7. Appendix – Electronic Supplements

7.1. *Carbon-length regressions used to convert abundance to carbon biomass*

This is a compendium of carbon-length or dry mass-length regressions newly estimated in the present study or taken from the literature in order to convert enumerations of organisms by length class to carbon biomass. Supplement figure 1 illustrates relationships between carbon or dry mass and length that have not been published previously. Supplement Table 1 indicates the regression equations and other conversion factors used for all taxa, with sources specified. Supplement Tables 2 and 3 indicate the diverse species and sources of data used to derive length-C relationships for copepods and chaetognaths, respectively. To obtain a broad range of body sizes, it was often necessary to consult the literature beyond the Northeast Pacific.

7.2. Time series of carbon biomass of additional major taxa

This appendix contains additional time series of carbon biomass for major taxa other than the four primary taxa reported on in the main body of the text. Results are presented for both Southern California and Central California.

Interdecadal series. Supplement figures 2–7 report interannual variations in springtime carbon biomass, together with anomalies from the long-term mean biomass (1951-2005), for each major taxon. Significant linear regressions are indicated when a temporal trend was detected. These figures are complementary to figures 6-7 in the main text, which depict the four primary contributors to zooplankton biomass. Y-axis scales vary among taxa but are comparable between regions. Open circles below x-axis are years that were not sampled.

Seasonal series. Supplement figures 8–9 report seasonal variations in carbon biomass for each major taxon, for the years 1969 and 1984. These figures are complementary to figure 13 in the main text, which depicts the four primary contributors to zooplankton biomass. Y-axis scales vary among taxa but are comparable between regions.

Supplement Table 1. Regressions estimated or selected from the literature used in the conversion from body length to carbon content.

TAXA	Function	L	SPECIES	Location	Source
COPEPODS	log C (µg) = -6.76 + 2.512 (log L)	Prosome (µm)	Estimated from 38 spp. (Fig 13a)	N Pacific	1
EUPHAUSIIDS	log C (µg) = -0.473 + 3.174 (log L)	Total length (mm)	*Euphausia pacifica*	Laboratory	32
OSTRACODS	DW (µg) = 17.072 $(L)^{2.545}$ C = 39.8% of DW	Carapace (mm)	Estimated using values of *Discoconchoecia pseudodiscophora*, *Orthoconchoecia haddoni*, and *Metaconchoecia skogsbergi*. (Fig. 13b) *M. skogsbergi*	Oyashio Current SE Hokkaido	16 17
HYPERIIDS	log DW (mg) = 2.314 + 2.957 (log L) C = 36.5% of DW	Total length	*Themisto japonica*	Japan Sea	14 15
DECAPODS Sergestidae	C (mg) = 0.133 $(L)^{2.44}$	Carapace (mm)	Estimated using values of *Sergestes henseni*, *S. paraseminudus*, *S. pectinatus*, *Sergia fillictum*, *S. grandis*, *S. robustus*, and *S. spendens*.	Gulf of Mexico	7
Penaeidae	C (mg) = 0.322 $(L)^{2.31}$	Carapace (mm)	Estimated using values of *Gennadas valens* and *Funchalia villosa*.	Gulf of Mexico	7
Pasiphaeidae	C (mg) = 0.810 $(L)^{1.77}$	Carapace (mm)	Estimated using values of *Parapasiphaea sulcatifrons* and *P. merriami*. Values for *P. multidentata* were also used, predicted by DW-L regression and 35.1% of carbon content.	Gulf of Mexico, Sweden waters	7, 28, 11
APPENDICULARIA	DW (µg) = 38.8 $(L)^{2.574}$ C (µg) = 0.49 $(DW)^{1.12}$	Trunk length (mm)	*Oikopleura longicauda* *Oikopleura dioica*	Mediterranean Mediterranean	8 11
DOLIOLIDS	C (µg) = 0.51 $(L)^{2.28}$	Total length (mm)	*Dolioletta gegenbauri*	Laboratory	9
SALPS	Carbon-Length regressions	Total length (mm)	Several species (see details in Lavaniegos & Ohman, 2003)	N Pacific, N Atlantic, and SE Australia	12, 22, 23, 24
PYROSOMES	DW (mg) = 0.111 $(L)^{1.90}$ C = 11.3% of DW	Colony length (mm)	*Pyrosoma atlanticum*	Mediterranean Mediterranean	3 11

THECOSOMES (snail-type shell) (other types)	log C (µg) = 1.469 + 3.102 (log L) log C (µg) = 0.911 + 2.498 (log L) DW (µg) = 2.6 $(L)^{2.659}$ C = 22.1% of DW	Shell (whole animal) Empty shell (mm) Shell (mm)	*Limacina retroversa*; carbon in the soft body obtained as the difference between these estimates. Estimated using values (soft body) of *Cavolinia gibbosa*, *C. longirostris*, *C. tridentata*, *C. uncinata*, *Diacria quadridentata*, *D. trispinosa*, *Hyalocylis striata*, *Corolla spectabilis*, and *Gleba cordata*. (Fig 13c) *C. longirostris*	Laboratory Laboratory N Pacific	5 10 29
GYMNOSOMES	DW (mg) = 1.615 $(e)^{0.088\ (L)}$ C = 26.3% of DW	Total length (mm)	*Clione limacina*	Artic S Long Island	4 6
POLYCHAETES (excluding Alciopidae)	C (µg) = 7.5 $(L)^{1.3848}$	Total length (mm)	Estimated from data of *Tomopteris planctonis* and *T. helgolandica* predicted by DW-L regressions; C% was considered 18.16 and 30.57 respectively (corresponding to *T. pacifica* and *Tomopteris* sp.) (Fig 13d)	W Norway California Current	27, 33
CHAETOGNATHS	C (µg) = 0.0956 $(L)^{2.9093}$	Total length (mm)	Estimated from 6 spp. (Fig 13e)	N Pacific and N Atlantic	2
HYDROMEDUSAE	C (µg) = 1.8885 $(L)^{2.619}$	Umbrella height (mm)	Estimated from data of *Aglantha digitale* and *Clytia hemisphaerica* predicted by DW-L regressions; C% was considered 4.7 and 8.9 respectively (corresponding to *A. digitale* and mean hydromedusae); also data of *Phialidium* predicted by C-L regression. (Fig 13f)	W Norway, English channel, and Laboratory	27, 21, 26, 20
SCYPHOMEDUSAE	WW (g) = 0.0748 $(L)^{2.86}$ C = 0.13% of WW	Umbrella diameter (cm)	*Aurelia aurita*	Japan Sea	34
SIPHONOPHORES	C (µg) = 20.47 $(L)^{0.834}$	Nectophore height or zooid length (mm)	Estimated from data of *Muggiaea atlantica* and *Sphaeronectes gracilis*, and predicted data of *Abylopsis tetragona* from DW-L and C-DW regressions. (Fig 13g)	Laboratory and Mediterranean	30, 31, 11
CTENOPHORES	C (mg) = 0.0048 $(x)^{1.775}$	Total length (mm)	Estimated from data of *Bolinopsis vitrea* and *Mnemiopsis mccradyi*, and predicted data of *Beroe ovata*, *Eurhamphaea vexilligera*, *Ocyropsis* spp., *Pleurobrachia bachei*, and *Bolinopsis infundibulum* from DW-L regressions and C% (The C% of *B. ovata* was used for the last two species). (Fig 13h)	Bahamas, Laboratory and Mediterranean	18, 19, 13, 25

(1) See Suppl. Table 2; (2) See Suppl.Table 3; (3) Andersen & Sardou, 1994; (4) Boer et al., 2005; (5) Conover & Lalli, 1974; (6) Curl, 1962; (7) Donelli, Stickney, & Torres, 1993; (8) Fenaux & Gorsky, 1983; (9) D.M. Gibson, pers. comm.; (10) Gilmer, 1974; (11) Gorsky et al., 1988; (12) Heron, McWilliam, & Dal-Pont, 1998; (13) Hirota, 1972; (14) Ikeda, 1990; (15) Ikeda & Shiga, 1999; (16) Kaeriyama & Ikeda, 2002; (17) Kaeriyama & Ikeda, 2004; (18) Kremer, Canino, & Gilmer, 1986 ; (19) Kremer, Reeve, & Syms; (20) Larson, 1986; (21) Lucas, Williams, Williams, & Sheader, 1995; (22) Madin & Deibel, 1998; (23) Madin & Purcell, 1992; (24) Madin, Cetta, & McAlister, 1981; (25) Martinussen & Båmstedt, 1999; (26) Matsakis & Nival, 1989; (27) Matthews & Hestad, 1977; (28) Norrbin & Bamstedt, 1984; (29) Omori, 1969; (30) Purcell, 1982; (31) Purcell & Kremer, 1983; (32) Ross, 1982 ; (33) Thuesen & Childress, 1993; (34) Uye & Shimauchi, 2005.

Supplement Table 2. Copepod species used to estimate the general carbon-length regression showed in Supplement figure 1. Type of data indicates when individual data points were incorporated into the fit, or predicted using specific regressions for the mean size of females (and copepodite V in some cases). (L) Length, (DW) Dry weight, (AFDW), Ash free dry weight, (C) Carbon. If % carbon was not available it was estimated as 45% of DW or 50% of AFDW.

SPECIES	Location	Type of data	Source
Acartia clausi	off Washington	C-L regression	7
	Japan Sea	C-L regression	15
	experimental	C-L regression	1
Acartia erythraea	Japan Sea	DW value; %C	15
Acartia omori	Japan Sea	C-L regression	8
Acartia pacifica	Japan Sea	DW value; %C	15
Acartia tsuensis	Japan Sea	C-L regression	15
Aetideus divergens	experimental	DW value	12
Euchirella pseudopulchra	California Current	C value	10
Calanus marshallae	off Oregon	DW-L regression	11
Calanus pacificus	Puget Sound	DW-L regression	13
	California Current	DW value	9
		C value	4
Calanus sinicus	Japan Sea	C-L regression	15
Neocalanus cristatus	Subarctic Pacific	DW value; %C	3
Neocalanus plumchrus	Subarctic Pacific	DW value; %C	3
Centropages abdominalis	Japan Sea	C-L regression	15
Centropages yamadai	Japan Sea	DW value; %C	15
Sinocalanus tenellus	Japan Sea	C-L regression	15
	experimental	C-L regression	6
Eucalanus californicus	California Current	DW value	9
		DW-L regression	14
Eucalanus hyalinus	California Current	C value	4
Rhincalanus nasutus	California Current	DW value	9
		DW-L regression	5
Euchaeta concinna	Japan Sea	C-L regression	15
Heterorhabdus tanneri	West Pacific	AFDW-L regression	19
Metridia pacifica	California Current	C value	9
Pleuromamma scutullata	West Pacific	AFDW-L regression	19
Paracalanus crassirostris	Japan Sea	DW value; %C	15
Paracalanus parvus	Japan Sea	DW value; %C	15
Paracalanus sp.	Japan Sea	C-L regression	17

Pseudodiaptomus marinus	Japan Sea	DW value; %C	15
		C-L regression	18
Calanopia thompsoni	Japan Sea	DW value; %C	15
Labidocera bispinnata	Japan Sea	DW value; %C	15
Labidocera trispinosa	California Current	C value	2
Pontella sp.	Japan Sea	DW value; %C	15
Pontellopsis tenuidacuda	Japan Sea	DW value; %C	15
Temora turbinata	Japan Sea	DW value; %C	15
Tortanus forcipatus	Japan Sea	C-L regression	15
	West Pacific	C-L regression	16
Oithona brevicornis	Japan Sea	C-L regression	15
Oithona similis	Japan Sea	C-L regression	15
Corycaeus affinis	Japan Sea	DW value; %C	15
Microsetella norvegica	Japan Sea	DW value; %C	15
COPEPODS	Japan Sea	C-L regression	15

(1) Ayukai, 1987; (2) Barnett, 1974; (3) Dagg & Wyman, 1983; (4) Flint, Drits, & Pasternak, 1991; (5) Hopcroft, Clarke, & Chavez, 2002; (6) Kimoto, Uye, & Onbe, 1986; (7) Landry, 1978; (8) Liang & Uye, 1996; (9) Ohman, 1988b; (10) Ohman & Townsend, 1998; (11) Peterson, 1980; (12) Robertson & Frost, 1977; (13) Runge, 1980; (14) Smith & Lane, 1991; (15) Uye, 1982; (16) Uye & Kayano, 1994; (17) Uye & Shibuno, 1992; (18) Uye, Iwai, & Kasahara, 1983; (19) Yamaguchi & Ikeda, 2000.

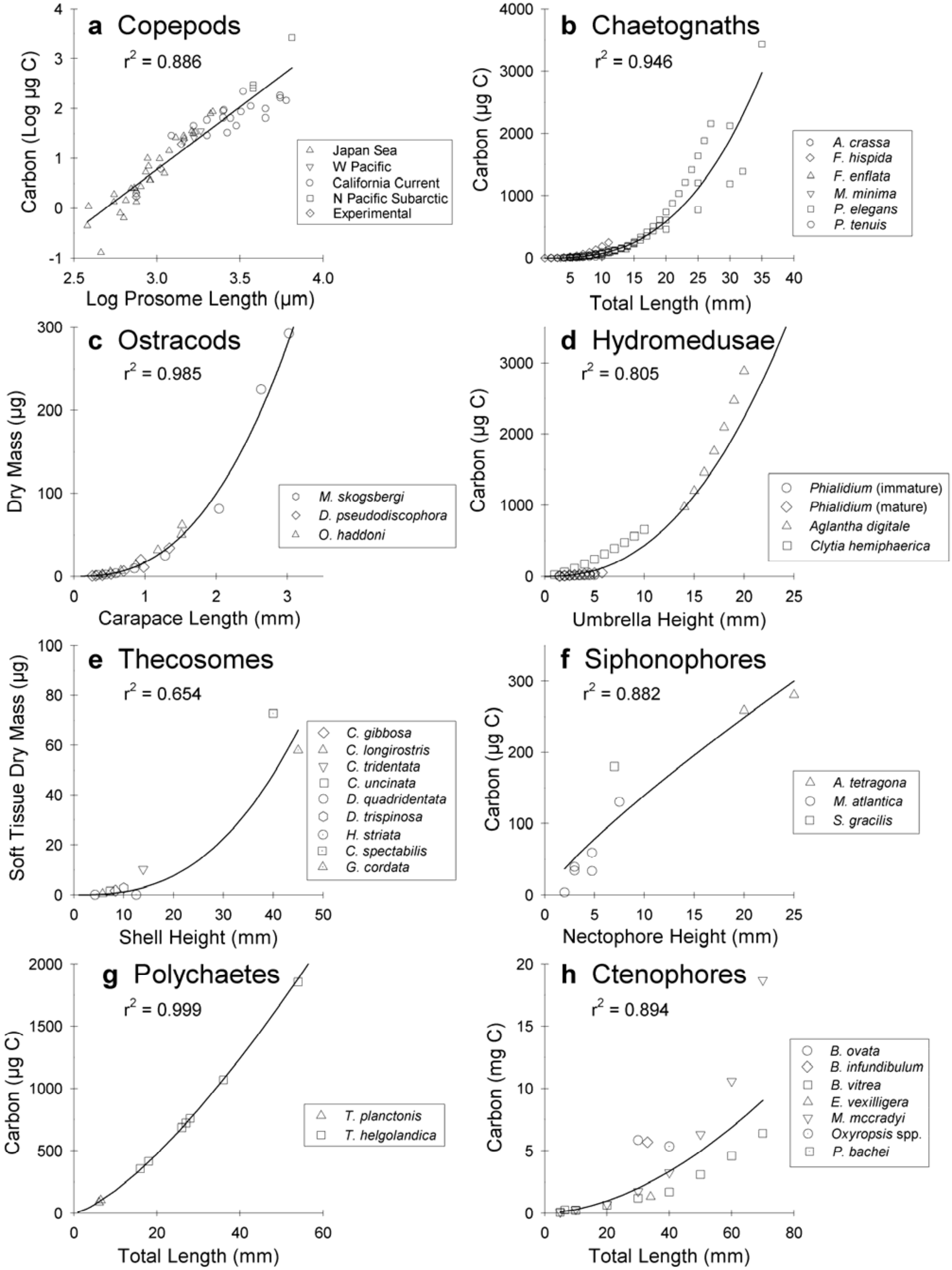
Supplement Table 3. Chaetognath species used to estimate the general carbon-length regression shown in Supplement figure 1. “Function” indicates the type of regression relationship used to estimate C. (L) Length, (DW) Dry weight, (AFDW), Ash free dry weight, (C) Carbon. If % carbon was not available (*) it was estimated from mixed Mediterranean chaetognaths (Gorsky et al., 1988).

SPECIES	Location	Function	Source
Aidanosagitta crassa	Japan Sea	DW-L regression *	4
		DW-L regression *	8
Ferosagitta hispida	Gulf of Mexico	AFDW-L regression; %C	9
Flaccisagitta enflata	Adriatic Sea	DW values; C-DW regression	1
Mesosagitta minima	Adriatic Sea	DW values; C-DW regression	1
Parasagitta elegans	NW Atlantic	DW-L regression; %C	10
	Bering Sea	DW-L regression *	5
	Norwegian Sea	DW-L regression *	6
	Celtic Sea	C-L regression	3
Parasagitta tenuis	Chesapeake Bay	DW-L regression; %C	2

(1) Batistic, 2003; (2) Canino & Grant, 1985; (3) Conway & Robins, 1991; (4) Hirota, 1981; (5) Kotori, 1976; (6) Matthews & Hestad, 1977; (8) Nagasawa, 1984; (9) Reeve & Baker, 1975; (10) Sameoto, 1971.

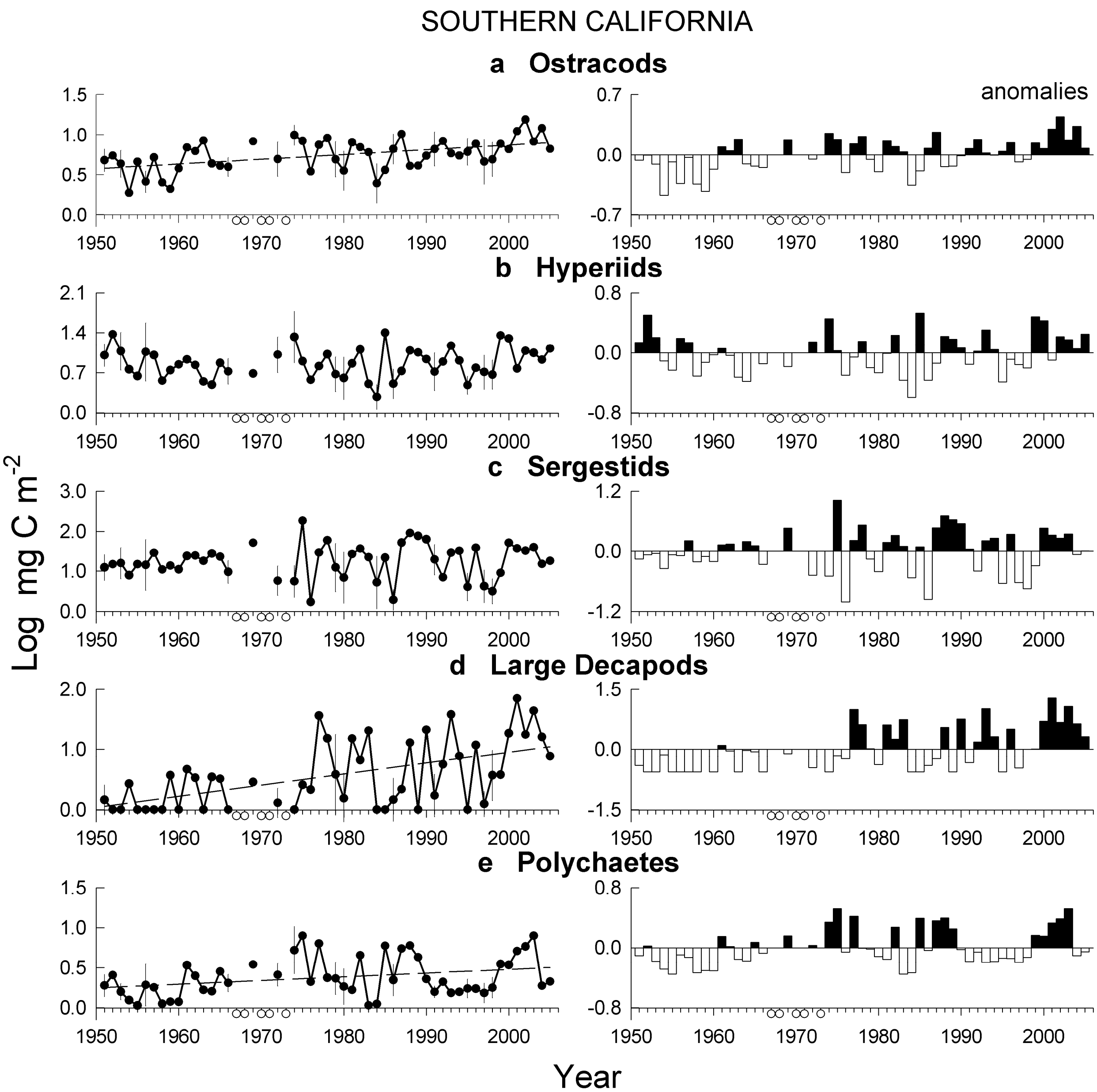
ELECTRONIC SUPPLEMENT FIGURES

Supp-Fig.1 Relationship between length and organic carbon content or body mass for a combination of species of: (a) copepods, (b) chaetognaths, (c) ostracods, (d) hydrodmedusae, (e) thecosome pteropods, (f) siphonophores, (g) polychaetes, and (h) ctenophores. Species used, sources of data, and regression equations indicated in Supplement Tables 1- 3.

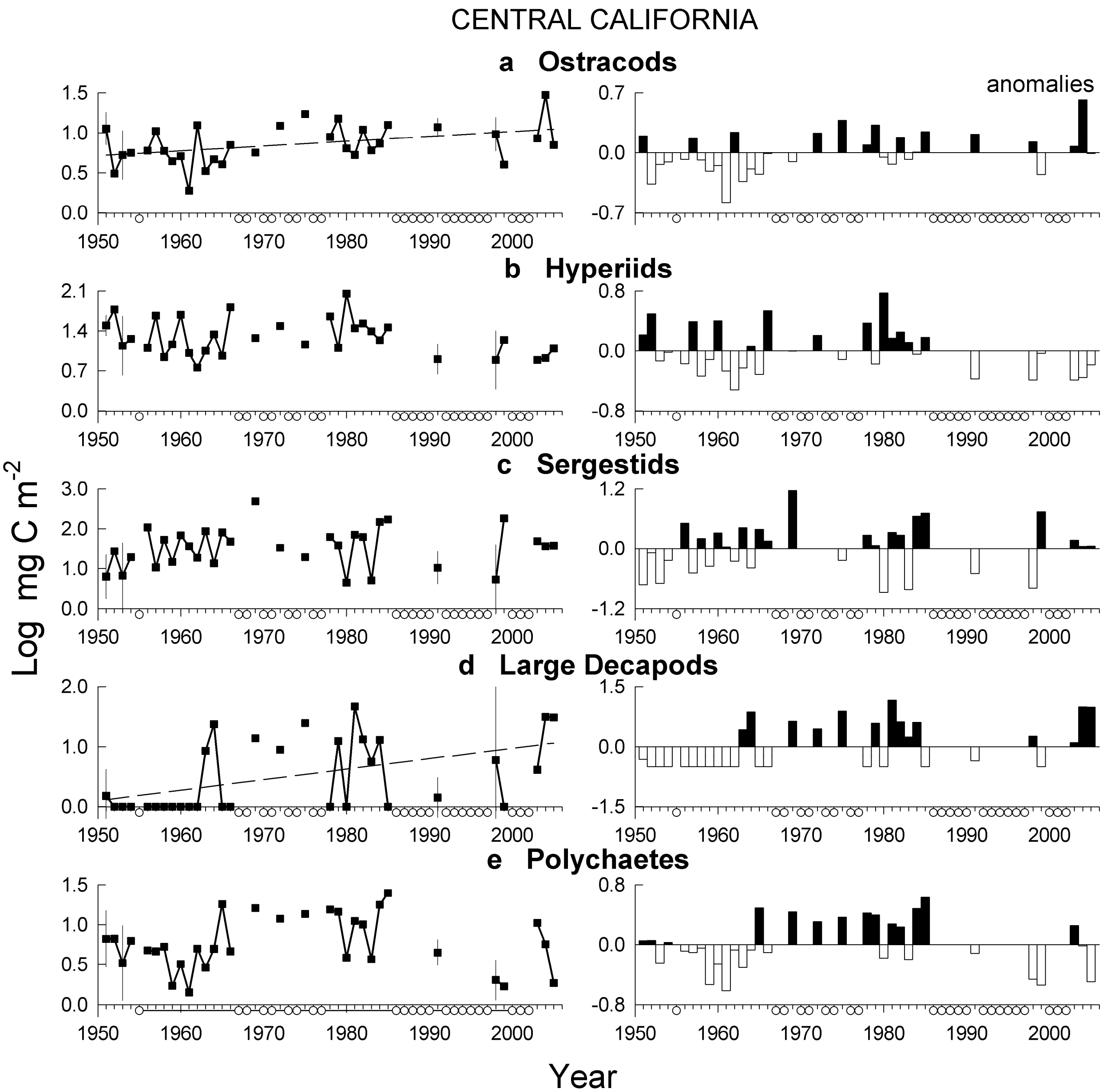


a Copepods
r2 = 0.886
Japan Sea
W Pacific
California Current
N Pacific Subarctic
Experimental
Carbon (Log µg C)
Log Prosome Length (µm)
b Chaetognaths
r2 = 0.946
A. crassa
F. hispida
F. enflata
M. minima
P. elegans
P. tenuis
Carbon (µg C)
Total Length (mm)
c Ostracods
r2 = 0.985
M. skogsbergi
D. pseudodiscophora
O. haddoni
Dry Mass (µg)
Carapace Length (mm)
d Hydromedusae
r2 = 0.805
Phialidium (immature)
Phialidium (mature)
Aglantha digitale
Clytia hemiphaerica
Carbon (µg C)
Umbrella Height (mm)
e Thecosomes
r2 = 0.654
C. gibbosa
C. longirostris
C. tridentata
C. uncinata
D. quadridentata
D. trispinosa
H. striata
C. spectabilis
G. cordata
Soft Tissue Dry Mass (µg)
Shell Height (mm)
f Siphonophores
r2 = 0.882
A. tetragona
M. atlantica
S. gracilis
Carbon (µg C)
Nectophore Height (mm)
g Polychaetes
r2 = 0.999
T. planctonis
T. helgolandica
Carbon (µg C)
Total Length (mm)
h Ctenophores
r2 = 0.894
B. ovata
B. infundibulum
B. vitrea
E. vexilligera
M. mccradyi
Oxyropsis spp.
P. bachei
Carbon (mg C)
Total Length (mm)

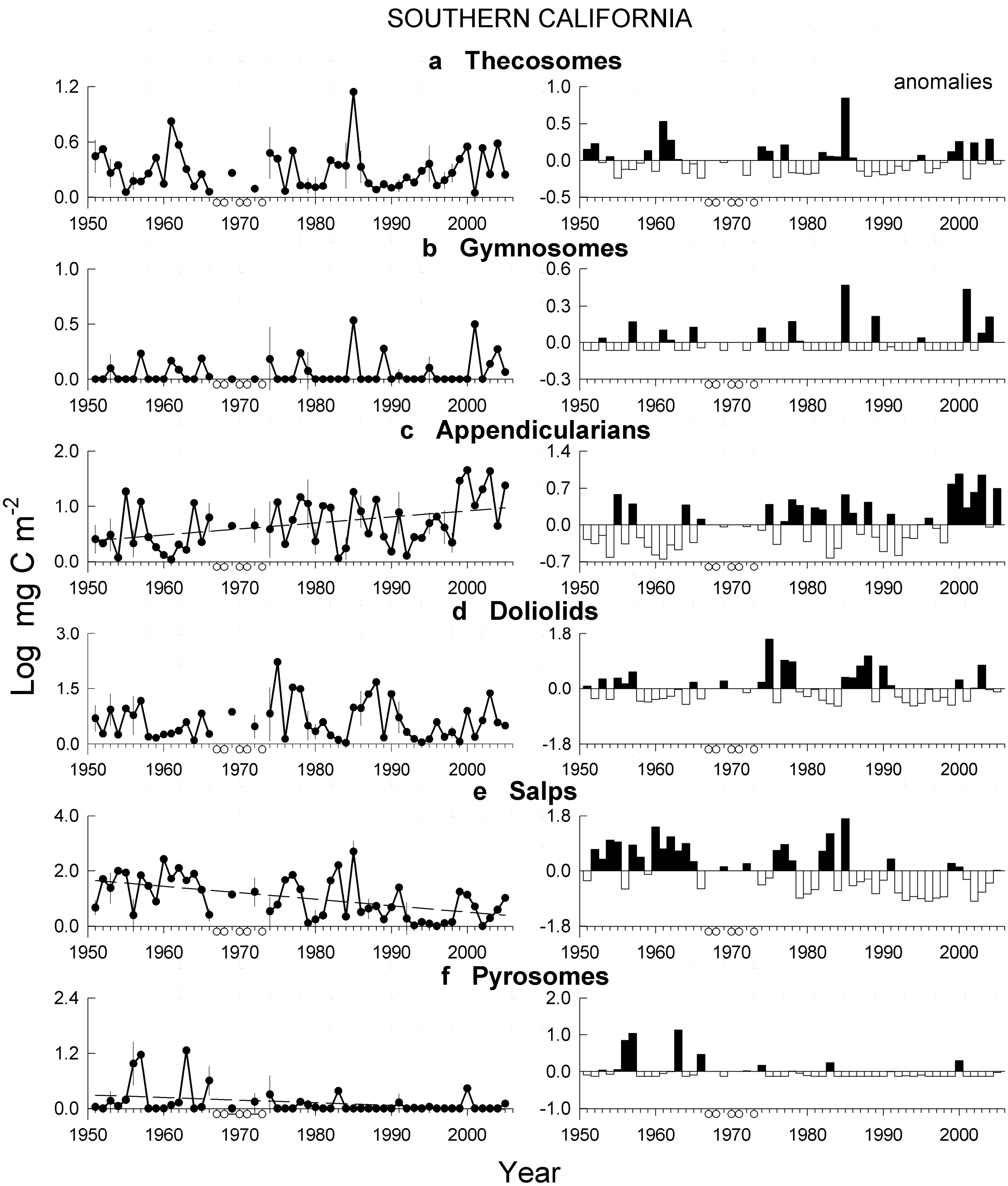
Supp-Fig. 2. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Southern California region: (a) ostracods, (b) hyperiid amphipods, (c) sergestids, (d) large decapods, (e) and polychaetes (Alciopidae excluded). Mean ± 95% confidence intervals in years when individual samples enumerated; anomalies illustrate departures from the mean of 1951-2005. Open circles below the y-axis indicate no samples available, in this and subsequent figures. Dashed lines indicate linear regressions significant at $P < 0.05$.



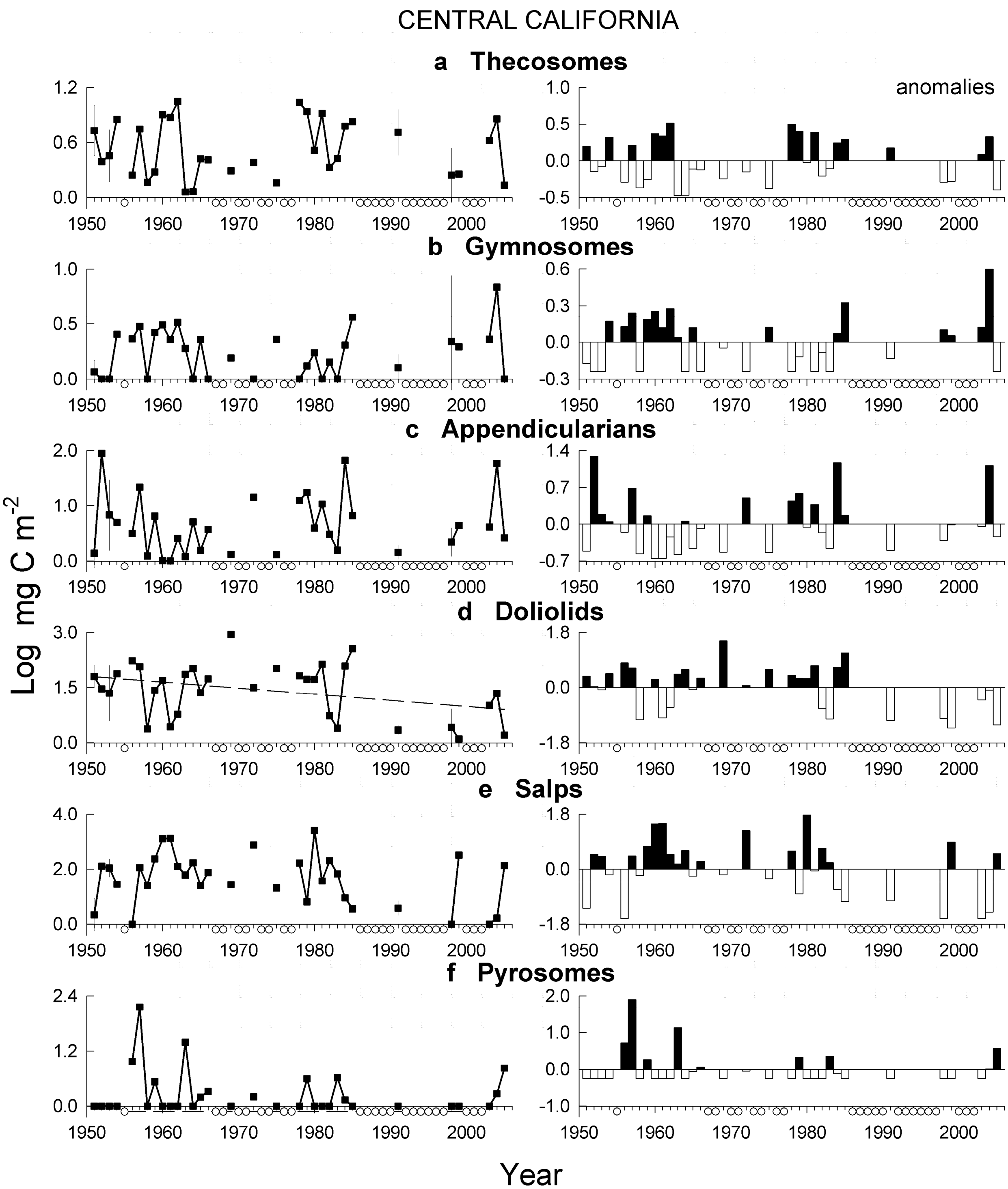
Supp-Fig. 3. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Central California region: (a) ostracods, (b) hyperiid amphipods, (c) sergestids, (d) large decapods, (e) and polychaetes (Alciopidae excluded). Dashed lines indicate linear regressions significant at $P < 0.05$.



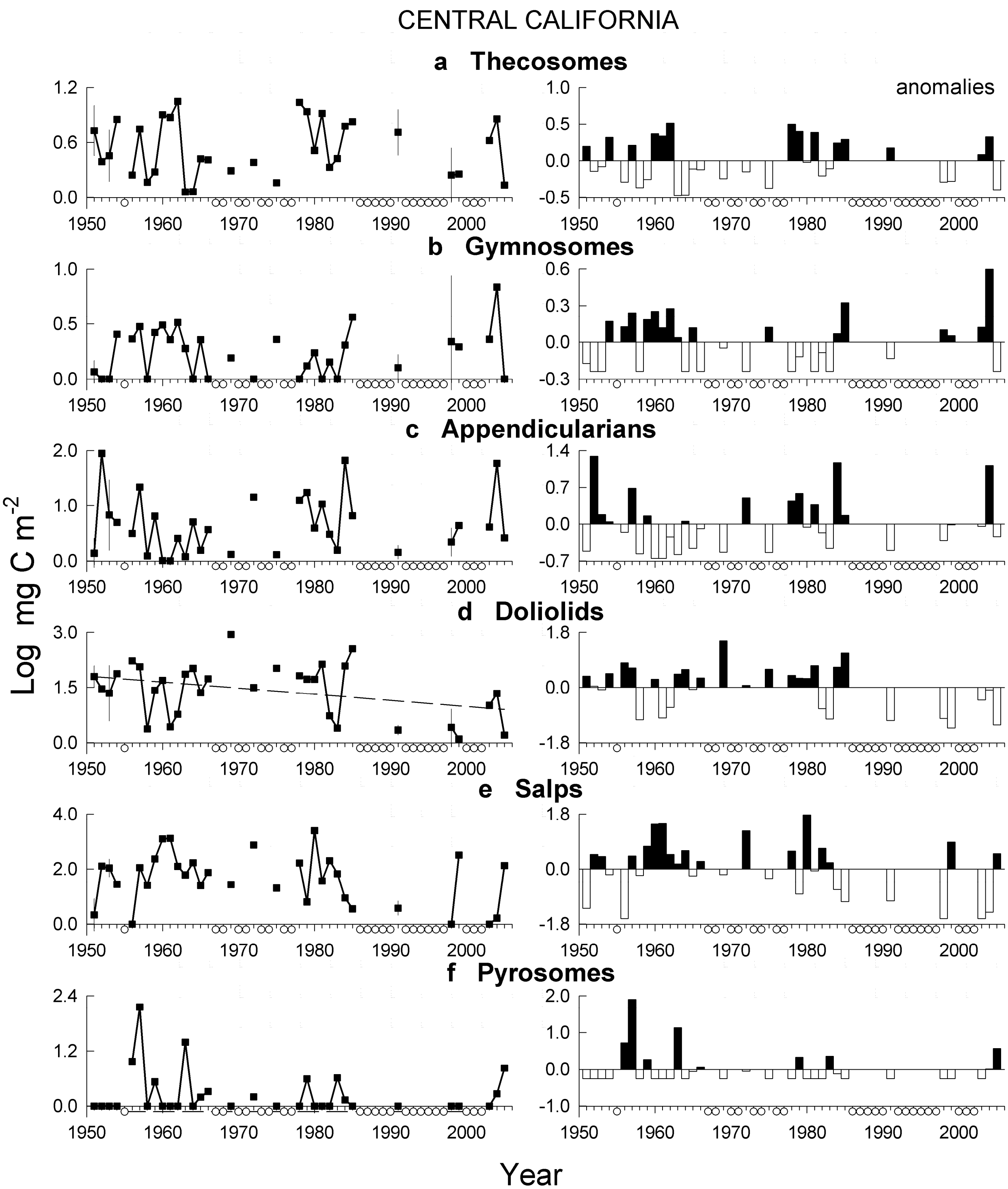
Supp-Fig. 4. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Southern California region: (a) thecosome pteropods, (b) gymnosome pteropods, (c) appendicularians, (d) doliolids, (e) salps, and (f) pyrosomes. Dashed lines indicate linear regressions significant at $P < 0.05$.



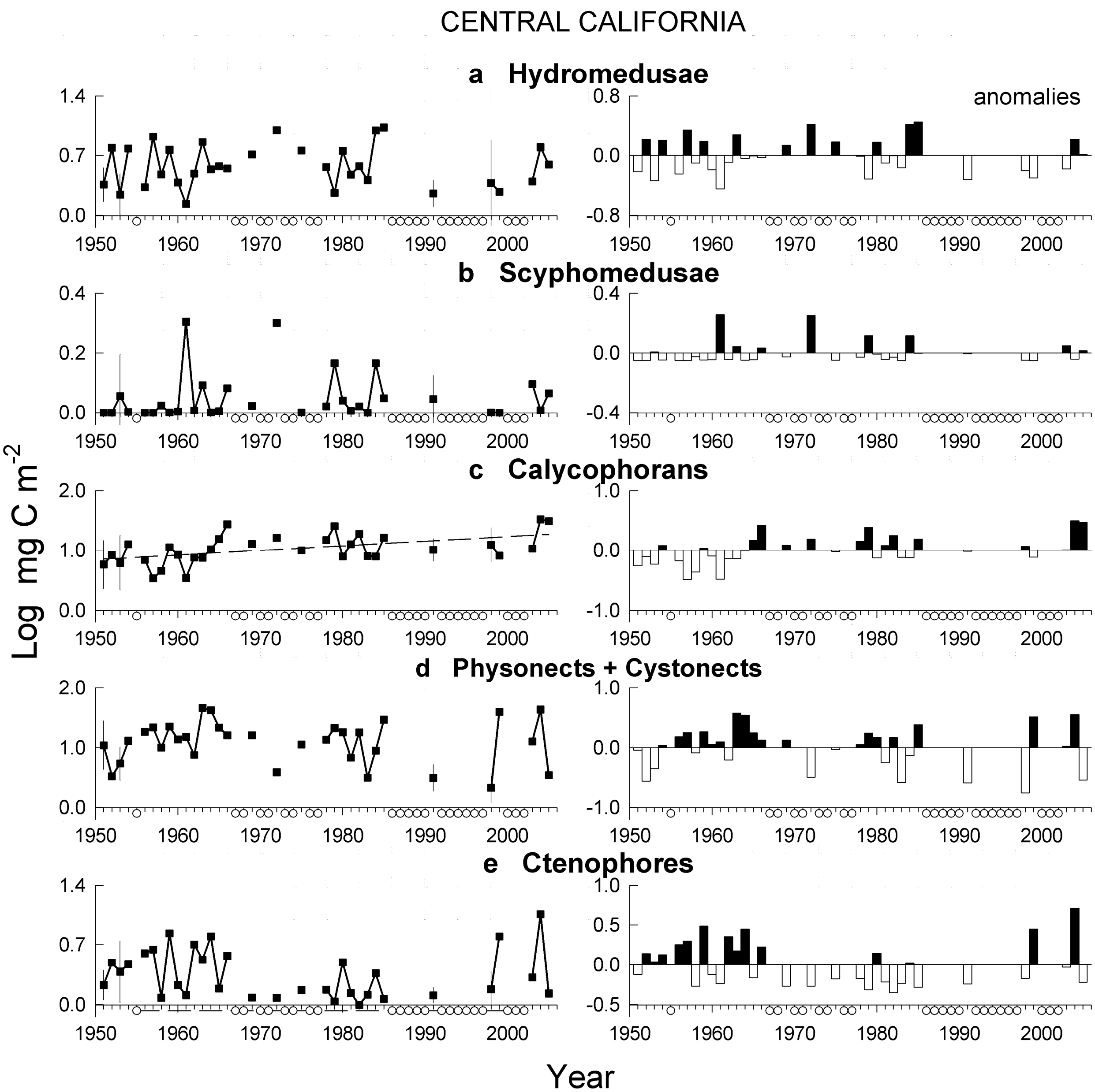
Supp-Fig. 5. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Central California region: (a) thecosome pteropods, (b) gymnosome pteropods, (c) appendicularians, (d) doliolids, (e) salps, and (f) pyrosomes. Dashed lines indicate linear regressions significant at $P < 0.05$.



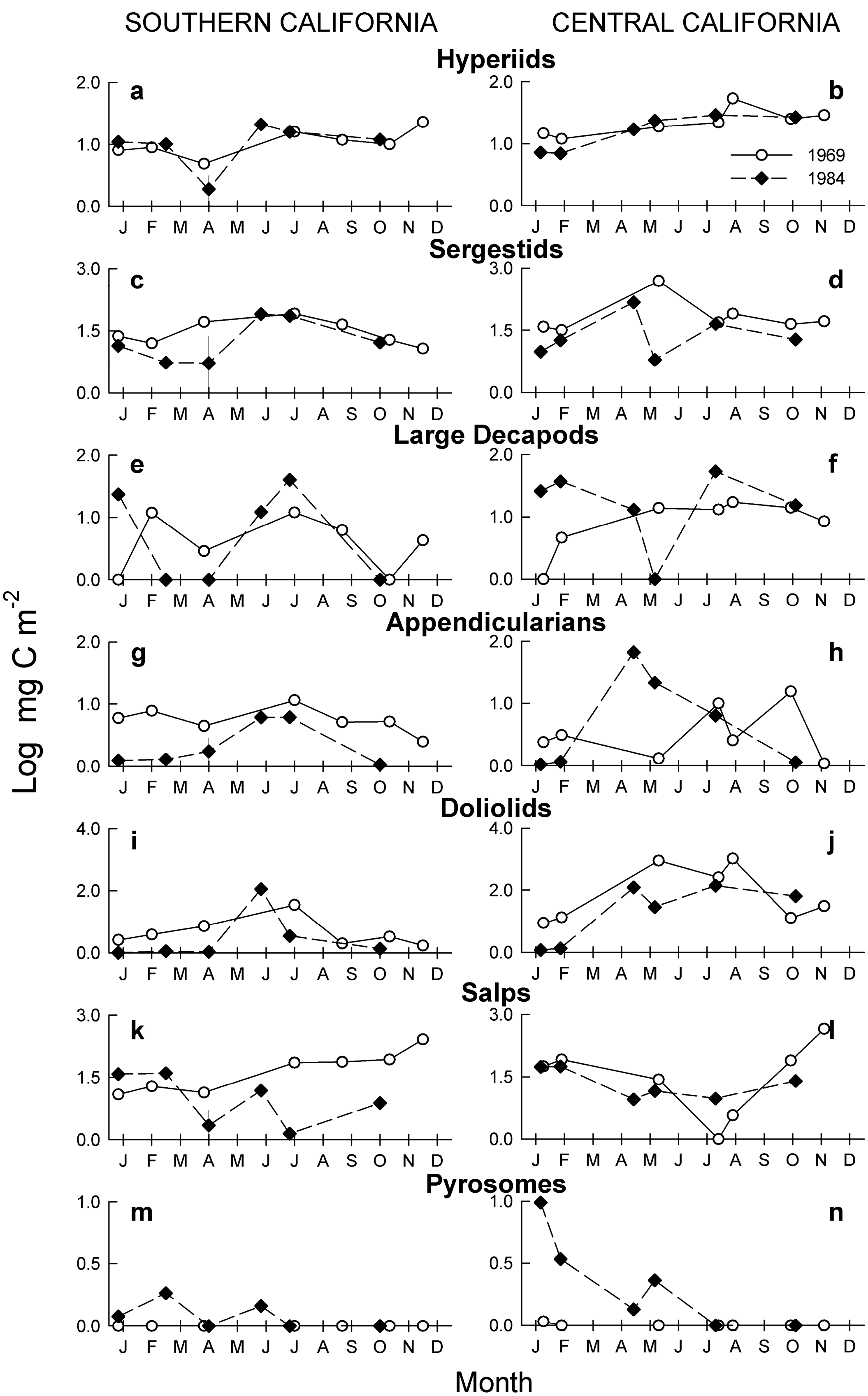
Supp-Fig. 6. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Southern California region: (a) hydromedusae, (b) scyphomedusae, (c) calycophoran siphonophores, (d) physonect+cystonect siphonophores, (e) ctenophores. Dashed lines indicate linear regressions significant at $P < 0.05$.



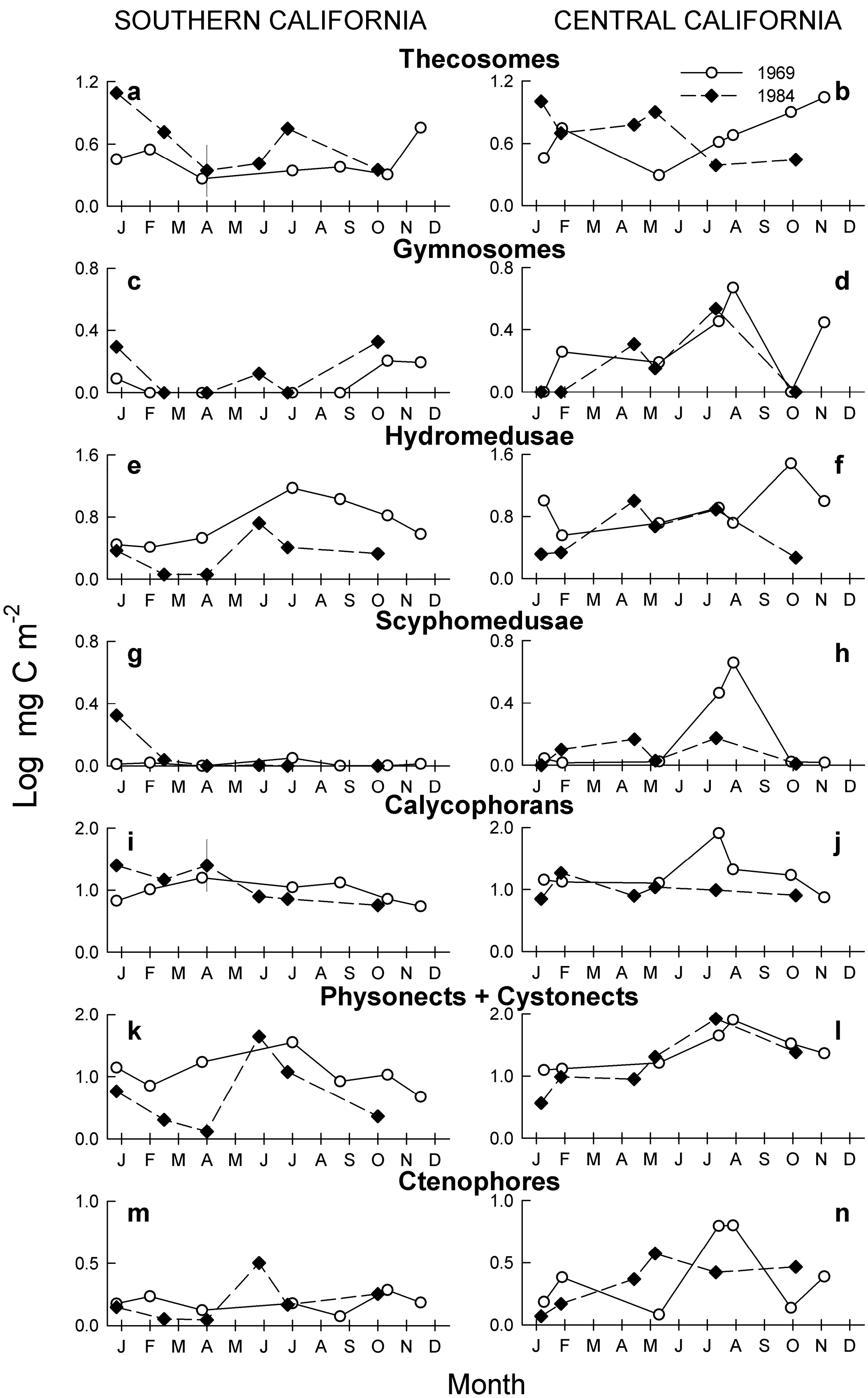
Supp-Fig. 7. Interannual variation in organic carbon biomass of zooplankton taxa from springtime CalCOFI cruises in the Central California region: (a) hydromedusae, (b) scyphomedusae, (c) calycophoran siphonophores, (d) physonect+cystonect siphonophores, (e) ctenophores. Dashed lines indicate linear regressions significant at $P < 0.05$.



Supp-Fig. 8. Seasonal variation of organic carbon biomass for: (a, b) hyperiid amphipods, (c, d) sergestids, (e,f) large decapods, (g, h) appendicularians, (i, j) doliolids, (k, l) salps, and (m, n) pyrosomes from Southern California (SC, left hand panels) and Central California (CC, right hand panels), during years representative of the cool (1969) and warm (1984) climate periods. For most taxa, 95% confidence intervals are available only from April 1984 (SC) when individual samples were analyzed; remaining points illustrate means from analysis of pooled samples.


SOUTHERN CALIFORNIA
CENTRAL CALIFORNIA
Hyperiids
Sergestids
Large Decapods
Appendicularians
Doliolids
Salps
Pyrosomes
a
b
c
d
e
f
g
h
i
j
k
l
m
n
1969
1984
Log mg C m-2
Month
J F M A M J J A S O N D

Supp-Fig. 9. Seasonal variation of organic carbon biomass for: (a, b) thecosome pteropods, (c, d) gymnosome pteropods, (e,f) hydromedusae, (g, h) scyphomedusae, (i, j) calycophoran siphonophores, (k, l) physonect+cystonect siphonophores, and (m, n) ctenophores, from Southern California (SC, left hand panels) and Central California (CC, right hand panels), during years representative of the cool (1969) and warm (1984) climate periods. For most taxa, 95% confidence intervals are available only from April 1984 (SC) when individual samples were analyzed; remaining points illustrate means from analysis of pooled samples.



SOUTHERN CALIFORNIA
CENTRAL CALIFORNIA
Thecosomes
Gymnosomes
Hydromedusae
Scyphomedusae
Calycophorans
Physonects + Cystonects
Ctenophores
1969
1984
a
b
c
d
e
f
g
h
i
j
k
l
m
n
Log mg C m-2
J F M A M J J A S O N D
Month