (continued)

Phylum	Subclassification	Example
Aschelminthes (roundworms)	Class Rotifera	Rotifers ( <u>Rotaria</u> )
	Class Gastrotricha	Gastrotrichs ( <u>Chaetonotus</u> )
	Class Kinorhyncha (= Echinodera)	<u>Pycnophynes</u>
	Class Nematoda	Round worms ( <u>Loa</u> )
Annelida (segmented worms)	Class Polychaeta	<u>Nereis</u> , <u>Chaetopterus</u>
	Class Oligochaeta	<u>Chaetogaster</u>
	Class Hirudinea	Leeches ( <u>Hirudo</u> )
Mollusca (snails, clams, oysters)	Class Gastropoda	<u>Busycon</u> , <u>Urosalpinx</u>
	Class Amphineura	<u>Chaetopleura</u>
	Class Monoplacophora	<u>Neopilina</u>
	Class Pelecypoda	<u>Crassostrea</u> , <u>Mercenaria</u>
	Class Scaphopoda	<u>Dentalium</u>
	Class Cephalopoda	<u>Nautilus</u> , <u>Loliguncula</u> , <u>Octopus</u>
	Arthropoda (crustaceans, insects)	Class Merostomata Subclass Xiphosura
Class Pycnogonida		<u>Nymphon</u>
Class Insecta		<u>Hexagenia</u> , <u>Chaoborus</u>
Class Crustacea Subclass Cephalocardia		<u>Hutchinsoniella</u>
Subclass Branchiopoda		<u>Artemia</u> , <u>Daphnia</u>

TABLE 24 (continued)

Phylum	Subclassification	Example
Arthropoda (continued)	Class Crustacea	
	Subclass Ostracoda	<u>Cytherella</u>
	Subclass Copepoda	<u>Calanus</u> , <u>Psuedodiaptomus</u>
	Subclass Cirripedia	<u>Balanus</u> (barnacles)
	Subclass Malacostraca	
	Order Stomatopoda	<u>Squilla</u> (mantid shrimp)
	Order Mysidacea	<u>Neomysis</u> (mysid shrimp)
	Order Cumacea	<u>Diastylis</u>
	Order Isopoda	<u>Cirolina</u>
	Order Amphipoda	<u>Gammarus</u>
	Order Euphausiacea	<u>Euphausia</u>
	Order Decapoda	<u>Penaeus</u> , <u>Callinectes</u> <u>Homarus</u> (shrimp, crabs and lobsters)
Bryozoa (moss animalcules)		<u>Plumatella</u>
Brachiopoda (lamp shells)	Class Inarticulata	<u>Lingula</u>
	Class Articulata	
Echinodermata	Class Asteroidea	<u>Astropecten</u> (starfish)
	Class Ophiuroidea	<u>Ophioderma</u> (brittle stars)
	Class Echinoidea	<u>Arbacia</u> (sea urchins, heart urchins, sand dollars)

T ABLE 24 (continued)

Phylum	Subclassification	Example
Echinodermata (continued)	Class Holothuroidea	<u>Cucumaria</u> (sea cucumbers)
	Class Crinoidea	<u>Ptilocrinus</u> (sea lilies)
Chaetognatha (arrow worms)		<u>Sagitta</u>
Chordata	Subphylum Urochordata	<u>Mogula</u> (tunicates)
	Subphylum Cephalochoradata	<u>Amphioxus</u>
	Subphylum Vertebrata	
	Class Chondrichthys	<u>Dasyatis</u> , <u>Carcharhinus</u> (sharks, skates and rays)
	Class Osteichthys	
	Subclass Actinopterygii	<u>Lepisosteus</u> , <u>Bairdiella</u> (ray-fin fishes)
	Subclass Sarcopterygii	<u>Protopterus</u> , <u>Latimeria</u> (fleshy-fin fishes)
Class Mammalia	<u>Tursiops</u> (porpoises and whales)	

Notes: This table is not meant to be exhaustive. Some of the lesser known marine and freshwater forms have not been included, and the taxonomy is not complete in many cases. Aquatic reptiles, amphibians and birds have been left out of this table for purposes of simplicity.

The taxonomy may be at odds with some authors, but is a compilation of many sources and the author's personal knowledge.

MEASUREMENT OF TELEOSTS  
AND INVERTEBRATES

TABLE 25

## Measurement techniques applied to fishes

Measurement	Definition
Head length	Distance from most anterior point on the fishes' head to the posterior edge of the opercle.
Fork length	Distance from most anterior point on the fishes' head to the most anterior part of the fork in the tail (of fish which have forked tails).
Standard length	Distance from most anterior point on the fishes' head to the hypural plate at the base of the caudal fin.
Total length	Distance from most anterior point on the fishes' head to the tip of the longest caudal fin ray when the caudal fin rays are placed parallel to the body of the fish.
Secondary measurements	
Eye	Diameter of the eye from anterior-posterior direction.
Fin	The length of the base of the fin indicated from the most anterior to the most posterior fin ray. In fish with more than one dorsal fin, a key will specify which to measure. The first dorsal fin is the most anterior, the second the next most anterior, etc.
Head in length	Many keys will include such entries as, "head in length 4.0-4.2. In such a case as this, divide the standard length (total or fork length, if indicated) by the head length and see if the result fits the couplet.
Height or Depth	The greatest vertical distance (dorsal to ventral) through the body of a fish. Many keys will call for

TABLE 25 (continued)

Measurement	Definition
	decisions based on the ratio of the standard length to body depth (similar to head in length measurement).
Counting of various structures	
Soft ray count:	The number of soft (flexible) rays in the fin indicated; e.g., dorsal, anal, pectoral, pelvic or caudal
Spiny or hard ray count	The number of spiny (inflexible) rays in the fin indicated. Spiny rays appear commonly in the anterior dorsal fin and at the anterior portion of the anal fin.
Scales in lateral line	The total number of scales in the row over the lateral line. The count begins just posterior to the opercle and proceeds to the base of the caudal fin.
Scales above the lateral line	The number of scales in the imaginary row beginning at the base of the first dorsal fin ray and proceeding diagonally in a posterior-ventral direction to the lateral line.
Scales below the lateral line	The number of scales in the imaginary row beginning at the anterior base of the anal fin and proceeding anterior-dorsally to the lateral line.

TABLE 26

## Measurement techniques applied to invertebrates

The variety of form of invertebrate organisms makes standardization of measurement impossible. Animals exhibiting radial symmetry and those having amorphous shapes are particularly difficult to measure. In some cases it is more realistic merely to obtain a biomass measurement and not be too concerned about specific dimensions. With very small organisms, measurement with an optical or stage micrometer through a microscope is necessary.

Some typical measurements are provided below, but should not be considered as the exclusive way to handle a particular organism. So long as the actual method of measurement is included, data may be converted from one technique to another if two investigators measure the same species in a different way.

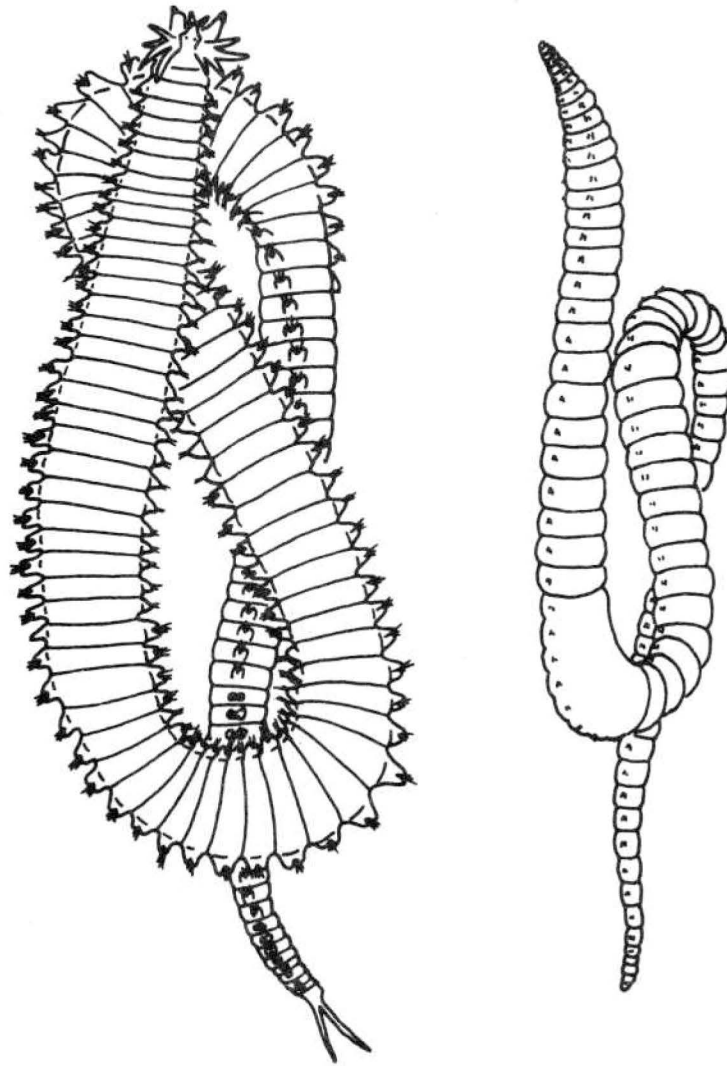
Measurement	Definition and examples
Carapace width	<p>The distance between the widest aspect of an organism possessing a carapace. This measurement is often applied to crabs and other crustaceans.</p> <p>In some species of crabs (e.g., <i>Callinectes</i>) the carapace is measured between the tips of the lateral spines of the carapace.</p>
Carapace length	<p>The distance from the anterior to the posterior aspects of the carapace. This measurement is also often applied to crustaceans.</p> <p>In some crustaceans, such as shrimp, a rostral spine might be found projecting from the anterior of the carapace. The measurement may then be made from the tip of the rostral spine to the base of the carapace.</p>
Height	<p>Invertebrates of indefinite shape which live attached to the substrate may best be measured by determining the total height of the individual organism (e.g., sponge) or community (e.g., whip coral).</p>
Mantle length	<p>In Cephalopods, especially, a convenient measurement</p>

TABLE 26 (continued)

Measurement	Definition and examples
Total length	<p>may be made by determining the distance between the mouth and the posterior end of the body. Since the tentacles are often of varying length, this tends to standardize the measurement.</p> <p>Total length is the measurement between the most anterior and most posterior aspects of an animals body or exoskeleton and is often used when examining mollusks, crustaceans, annelids and many others.</p>
Volume displacement	<p>In cases where an animal does not present a good aspect for measurement, the amount of liquid (water, usually distilled) it displaces is often measured. This is easily accomplished by placing the organism into a sufficient volume of solution in a graduated container and determining the change in volume. This technique can be applied to sponges, coelenterates (e.g., jellyfish), bryozoans (= ectoprocts) and others.</p>

DRAWINGS OF  
REPRESENTATIVE ORGANISMS

ANNELIDS



Polychaete

Oligochaete

Figure 2. Representative polychaete and oligochaete Annelids.

SMALL CRUSTACEA

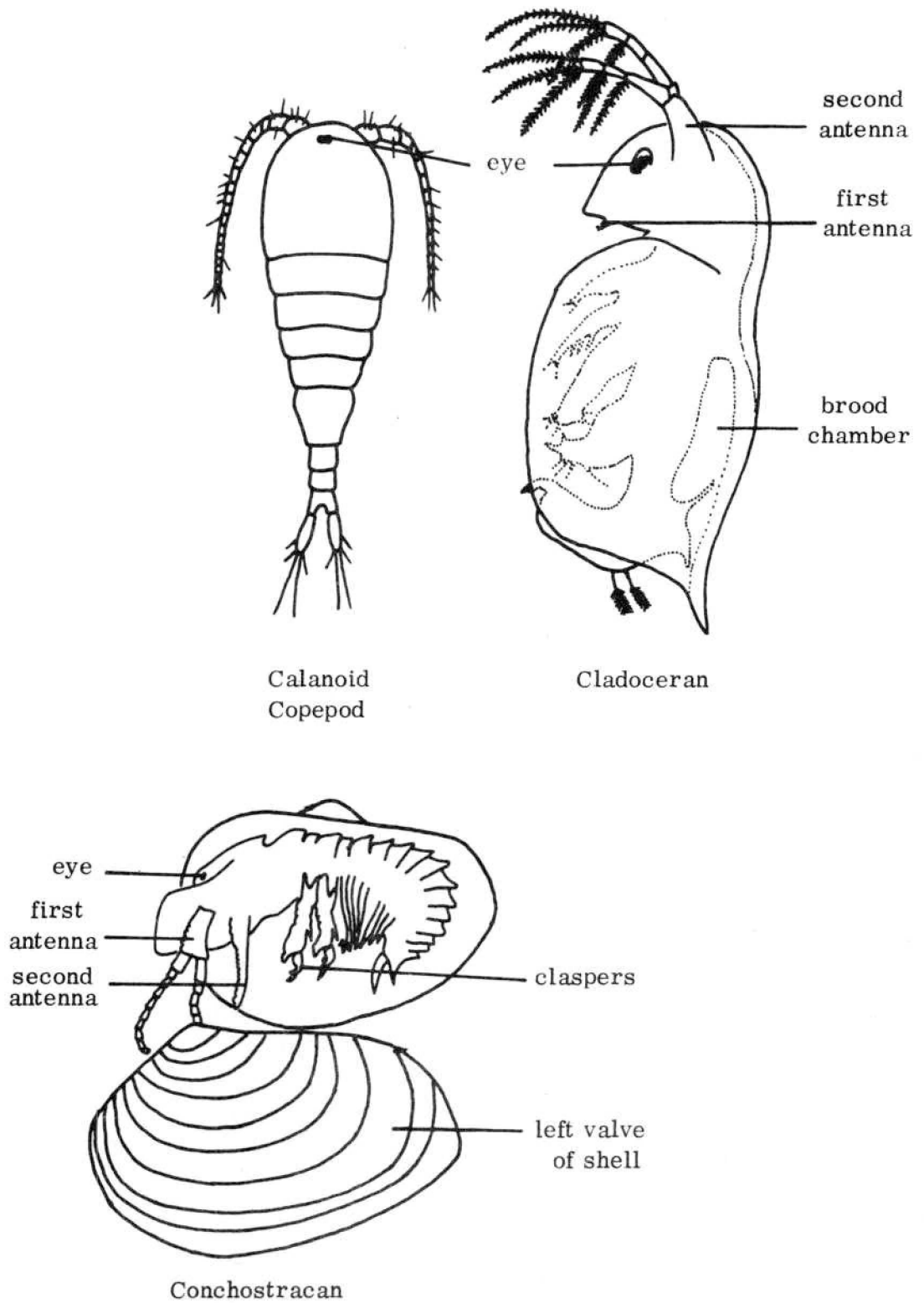


Figure 3. Representatives of small crustacea. (Cladoceran and Conchostracan redrawn from Barnes, R.D. 1963. Invertebrate Zoology. W.B. Saunders Co., Philadelphia. 632 p.

AMPHIPOD

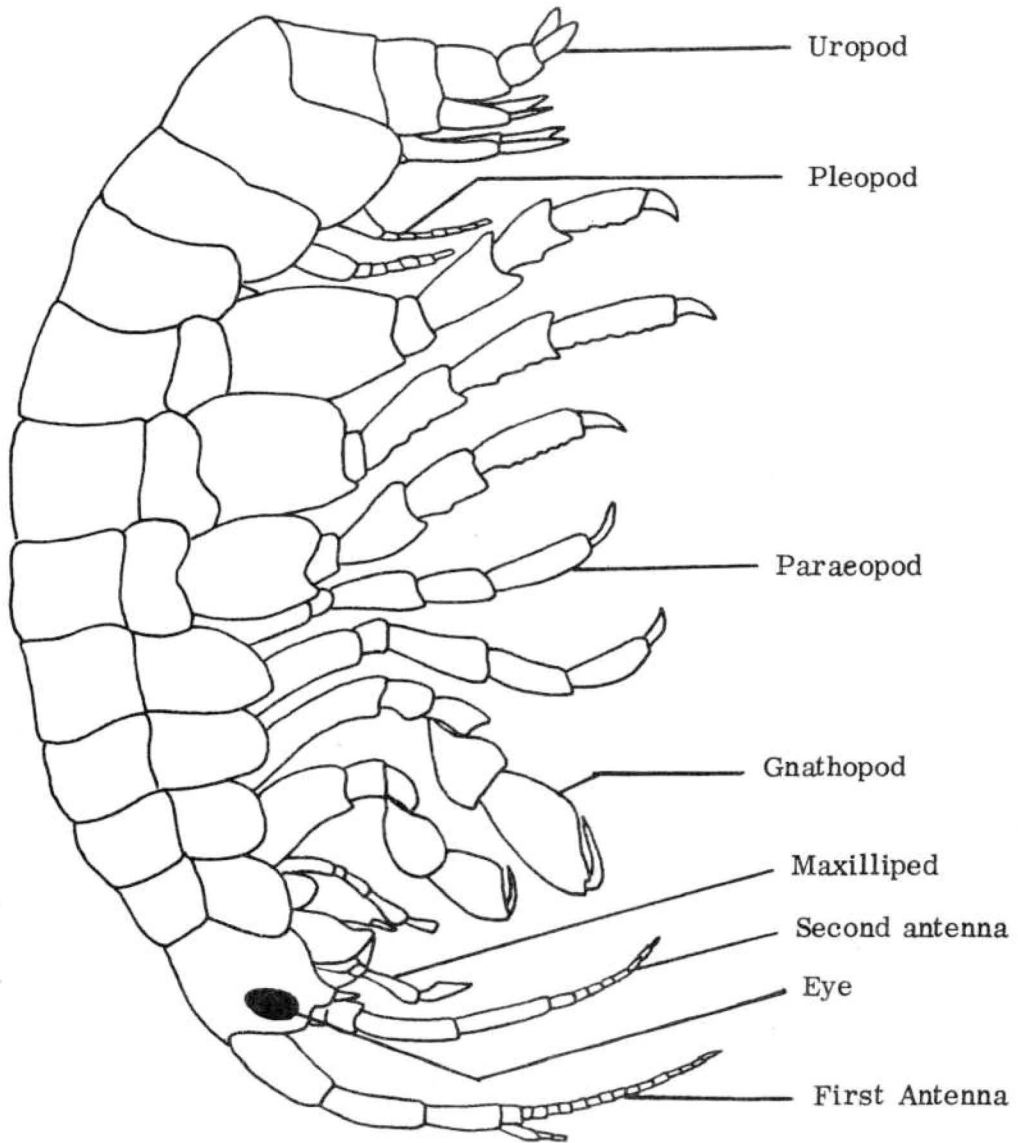


Figure 4. Generalized gammarid-type Amphipod (Crustacea).

ISOPOD

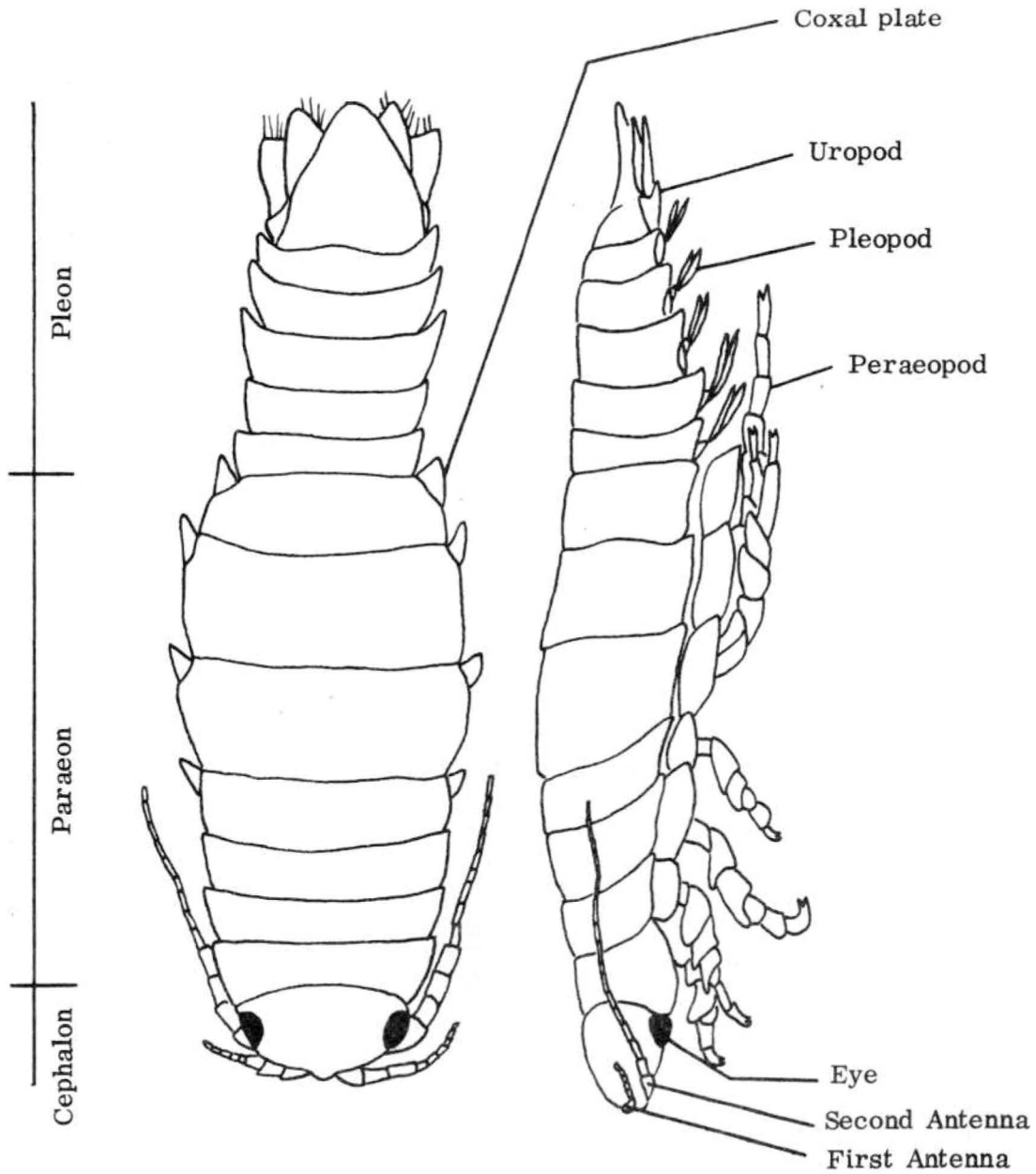


Figure 5. General morphology of a Cirolanid-type Isopod (CRUSTACEA). Redrawn from Menzies, R.J., and D. Frankenberg. 1966. Handbook on the Common Marine Isopod Crustacea of Georgia. University of Georgia Press, Athens, Ga. 93 p.

CRUSTACEA

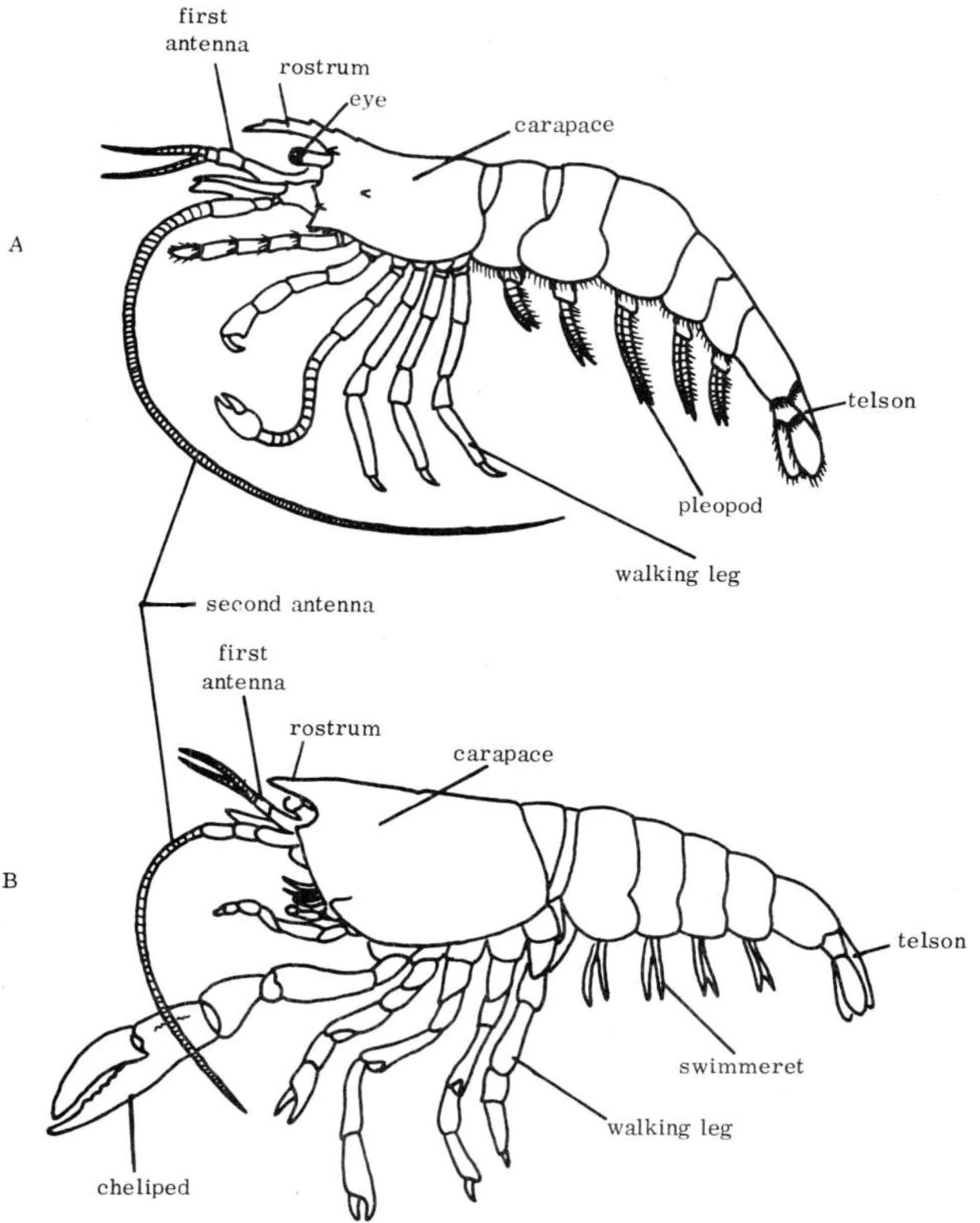
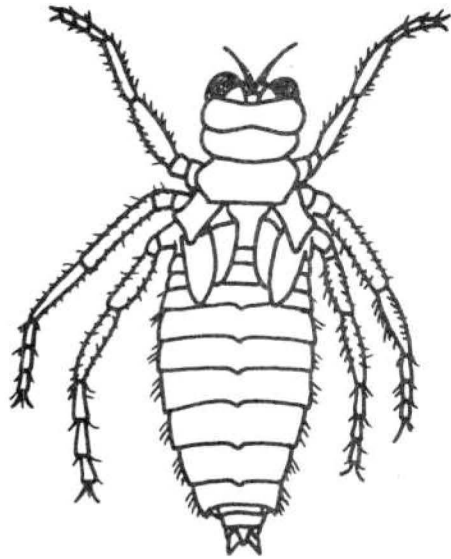


Figure 6. Generalized morphology of a shrimp-like decapod crustacean (A) and a generalized crayfish of the subclass malacostraca (B).

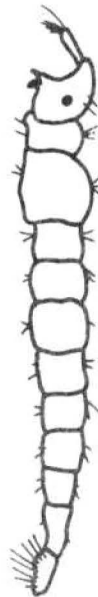
AQUATIC INSECTS



Order Odonata  
(Genus Libellura)



Order Ephemeroptera  
(Genus Hexagenia)



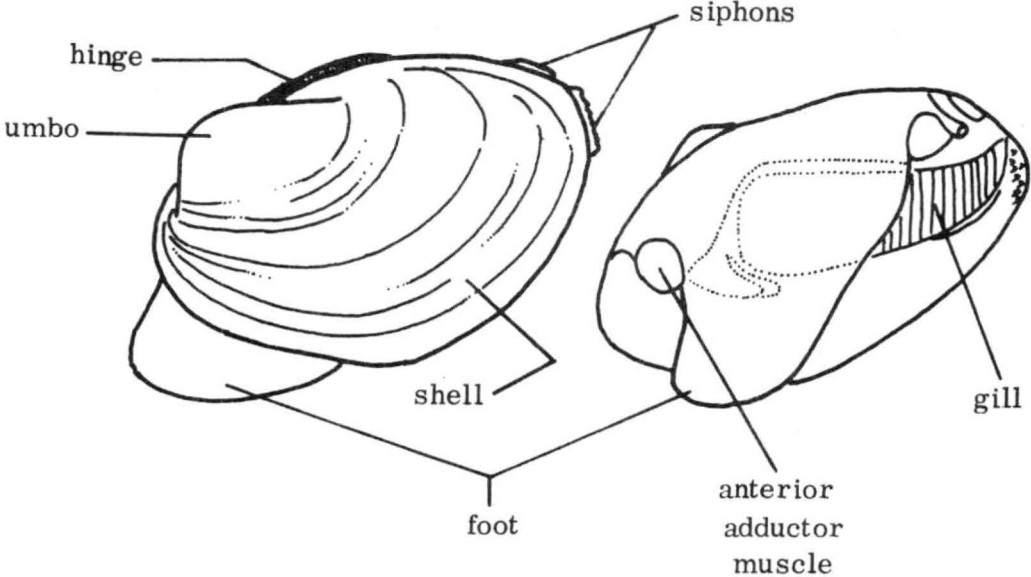
Order Diptera  
(Genus Chaoborus)



Order Diptera  
(Genus Tendipes)

Figure 7. Representative aquatic insects (redrawn from Eddy, S. and A.C. Hodson. 1961. Taxonomic Keys to the Common Animals of the North Central States. Burgess Publishing Co., Minneapolis, Minn. 162 p.)

PELYCEPOD



GASTROPOD

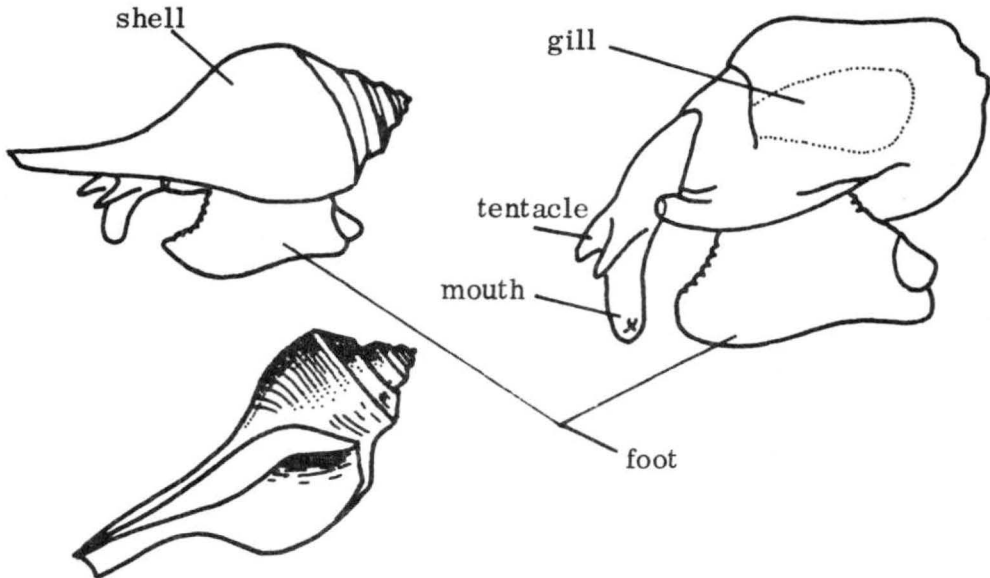
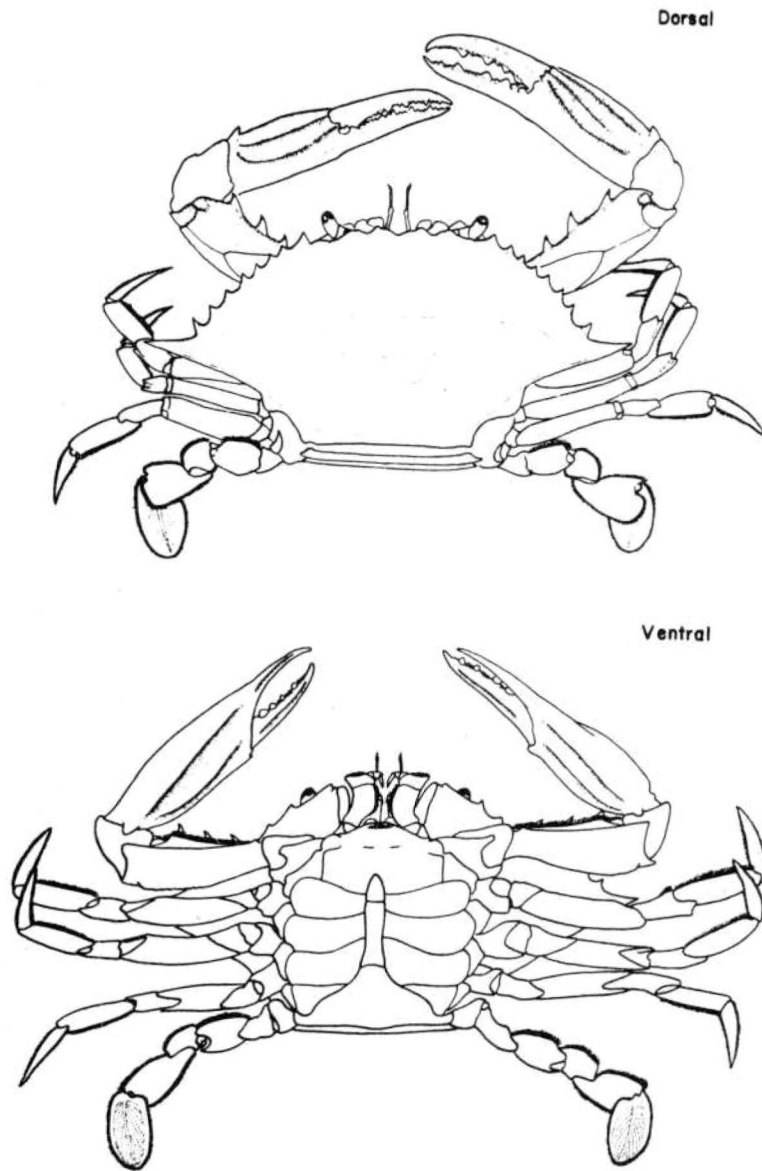


Figure 8. Representative Pelecypod and Gastropod



Figure 9. Green sea turtle, Chelonia mydas.

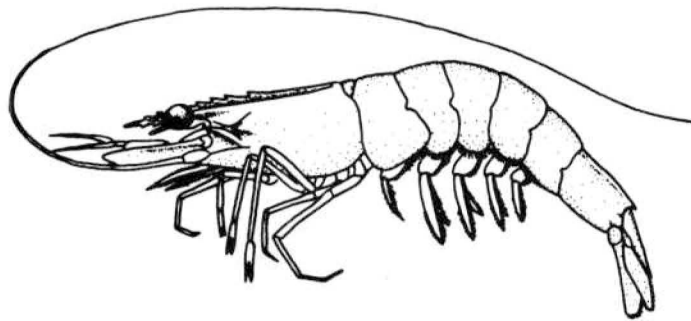


Phylum ARTHROPODA

family PORTUNIDAE

Callinectes sapidus

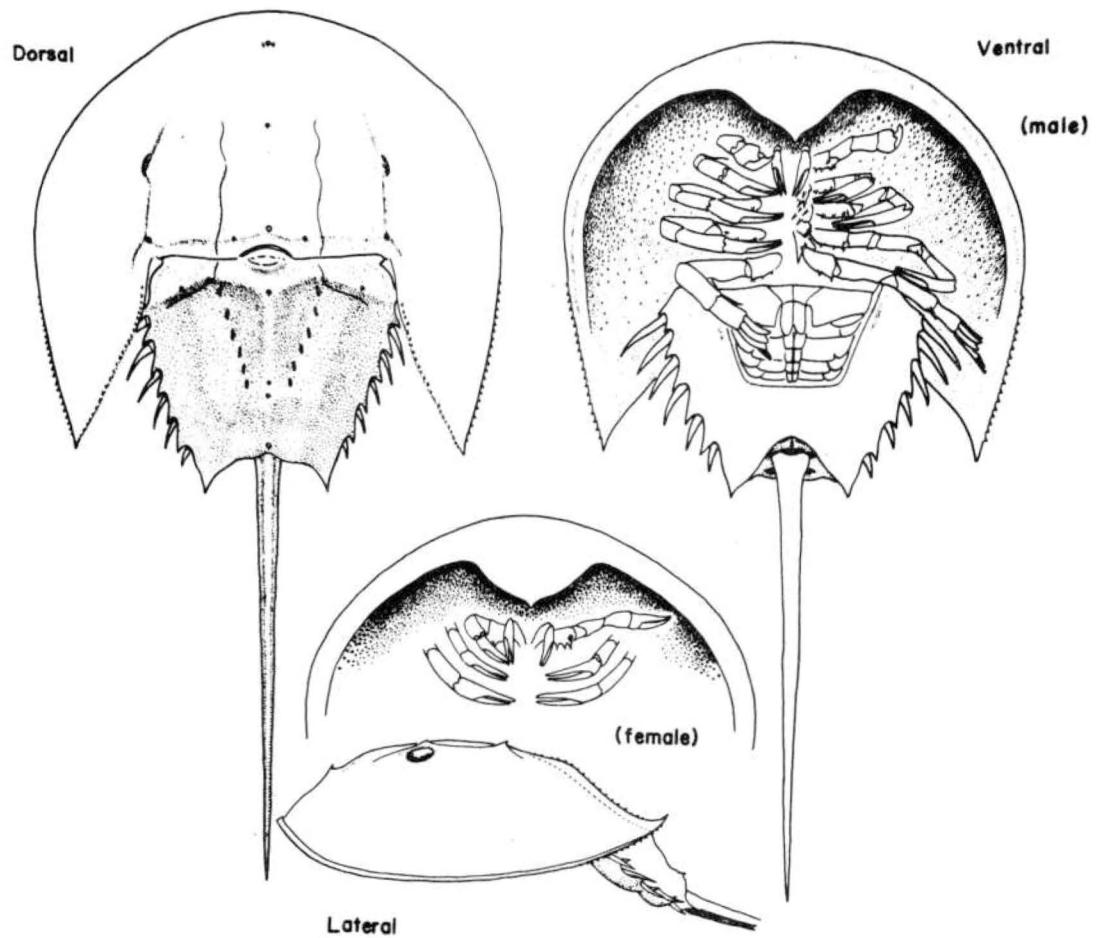
Figure 10. Male blue crab morphology.



Phylum **ARTHROPODA**      Family **PENAEIDAE**

**Peneus setiferus**

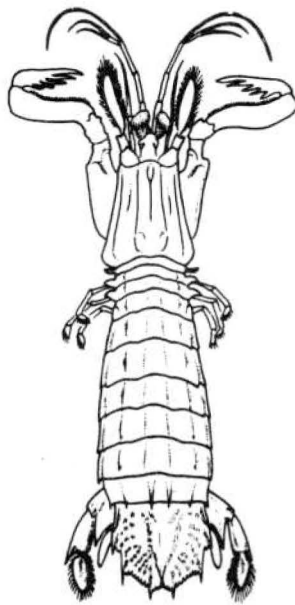
Figure 11. White shrimp morphology.



Phylum ARTHROPODA      Subclass XIPHOSURA

Limulus polyphemus

Figure 12. Horseshoe crab morphology.



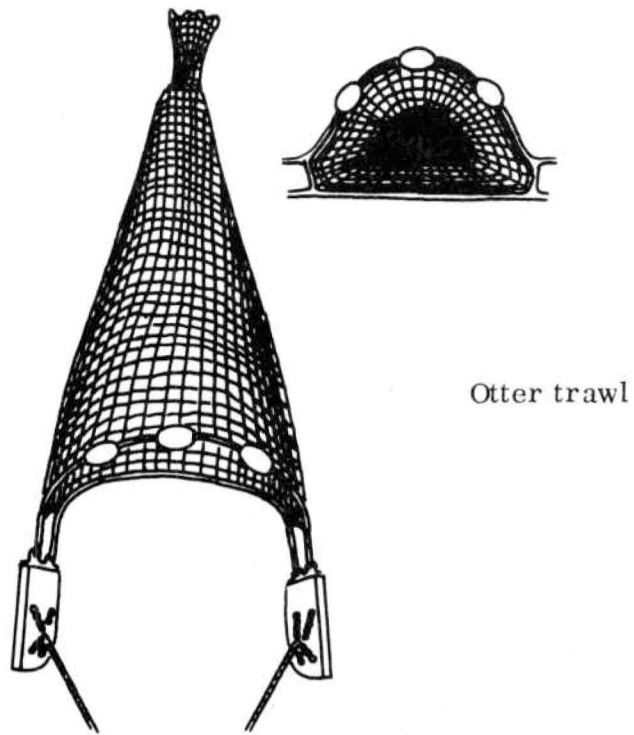
Phylum ARTHROPODA

Order STOMATOPODA

Squilla empusa

Figure 13. Mantid shrimp morphology.

FISH SAMPLING DEVICES



Otter trawl

Purse seine

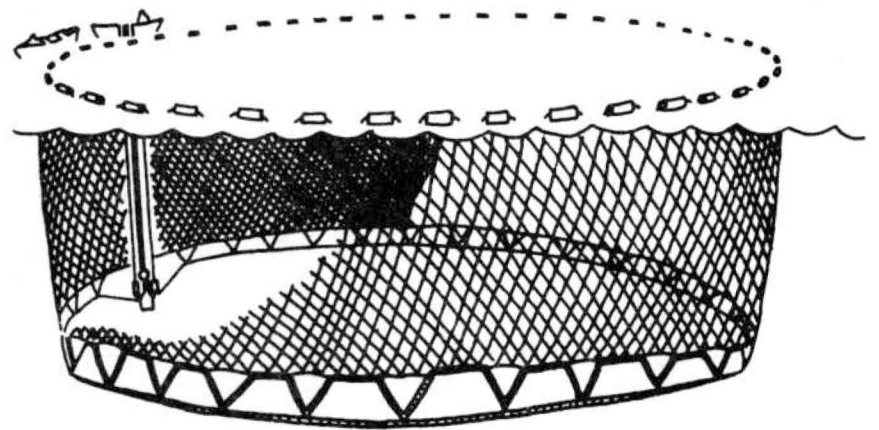


Figure 14. Otter trawl and purse seine.

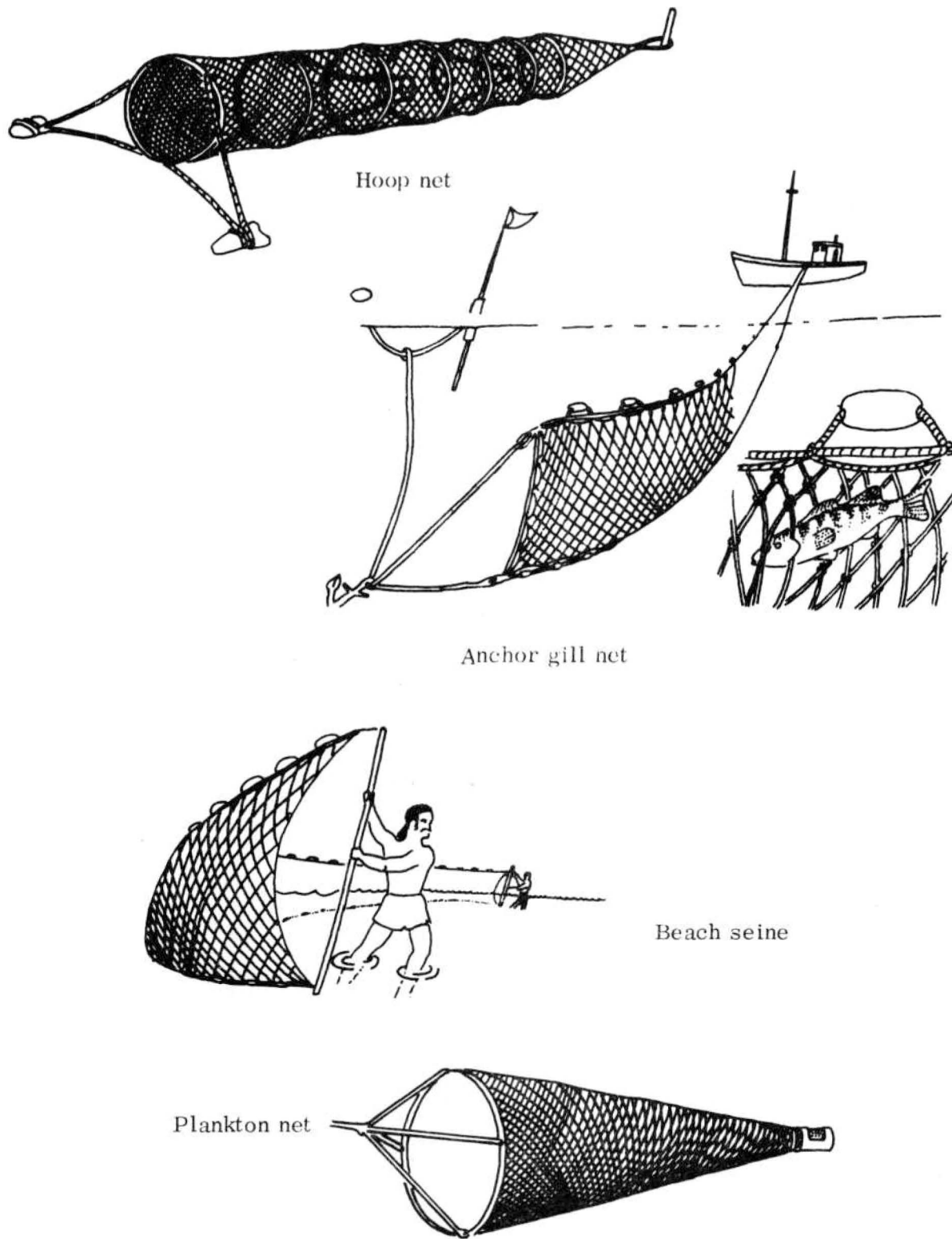


Figure 15. Hoop net, gill net, beach seine and plankton net. (Plankton net mesh much enlarged.)

**BENTHOS SAMPLERS**

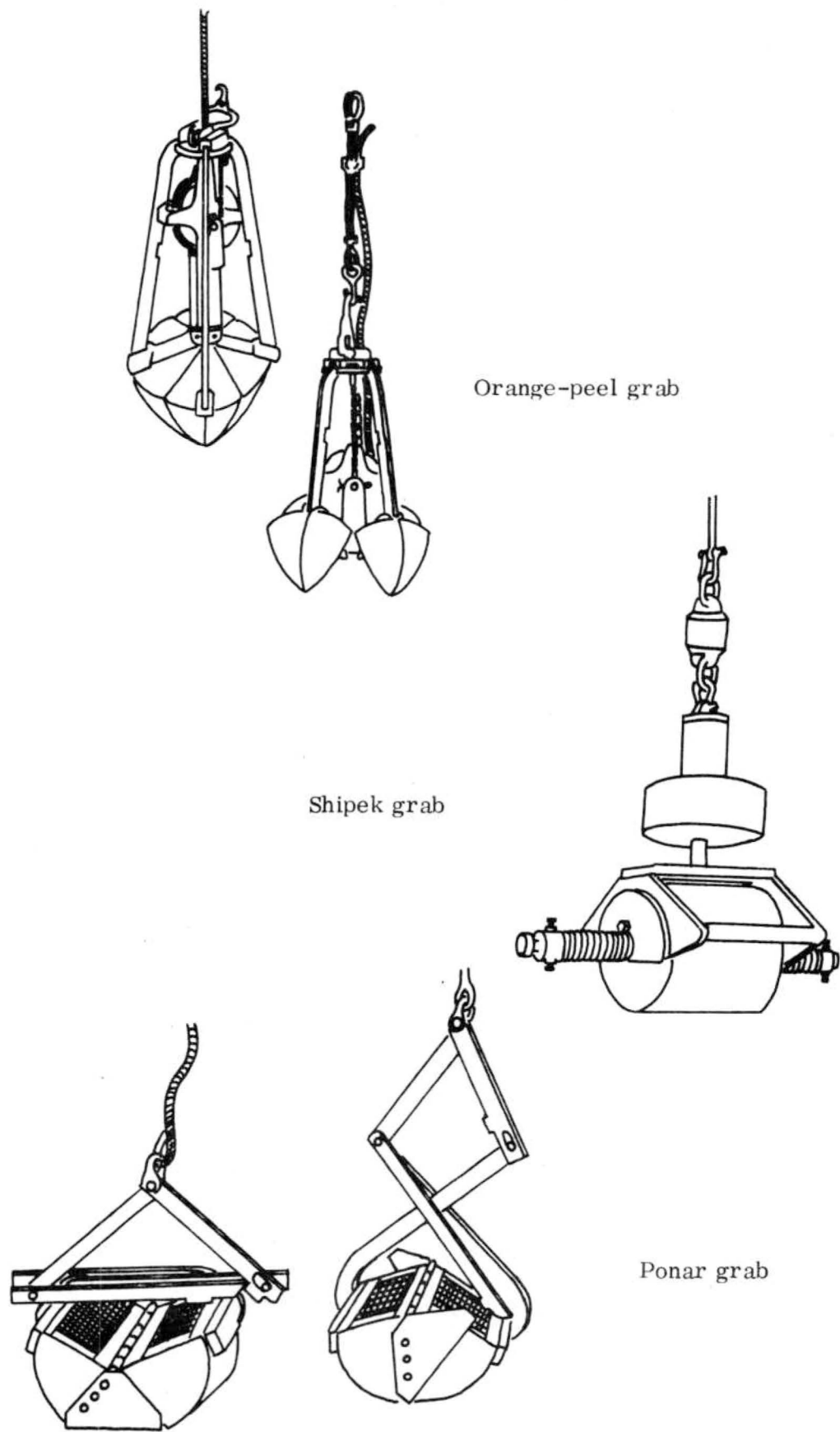
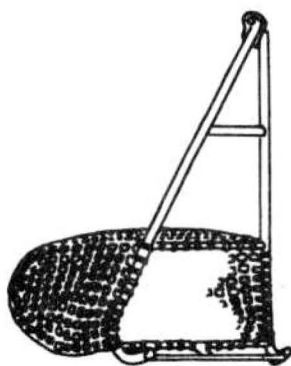
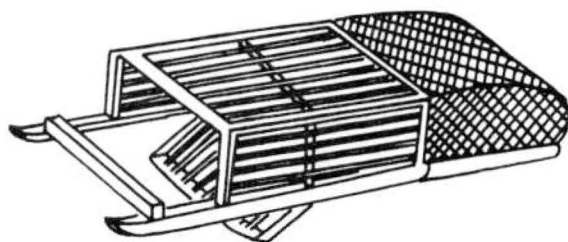


Figure 16. Examples of commonly used benthic grab samplers.

DREDGES



"A" frame dredge



Clam dredge



Shell dredge



Tumbler dredge

Figure 17. Assorted dredges for benthos sampling. The "A" frame and shell dredges are small, while the clam and tumbler dredges must be towed by a suitable boat.

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