

# CHAPTER 14: PLANKTON

*Olga K. Baranova, John I. Antonov, Tim P. Boyer, Daphne R. Johnson, Hernán E. García, Ricardo A. Locarnini, Alexey V. Mishonov, Michelle T. Pitcher, Igor V. Smolyar*

*Ocean Climate Laboratory  
National Oceanographic Data Center / NOAA  
Silver Spring, Maryland, USA*

## 14.1. INTRODUCTION

“The term ‘plankton’ comes from the Greek ‘*planktos*’ (drifter)”, (Lalli *et al.*, 1997). Plankton refers to floating or drifting organisms with limited locomotion powers, (Kennish, 1990). While some forms of plankton passively drift by tides and currents, others are capable of independent swimming. The major plankton subdivisions include bacteria, phytoplankton, and zooplankton, (Kennish, 1990). Planktonic organisms range in size from less than 2 microns to more than 2,000 microns, (Levinton, 1995).

The plankton subset of the *World Ocean Database 2005* (WOD05) includes and extends the previously released *World Ocean Database 1998*, (Conkright *et al.*, 1998) and *World Ocean Database 2001*, (O'Brien *et al.*, 2001). The WOD05 plankton data subset is a collection of measurements from serial bottle and plankton net-tow. The plankton measurements are represented in WOD05 as quantitative and qualitative abundance, and biomass data. The plankton measurements are stored in the OSD dataset.

Scientific taxonomic names in the WOD05 are stored as ITIS (Integrated Taxonomic Information System, <http://www.itis.usda.gov>) serial numbers. ITIS codes are not available for all plankton descriptions and biomass. WOD05 negative taxonomic codes (sequentially assigned numbers) were developed to preserve the original descriptions.

In addition to ITIS or negative taxonomic codes, each plankton description has a *Biological Grouping Code* (BGC) developed by O'Brien *et al.* (2001). The BGC is an

BGC Example: *Calanus finmarchicus*



ancillary code which places each taxon into broader groupings (e.g., diatoms, copepods, phytoplankton). The WOD05 user can access hundreds of individual taxons by using a single BGC code. The BGC groups are divided into *Primary* (e.g., Bacteria, Phytoplankton, Zooplankton), *Secondary* (e.g., cyanobacteria, diatoms, crustaceans), and *Tertiary Groups* (e.g., copepods). For example, the copepod *Calanus finmarchicus* has a BGC code of “4282000”, specifying that it is in *Primary Group* “4” (zooplankton), *Secondary Group* “28” (crustaceans), and

*Tertiary Group* "2000" (Copepods).

Broad, taxonomic group-based value range checks were used in WOD01 (O'Brien *et al.*, 2001) to flag extremely large or small values.

**Table 14.1 WOD05 broad taxonomic group-based ranges.**

Group	Min Value	Max Value	Units
Bacteria	0.001	5,000	# / $\mu\text{l}$
Phytoplankton	0.001	50,000	# / ml
Zooplankton	0.001	200,000	# / $\text{m}^3$

**Table 14.2 WOD05 biomass ranges.**

Group	Min Value	Max Value	Units
Total Displacement Volume	0.005	10	ml / $\text{m}^3$
Total Settled Volume	0.025	50	ml / $\text{m}^3$
Total Wet Weight	0.5	10,000	mg / $\text{m}^3$
Total Dry Weight	0.01	500	mg / $\text{m}^3$
Total Ashfree Dry Weight	0.001	100	mg / $\text{m}^3$

Plankton counts and biomass measurements are stored with the data originator's units in WOD05 (*e.g.* counts in units of "number per  $\text{m}^3$ ", "count per  $\text{m}^2$ ", "count per haul", "count per ml"). To make comparison of different units easier, each count or biomass measurement has been recalculated into a common unit named *Common Biological Value* (CBV). The CBV value has a quality control flag associated with it.

WOD05 flags applied to Common Biological Values as follows:

- 0 - accepted value
- 1 - range outlier (outside of broad range check)
- 2 - questionable value
- 3 - group was not reviewed
- 4 - failed annual standard deviation check

The calculation method used to create the CBV is stored in the *CBV calculation method* field and described in detail in WOD05 documentation, Appendix 6.9, (Johnson *et al.*, 2006).

The typical plankton cast (for cast definition see Chapter 1), as represented in WOD05, stores taxon specific and/or biomass data in individual sets, called "Taxa-Record". Each "Taxa-Record" contains a taxonomic description, depth range (the upper

and lower depth) of observation, the original measurements (*e.g.*, abundance, biomass or volume), and all provided qualifiers (*e.g.*, lifestage, sex, size, etc.) required to represent that plankton observation.

In addition to the observed data, a cast may include additional originator's metadata information such as the "institution" which collected and identified the species of plankton, the "voucher institution" (institution which stores samples), sampling gear (*e.g.*, Bongo Net, Continuous Plankton Recorder), net mesh size, sampling method (*e.g.*, vertical, horizontal, or oblique haul), meteorology, and other general header information which are described in detail in WOD05 documentation, (Johnson *et al.*, 2006).

Longitude	Latitude	Year	Month	Day	Time	Cruise#	CC	Prof_#
-4.883	79.017	1991	6	9	----	10438	06	2087562
<b>Mesh_size</b> 200.000 <b>Type_tow</b> 2.000 <b>Lge_removed</b> 1.000								
<b>Gear_code</b>	118.000	<b>net_mouth_area</b>		0.300	<b>Lge_removed_len</b>	1.000		
<b>Tow_speed_avg</b>	1.944							
<b>Taxa-Record #1</b>								
<b>Param_number</b>	85263.000		<b>upper_depth</b>	0	<b>lower_depth</b>		100.000	
<b>Taxon_lifestage</b>	25.000		<b>Taxon_count</b>	18.600	<b>Taxon_modifier</b>		2.000	
<b>Units</b>	70.000		<b>CBV_value</b>	18.600	<b>CBV_calc_meth</b>		70.000	
<b>CBV_flag</b>	3.000		<b>BGC_group_code</b>		4282000.000			
<b>Taxa-Record #2</b>								
<b>Param_number</b>	-404.000000		<b>upper_depth</b>	0	<b>lower_depth</b>		100.000	
<b>int_value</b>	3100.000		<b>Units</b>	69.000	<b>CBV_value</b>	31.000		
<b>CBV_calc_meth</b>	69.100		<b>CBV_flag</b>	3.000	<b>BGC_group_code</b>		-404.000000	
<b>Taxa-Record #3</b>								
<b>Param_number</b>	85263.000		<b>upper_depth</b>	0	<b>lower_depth</b>		100.000	
<b>Taxon_lifestage</b>	26.000		<b>Taxon_count</b>	0.100	<b>Taxon_modifier</b>		2.000	
<b>Units</b>	70.000		<b>CBV_value</b>	0.100	<b>CBV_calc_meth</b>		70.000	
<b>CBV_flag</b>	3.000		<b>BGC_group_code</b>		4282000.000	etc .....		
<b>Access#</b>	772							
<b>Project</b>	435							
<b>Platform</b>	199							
<b>Institution</b>	892							
<b>Station_Number</b>	9617720							
<b>Orig_Stat_Num</b>	7							
<b>Bottom_Depth</b>	1413.000							
<b>T-S_Probe</b>	7.000							
<b>NODCorig</b>	3.000							

**Figure 14.1 An example of a plankton cast in WOD05 (using provided output software).**

The alternative way to look at plankton cast is a “csv” (comma-separated value) Excel output file, which is available only through the WODselect – online WOD05 database retrieval system (<http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html>).

```
STATION,,9617720,WOD Unique Station Number,WOD code,,,,,,,,,,  
NODC Cruise ID,,06-10438 ,,,,,,,,,,,  
Originators Station ID,,7,,,integer, ,,,  
Originators Cruise ID, ,,,  
Latitude,,79.0167,decimal degrees, ,,,  
Longitude,, -4.8833,decimal degrees, ,,,  
Year,,1991, ,,,  
Month,,6, ,,,  
Day,,9, ,,,  
METADATA, ,,,  
Country,,6,NODC code,GERMANY, FEDERAL REPUBLIC OF, ,,,  
Accession Number,,772,NODC code, ,,,  
Project,,435,NODC code,IAPP (International Arctic Polynya Programme), ,,,  
Platform,,199,OCL code,POLARSTERN, ,,,  
Institute,,892,NODC code,ALFRED-WEGENER-INSTITUTE (BREMERHAVEN), ,,,  
Bottom depth,,1413,meters, ,,,  
Database origin,,3,WOD code,GODAR Project, ,,,  
BIOLOGY METADATA, ,,,  
Mesh size,,200,microns, ,,,  
Type of tow,,2,WOD code,VERTICAL TOW, ,,,  
Large plankters removed, ,1,WOD code, yes, ,,,  
Gear,,118,WOD code,Bongo Net, ,,,  
Net mouth area,,0.3,m2, ,,,  
Min length removed,,1,cm, ,,,  
Average tow speed,,2,knots, ,,,  
BIOLOGY,Upper Z,Lower Z,Measuremnt Type,ORIGINAL VALUE ,F,Orig unit,WOD CBV value  
,F,_unit,_meth,WOD BGC,ITIS TSN,mod,lif,  
1.0. meters,100. meters,Taxon_count,18.6,0,#/m3,18.6,3,  
#/m3,70,4282010,CALANUS,MODIFIER=spp. (multiple species),LIFE STAGE=C1: COPEPODITE I  
2.0. meters,100. meters,Total Dry Mass,3100,0,mg/m2,31,3,mg/m3,69.1,-404,Zooplankton Dry Weight  
(mg/unit), ,,,  
3.0. meters,100. meters,Taxon_count,0.1,0,#/m3,0.1,3, #/m3,70,4282010,CALANUS,MODIFIER=spp.  
(multiple species),LIFE STAGE=C2: COPEPODITE II  
.....  
END OF BIOLOGY SECTION
```

**Figure 14.2 An example of a plankton cast in ‘csv’ output file available on-line through the WODselect**

## **14.2. DATA SOURCES**

The plankton data that comprised WOD05 have been contributed by 32 countries, 125 institutions and involved more than 40 projects. Significant amounts of data (49,867 casts) have no information about the submitting organization. Substantial amounts of historical biomass and abundance data are from the archives of the National Oceanographic Data Center (NODC) and the World Data Center for oceanography, Silver Spring.

The largest portion (34,897 casts; 47.56 %) of the zooplankton and biomass data have been acquired through the California Cooperative Oceanic Fisheries Investigations (CALCOFI) project. The CALCOFI project was initiated in 1949 to study the collapse of the U.S. west coast sardine fishery. Hydrographic casts have been occupied from 1950 to the present along cross-shelf transects. Additional information can be found on CALCOFI's Web Page, <http://www.calcofi.org>.

The Outer Continental Shelf Environmental Assessment Program (OCSEAP) contributed another large portion of the plankton data (7,920 casts; 10.79 %). The OCSEAP was established in 1984 by basic agreement between the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of the Interior (USDOI), Minerals Management Service (MMS) for environmental studies of Alaskan Outer Continental Shelf waters considered for oil development. The OCSEAP office located in Fairbanks issues a monthly Arctic Project Bulletin, Truett, J. C. (ed.), 1985.

A significant amount of data was received through the Eastern Tropical Pacific Ocean (EASTROPAC ) program (5,544 casts; 7.56 %). The first EASTROPAC survey (February 1967 through March 1968) was a cooperative effort towards the understanding of the oceanography of the eastern Tropical Pacific Ocean. The main goals were to provide data necessary for a more efficient use of the marine resources of the area, especially tropical tunas, and also to increase knowledge of the ocean circulation, air-sea interaction, and ecology of the region. The U.S. Bureau of Commercial Fisheries (presently National Marine Fisheries Service) NMFS was the coordinating agency. Participating scientists were primarily from the NMFS, Scripps Institution of Oceanography, and the Inter-American Tropical Tuna Commission, (<http://swfsc.nmfs.noaa.gov/PRD/atlas/eastropacsplash.html>).

The Kuroshio Exploitation and Utilization Research (KER) program provided (4,234 casts; 5.77 %). KER was designed to study the subtropical circulation system, marine ecology, and fishery around Japan. The program was conducted in 1977 – 1995.

Table 14.3 gives project contributions of plankton casts sorted by percent contribution from each project.

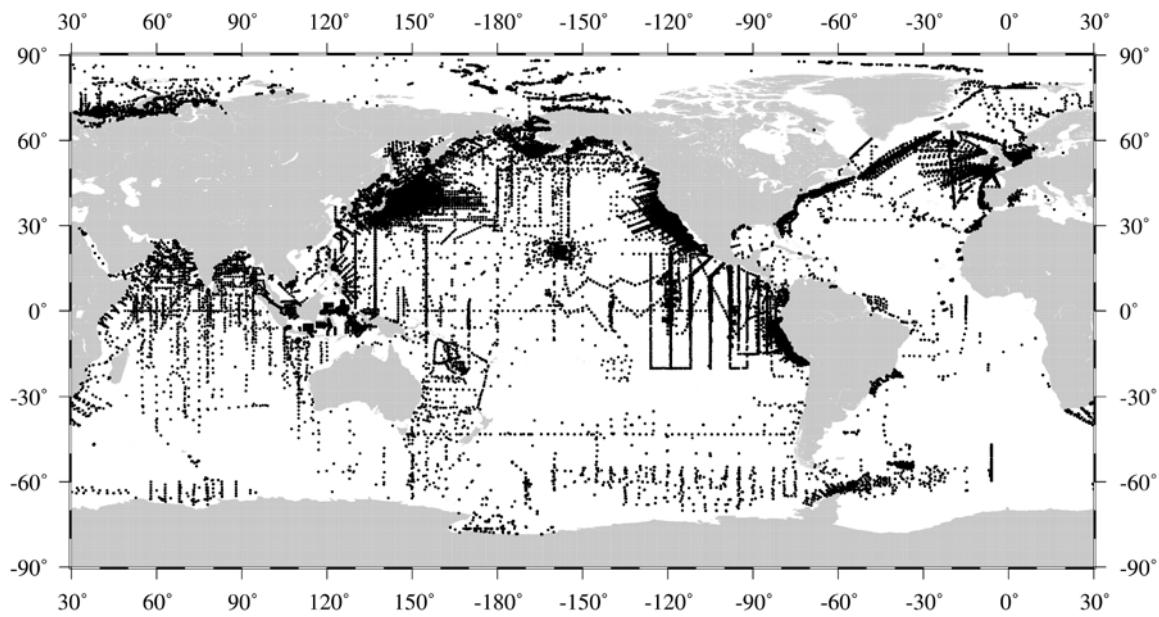
**Table 14.3 Project contributions of plankton casts sorted by percent contribution from each project.**

NODC Project Code	Project Name	# Casts	% of Total
33	CALCOFI (California Cooperative Oceanice Fisheries Investigation)	34,897	47.58
81	OCSEAP Outer continental shelf of environmental assessment program	7,920	10.80
3	EASTROPAC (1967-1968)	5,544	7.56
243	KER Kuroshio exploitation and utilization research (1977 - 1995)	4,234	5.77
93	BRINE DISPOSAL	4,193	5.72
51	MARMAP Marine Resource Monitoring Assessment Prediction Program	2,208	3.01
25	IIOE International Indian Ocean Expedition	2,045	2.79
240	USAP or USARP United States Antarctic Research Project	1,770	2.41
372	OMEX Ocean margin exchange project	1,234	1.68
367	GLOBEC Georges Bank Program	951	1.30
361	JGOFS/AESOPS US JGOFS Antarctic Environments Southern Ocean Process Study	943	1.29
345	North Sea Project	827	1.13
241	BIOMASS Biological Investigations of Marine Antarctic Systems and Stocks	712	0.97
322	SKIPJACK	684	0.93
365	JGOFS/ARABIAN Sea Process Studies	657	0.90
31	CSK Cooperative Study of the Kuroshio	599	0.82
83	OCS-SOUTH Texas	533	0.73
275	JGOFS - BATS Bermuda Atlantic Time Series	495	0.67
82	PSERP Mesa Puget Sound	396	0.54
200	JGOFS Joint Global Ocean Flux Study	363	0.49
273	EASTROPIC Eastern Tropical Pacific 1955	323	0.44
410	TASC Trans Atlantic Study of Calanus	300	0.41
310	JGOFS/EQPAC Equatorial Pacific basin study	279	0.38
96	EPA Buccaneer oil field	214	0.29
321	BOFS	180	0.25

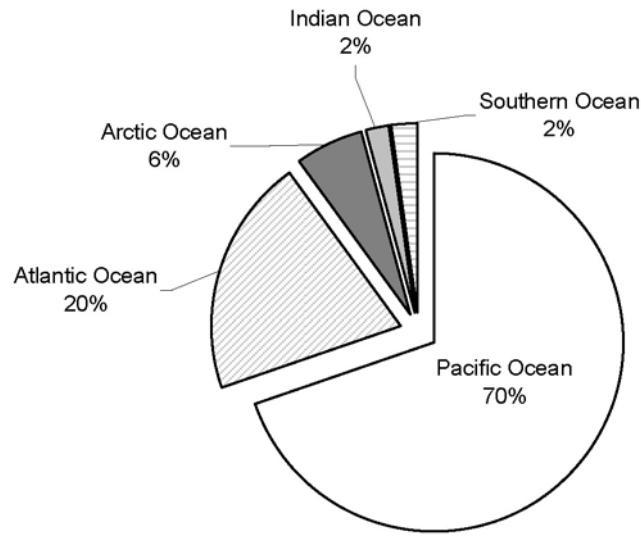
NODC Project Code	Project Name	# Casts	% of Total
	Biogeochemical Ocean Flux Study		
443	IMECOCAL Investigaciones Mexicanas De La Corriente De California	174	0.24
34	MAZATLAN	119	0.16
280	Coastal Transition Zone	100	0.14
245	SEFCAR South Eastern Florida and Caribbean Recruitment	88	0.12
344	POFI Pacific Ocean Fish & Inverts	86	0.12
328	SIBEX Second International Biomass Experiment - Fr	63	0.09
312	CEAREX Coordinated Eastern Arctic Experiment	63	0.09
435	IAPP International Arctic Polynya Programme	41	0.06
90	ONR Office of Naval Research	39	0.05
71	IDOE/CUEA	30	0.04
434	ARCTIC OCEAN SECTION Canada/U.S. joint expedition	18	0.02
77	SCOPE	11	0.01
447	Marine Food Chain Research Group	10	0.01
444	GSP Greenland Sea Project	5	0.01
	<i>Total</i>	73,348	100.0

### **14.3. PLANKTON DATA DISTRIBUTION**

The WOD05 plankton subset consists of 150,250 globally distributed casts for the period 1905 - 2004. The geographic distribution of plankton casts for WOD05 is shown in Figure 14.2. Table 14.4 gives the yearly counts of plankton casts in the WOD05. Table 14.5 gives national contribution of plankton casts sorted by percent contribution from each country.



**Figure 14.3. Geographic distribution of plankton (150,250 casts) in WOD05.**

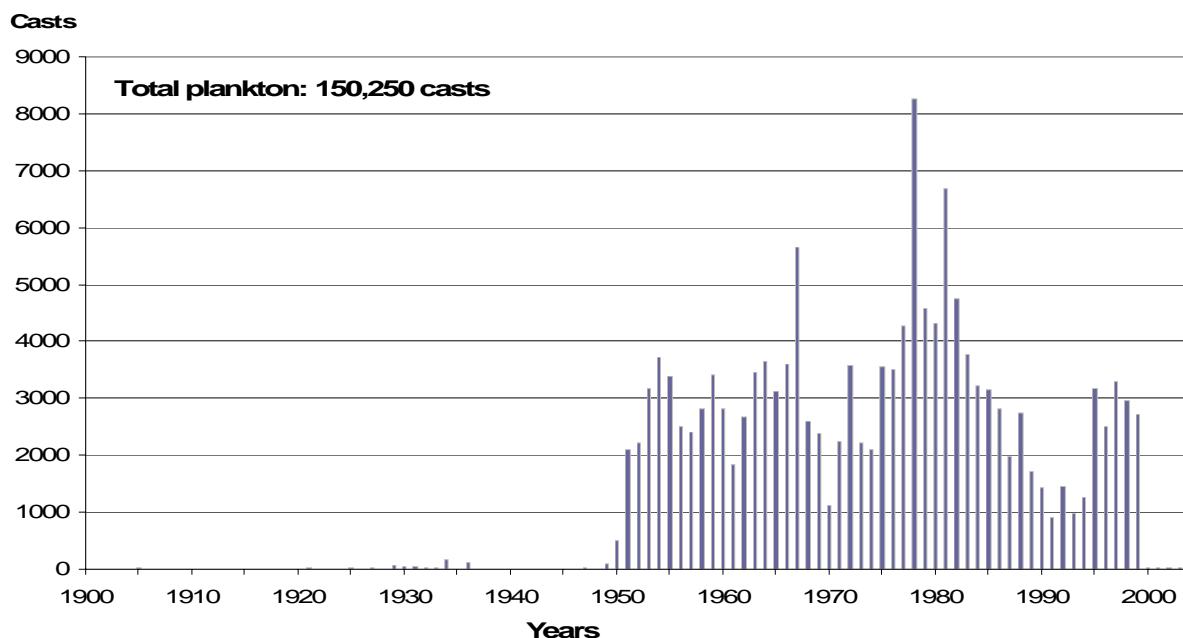


**Figure 14.4. Contributions of plankton casts from different basins.**

**Table 14.4 The number of plankton casts in WOD05 as a function of year for the World Ocean.**

Total Number of Casts = 150,250

YEAR	CASTS	YEAR	CASTS	YEAR	CASTS	YEAR	CASTS
1905	34	1947	24	1968	2613	1988	2735
1913	6	1949	98	1969	2382	1989	1711
1914	5	1950	509	1970	1115	1990	1438
1915	9	1951	2089	1971	2255	1991	914
1921	17	1952	2218	1972	3586	1992	1455
1925	17	1953	3165	1973	2228	1993	978
1927	16	1954	3725	1974	2104	1994	1264
1928	2	1955	3386	1975	3563	1995	3165
1929	71	1956	2497	1976	3520	1996	2500
1930	46	1957	2404	1977	4277	1997	3301
1931	36	1958	2824	1978	8269	1998	2950
1932	18	1959	3412	1979	4586	1999	2728
1933	19	1960	2821	1980	4314	2000	22
1934	179	1961	1834	1981	6685	2001	20
1936	123	1962	2666	1982	4739	2002	22
1938	6	1963	3459	1983	3770	2003	24
1939	10	1964	3662	1984	3217	2004	21
1940	2	1965	3131	1985	3142		
1942	2	1966	3614	1986	2825		
1946	6	1967	5668	1987	1982		



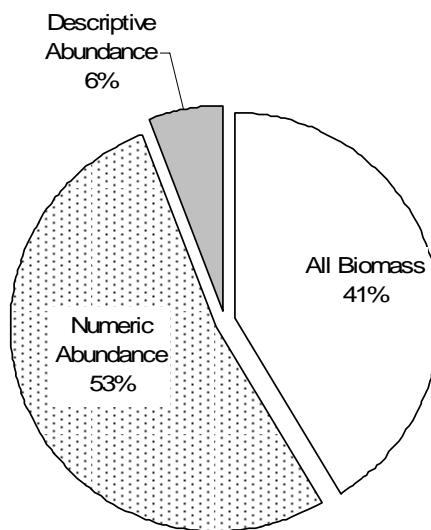
**Figure 14.5. Temporal distributions of plankton casts in WOD05 as a function of year.**

**Table 14.5 National contributions of plankton casts sorted by percent contribution from each country.**

NODC Country Code	Country Name	# Casts	% of Total
31	United States	71,309	47.46
49	Japan	38,077	25.34
74	United Kingdom	15,680	10.44
90, RU	Union of Soviet Socialist Republics and Russia	8,108	5.40
65	Peru	6,827	4.54
42	Indonesia	2,098	1.40
68	Portugal	1,611	1.07
41	India	970	0.66
06	Germany Federal Republic of	868	0.58
09	Australia	763	0.51
58	Norway	403	0.27
28	Ecuador	352	0.23
57	Mexico	293	0.20
14	Brazil	199	0.13
24	Korea Republic of	193	0.13
66	Philippines	184	0.12
67	Poland	158	0.11
21	Taiwan	141	0.09
91	South Africa	141	0.09
59	New Caledonia	136	0.09
22	Colombia	97	0.06
29	Spain	71	0.05
11	Belgium	38	0.03
64	Netherlands	36	0.02
SI	Singapore	35	0.02
62	Pakistan	22	0.01
08	Argentina	11	0.01
77	Sweden	11	0.01
86	Thailand	10	0.01
	<i>Total</i>	150,250	100.00

#### **14.4. PLANKTON CONTENT**

The plankton measurements are represented in WOD05 as quantitative and qualitative abundance, and biomass data. The majority (53 %) of plankton measurements are numeric abundance.



**Figure 14.6. Contributions of plankton casts from different measurements.**

#### 14.4a. Abundance

The majority (89 %) of plankton abundance measurements are numeric (*e.g.*, the number of individuals counted per sample or haul). The descriptive abundance measurements (*e.g.*, individual was "rare", "common", or "abundant" in sample or haul) are present in smaller amount (11 %) of total abundance.

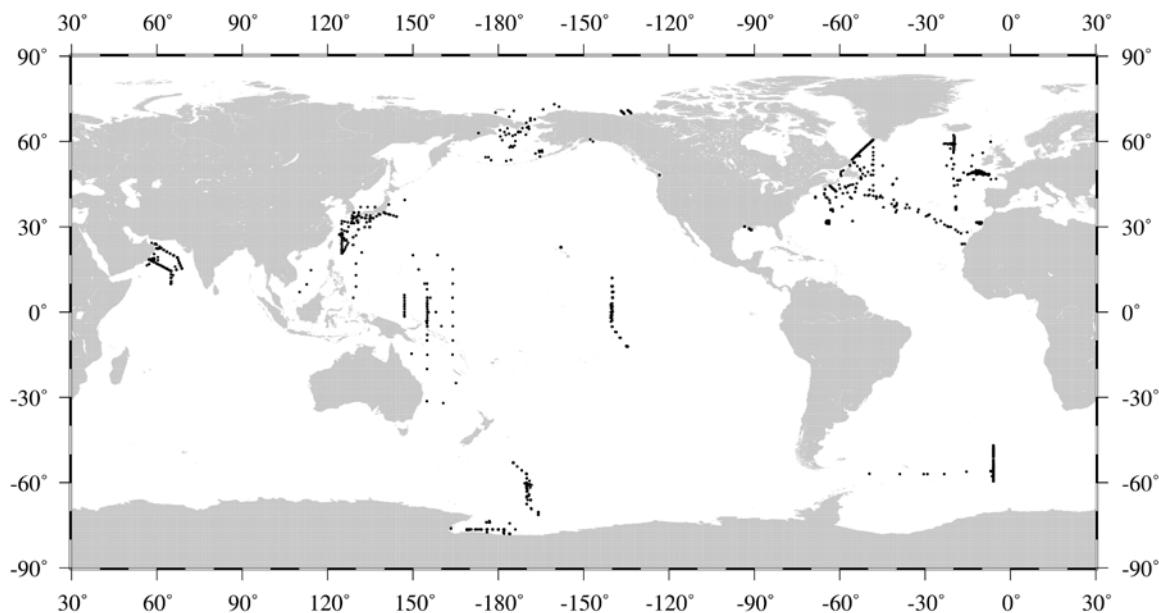
**Table 14.6 WOD05 abundance measurements content.**

BGC Code	Taxonomic Description	Number of casts. Numeric abundance	Number of casts. Descriptive abundance
<b>1000000</b>	<b>BACTERIOPLANKTON all sub-groups</b>	<b>1,986</b>	<b>26</b>
1010000	CYANOBACTERIA	974	25
<b>2000000</b>	<b>PHYTOPLANKTON all sub-groups</b>	<b>24,344</b>	<b>7,223</b>
2010000	BACILLARIOPHYTA (DIATOMS)	20,622	5,666
2020000	DINOFLAGELLATA	12,582	6,771
2030000	CHRYPSOPHYTA (CHROMOPHYTES)	4,919	1,065
2040000	EUGLENOPHYTA (CHLOROPHYTA)	1,357	162
2050000	HAPTOPHYTA (COCCOLITHOPHORES)	3,777	291
<b>3000000</b>	<b>PROTISTS all sub-groups</b>	<b>12,773</b>	<b>2,400</b>
3010000	MASTIGOPHORA miscellaneous flagellate protozoa <i>excludes groups below</i>	380	9
3020000	AMOEVIDAE	42	0
3030000	FORAMINIFERA	4,215	96
3040000	HELIOZOA	30	53
3050000	RADIOLARIA	3,651	263
3060000	CILIOPHORA	3,727	2,080

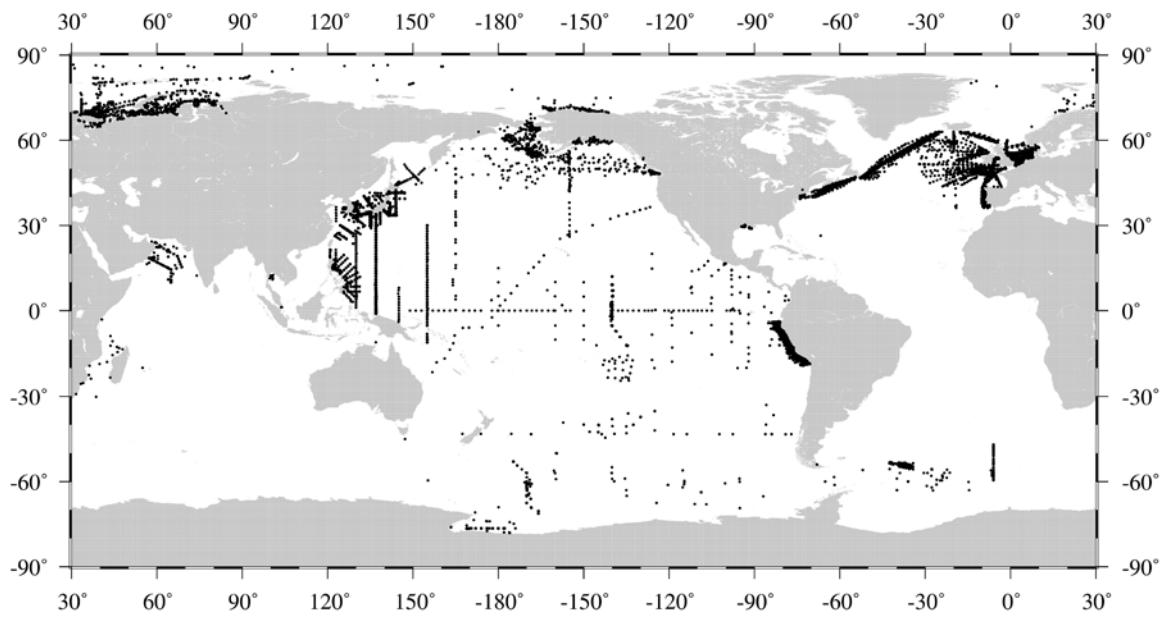
BGC Code	Taxonomic Description	Number of casts. Numeric abundance	Number of casts. Descriptive abundance
4000000	ZOOPLANKTON <i>all sub-groups</i>	38,043	4,172
4020000	PORIFERA	1,941	3
4030000	CNIDARIA	12,787	2,184
4040000	CTENOPHORA	3,720	97
4060000	PLATYHELMINTHES	2,038	0
4070000	NERMETEA	2,326	1
4100000	ROTIFERA	3,635	92
4110000	KINORHYNCHA	0	1
4140000	ENTOPOCTA	1	0
4150000	NEMATODA	2,047	7
4170000	BRYOZOA	3,135	27
4180000	PHORONIDA	2,198	0
4190000	BRACHIOPODA	2,012	1
4200000	MOLLUSCA	33,703	1,120
4202500	Gastropoda	12,947	366
4205000	Bivalvia	2,348	115
4206000	Scaphopoda	85	0
4207500	Cephalopoda	4,103	26
4210000	PRIAPULIDA	0	1
4220000	SIPUNCULA	2,075	2
4240000	ANNELIDA	10,716	1,771
4245000	Polychaeta	8,956	1,766
4270000	ARTHROPODA	2,529	31
4280000	CRUSTACEA	32,765	3,947
4281000	Ostracoda	9,017	208
4282000	Copepoda	29,431	3,692
4283000	Cirripedia	6,686	489
4284000	Mysidacea	4,246	26
4286000	Isopoda	3,828	55
4287000	Amphipoda	13,830	1,372
4288000	Euphausiacea	14,773	1,649
4289000	Decapoda	13,177	1,025
4290000	POGONOPHORA	1	0
4300000	ECHINODERMATA	25,282	475
4310000	CHAETOGNATHA	21,605	2,720
4320000	HEMICHORDATA	2,003	0
4330000	TUNICATA	15,309	2,811
4335000	Thaliacea	5,058	53

BGC Code	Taxonomic Description	Number of casts. Numeric abundance	Number of casts. Descriptive abundance
4337500	Appendicularia	14,003	662
4339000	Cephalochordata	2,458	17
<b>5000000</b>	<b>ICHTHYOPLANKTON all sub-groups</b>	<b>49,091</b>	<b>177</b>

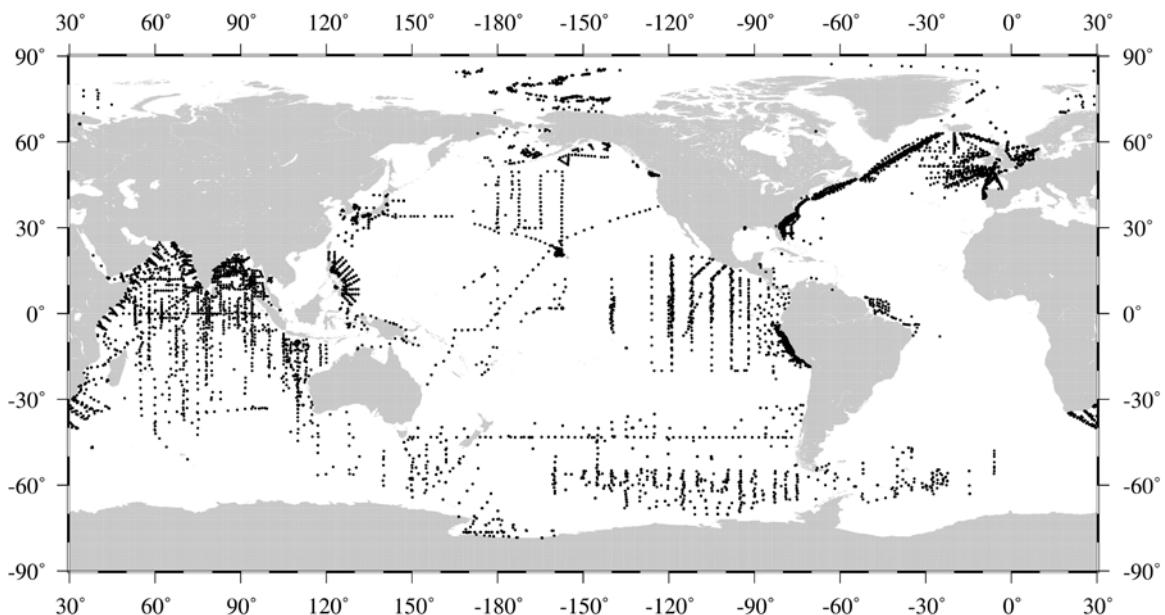
The geographic distribution of numerical abundance casts of major plankton groups for WOD05 is shown in Figures 14.7 – 14.11.



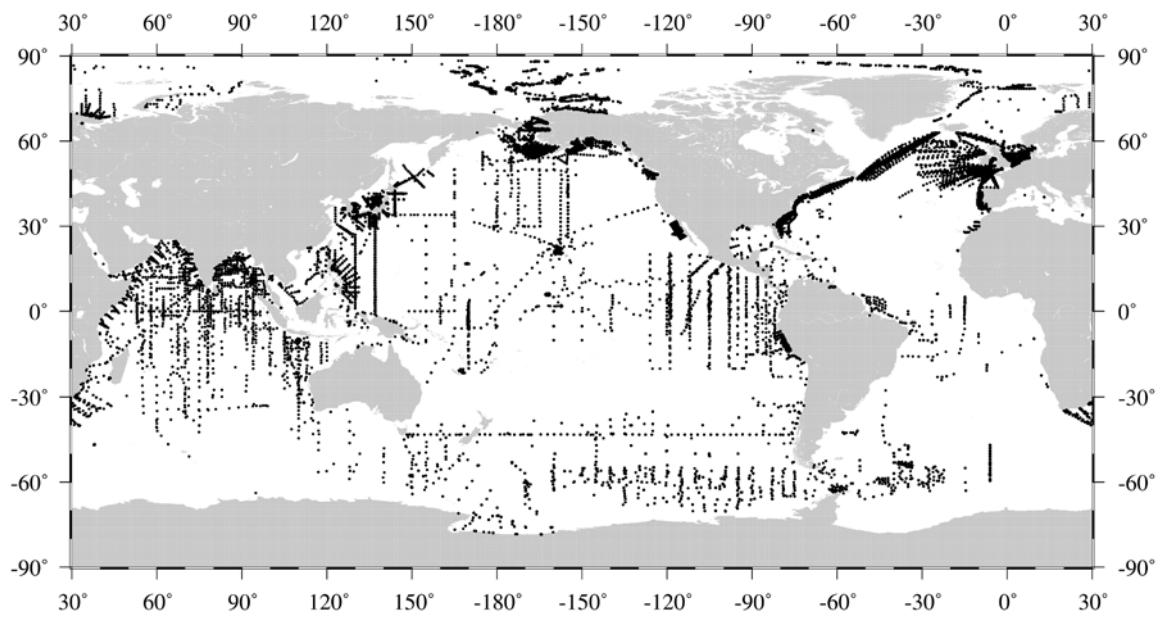
**Figure 14.7. Geographic distribution of bacterioplankton numerical abundance (1,986 casts) in WOD05.**



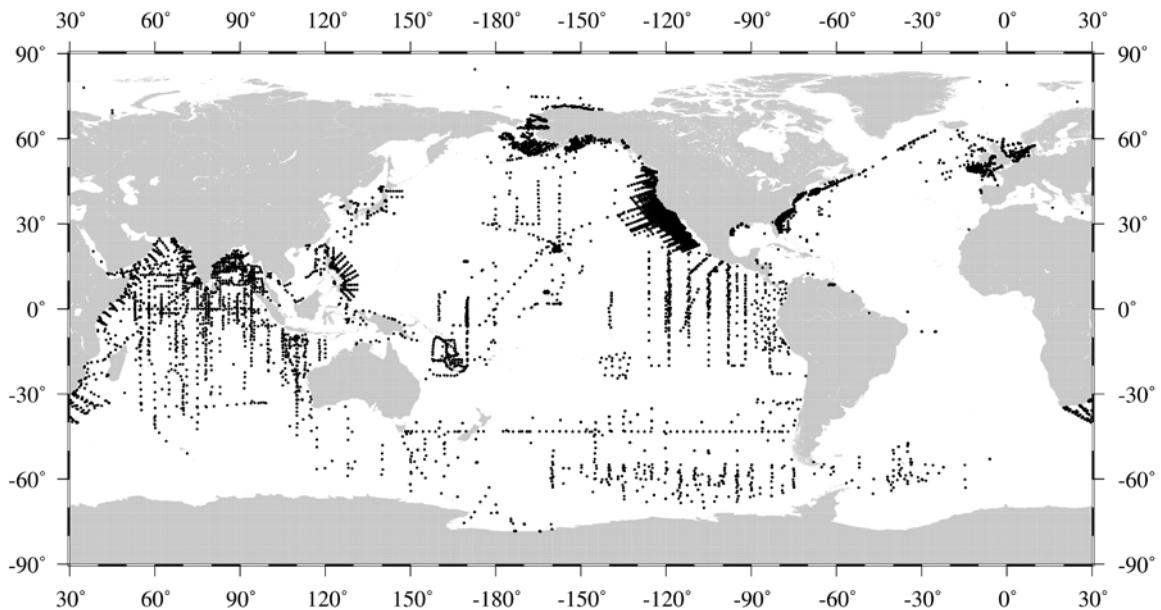
**Figure 14.8. Geographic distribution of phytoplankton numerical abundance (24,344 casts) in WOD05.**



**Figure 14.9. Geographic distribution of protists numerical abundance (12,773 casts) in WOD05.**



**Figure 14.10.** Geographic distribution of zooplankton numerical abundance (38,043 casts) in WOD05.



**Figure 14.11.** Geographic distribution of ichthyoplankton numerical abundance (49,091 casts) in WOD05.

## 14.4b. Biomass

Biomass has been expressed by settled volume, displacement volume, wet weight, dry weight, and ash-free dry weight, defined by Omori and Ikeda (1984) as:

“*Settled volume*: the volume of a plankton sample poured into a graduated cylinder or sedimentation tube of 50-100 ml in volume and allowed to settle for 24 hours.

“*Displacement volume*: the volume of plankton estimated by the volume of water displaced after adding the plankton sample into a graduated cylinder.

“*Wet Weight*: the weight of plankton determined after eliminating as much surrounding water as possible.

“*Dry Weight*: the weight of plankton determined after removal of all water and heat dried to a final weight at 60-70°C.

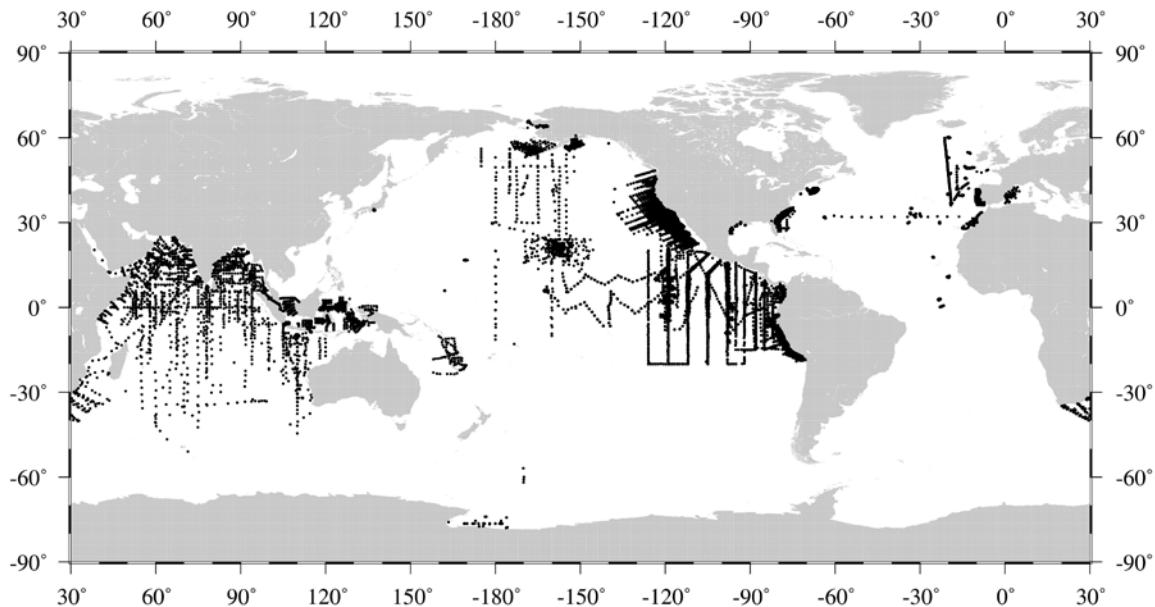
“*Ash-free Dry Weight*: a known weight of the dry sample ashed to a final weight at 450-500°C”.

The majority of WOD05 plankton biomass measurements are displacement volumes.

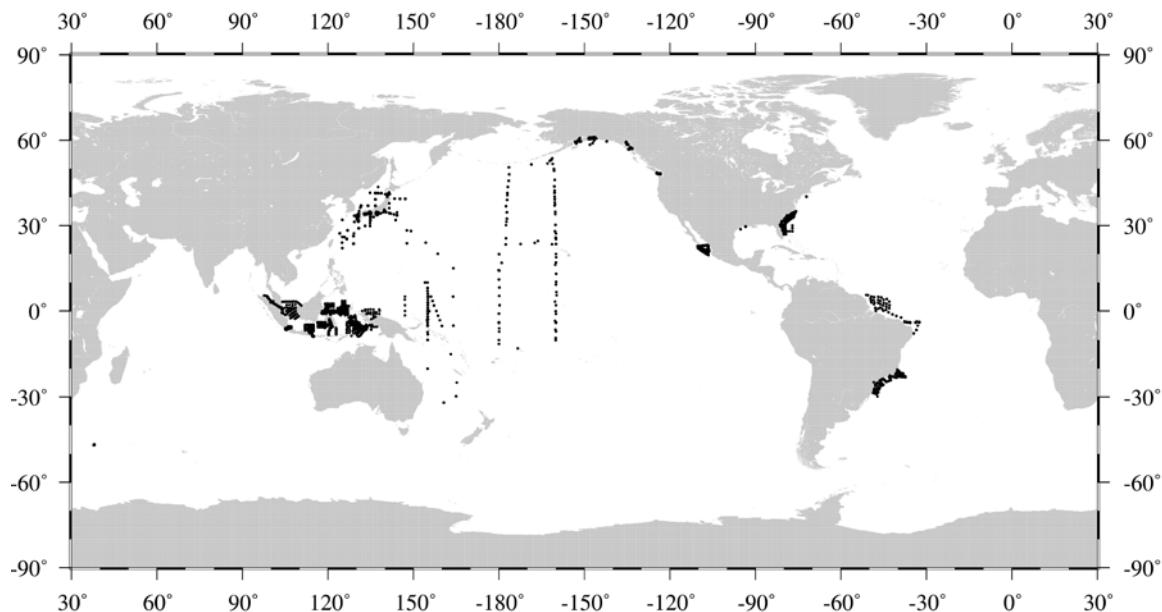
**Table 14.7 WOD05 biomass measurements content.**

BGC Code	Taxonomic Description	# Casts	% of Total
-401	Total Displacement Volume	62,747	61.62
-402	Total Settled Volume	7,984	7.84
-403	Total Wet Weight	28,988	28.47
-404	Total Dry Weight	1,008	0.99
-405	Total Ash-free Dry Weight	274	0.27
-501	Ichthyoplankton Displacement Volume	216	0.21
-503	Ichthyoplankton Wet Weight	606	0.60

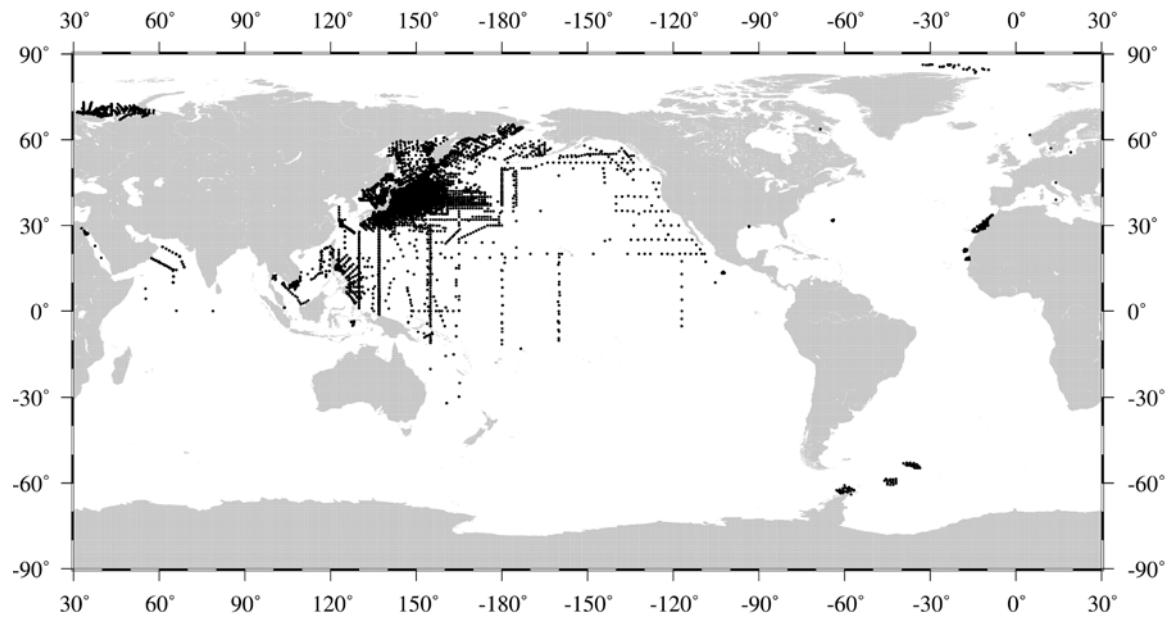
The geographic distribution of biomass casts for WOD05 is shown in Figures 14.12 – 14.18.



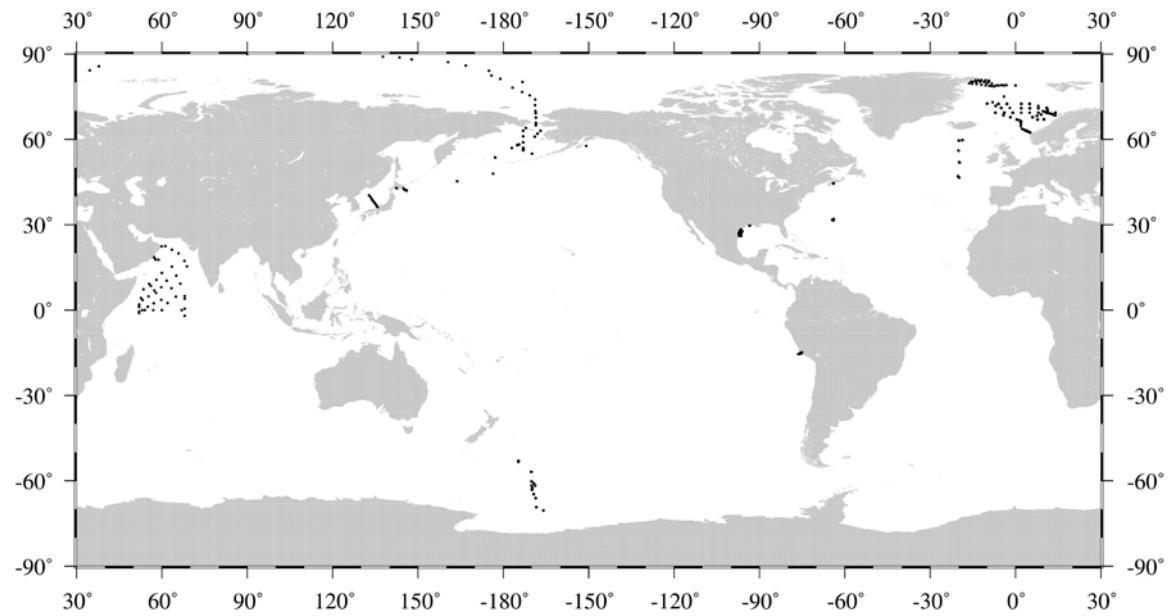
**Figure 14.12. Geographic distribution of total displacement volume (62,747 casts) in WOD05.**



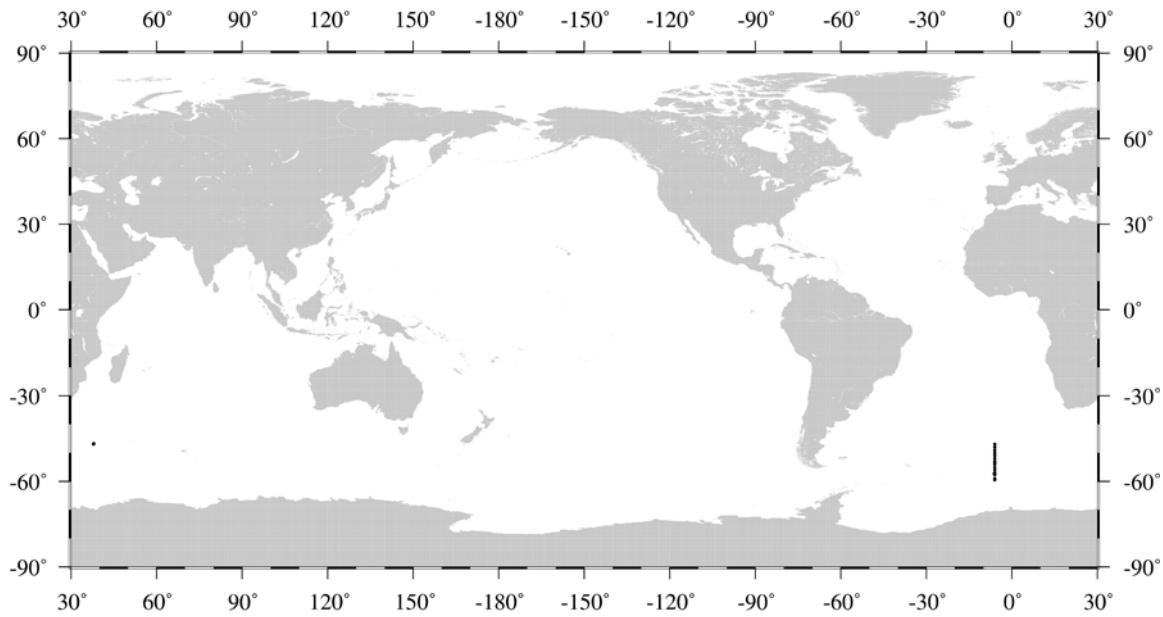
**Figure 14.13. Geographic distribution of total settled volume (7,984 casts) in WOD05.**



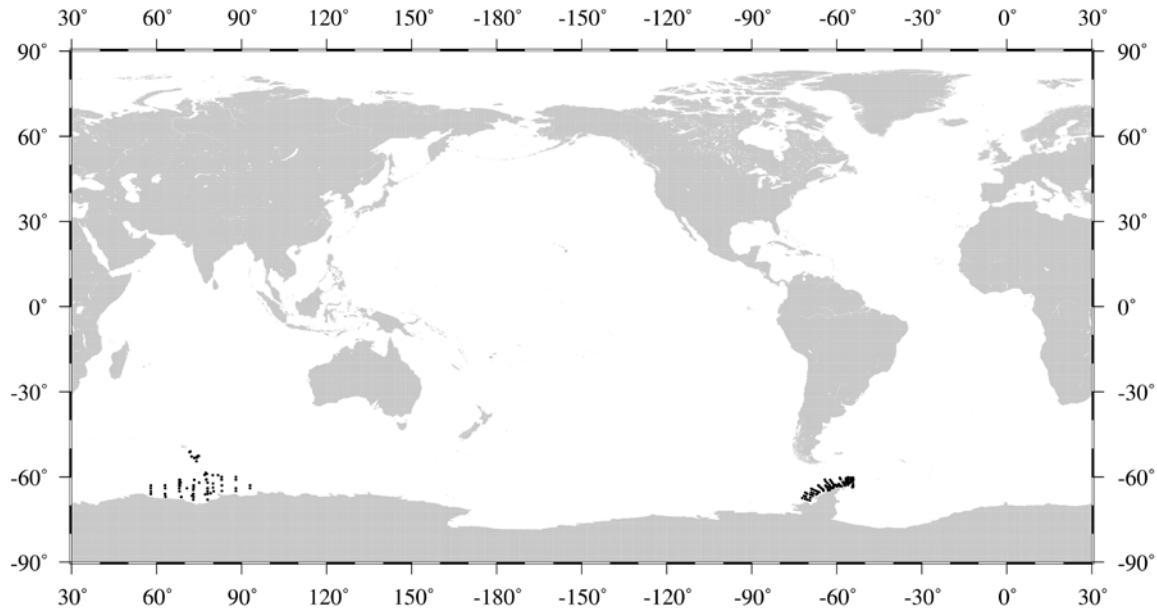
**Figure 14.14.** Geographic distribution of total wet weight (28,988 casts) in WOD05.



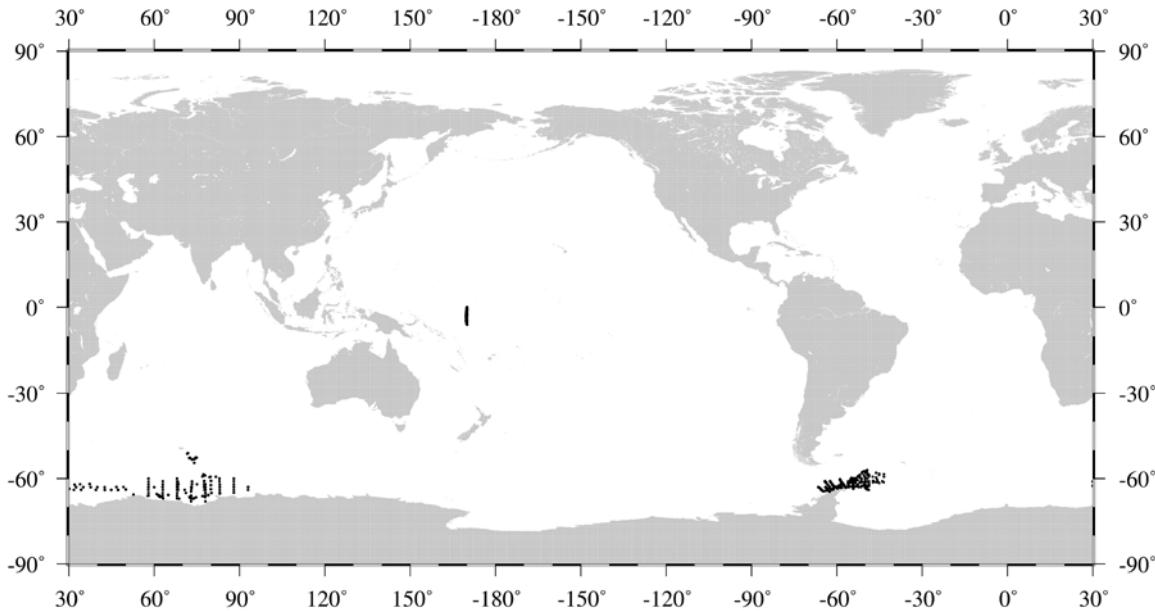
**Figure 14.15.** Geographic distribution of total dry weight (1,008 casts) in WOD05.



**Figure 14.16. Geographic distribution of total ash-free dry weight (274 casts) in WOD05.**



**Figure 14.17. Geographic distribution of ichtyoplankton displacement volume (216 casts) in WOD05.**



**Figure 14.18. Geographic distribution of ichthyoplankton wet weight (606 casts) in WOD05.**

#### **14.5. BIBLIOGRAPHY AND FURTHER READING REFERENCES**

- Johnson, D.R., T.P. Boyer, H.E. Garcia, R.A. Locarnini, A.V. Mishonov, M.T. Pitcher, J.I. Antonov, O.K. Baranova, and I.V. Smolyar, 2006. *World Ocean Database 2005*. Ed: Sydney Levitus, NOAA Atlas NESDIS XX, U.S. Government Printing Office, Washington, D.C., XXX pp.
- O'Brien, T. D., M. E. Conkright, T. P. Boyer, C. Stephens, J. I. Antonov, R. A. Locarnini, H. E. Garcia, 2002: *World Ocean Atlas 2001*, Volume 5: Plankton. S. Levitus, Ed., NOAA Atlas NESDIS 53, U.S. Government Printing Office, Wash., D.C., 89 pp., CD-ROMs.
- O'Brien, T. D. Murphy, P. P., Conkright, M. E., T. P. Boyer, J. I. Antonov, O. K. Baranova, H. E. Garcia, R. Gelfeld, D. Johnson, R. A. Locarnini, I. Smolyar, C. Stephens, 2002: *World Ocean Database 2001*, Volume 7: Temporal Distribution of Chlorophyll and Plankton Data. S. Levitus, Ed., NOAA Atlas NESDIS 48, U.S. Government Printing Office, Wash., D.C., 219 pp., CD-ROMs.
- Conkright, M.E., T. O'Brien, L. Stathoplos, C. Stephens, T.P. Boyer, D. Johnson, S. Levitus, R. Gelfeld, 1998: *World Ocean Database 1998* Volume 8: Temporal Distribution of Station Data Chlorophyll and Plankton Profiles, NOAA Atlas NESDIS 25, U.S. Gov. Printing Office, Wash., D.C., 129 pp.
- Kennish, M.J., (ed.), 1990: *Practical Handbook of Marine Science*, CRC Press, Boca Raton, Ann Arbor, Boston, 710 pp.
- Lalli, C.M. and T.R. Parsons, 1997: *Biological Oceanography. Introduction*, University of British Columbia, Vancouver, Canada, 314 pp.
- Levington, J.S., 1995: *Marine Biology. Function, Biodiversity, Ecology*, Oxford University Press, New York, Oxford, 420 pp.

- Omori, M. and T. Ikeda, 1984: *Methods in Marine Zooplankton Ecology*, A Wiley-Interscience Publication, John Wiley & Sons, New York, Chichester, Brisbane, Toronto, Singapore, 332 pp.
- Truett, J. C., (ed.), 1985: *The Norton Basin Environment and Possible Consequences of Planned Offshore Oil and Gas Development*. A final report for the U.S. Department of the Interior, Minerals Management Service Alaska OCS Region, Anchorage, AK and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, OCS Environmental Assessment Program, Anchorage, AK. NTIS No. PB86-200946/AS. MMS Report 85-0081. 123 pp.