

The following supplement accompanies the article

Changes in parasite-chaetognath species assemblages in the Mexican Central Pacific before and during El Niño 1997–1998

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Table S1. Historic records of nine types of parasites that interact with chaetognaths and infection site reported from studies carried out in the Pacific Ocean. A = Acanthocephala, AG = Apicomplexa Gregarinidae, Ba = Bacteria, Ce = Cestoda, Ci = Ciliata, Di = Digenea, Dino = Dinoflagellata, N = Nematoda, Po = Polychaeta, and Up = Unidentified parasites. Records are shown in chronological order

References	Area of study	Chaetognath host species	Parasites		
			Type	Taxon	Site of infection
Shimazu (1978)	Suruga Bay, Japan	<i>Aidanosagitta neglecta</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Aidanosagitta regularis</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Ferosagitta ferox</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Flaccisagitta enflata</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Serratosagitta pacifica</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Zonosagitta nagae</i>	Di	<i>Monilicaecum</i> type	Trunk coelom
		<i>Flaccisagitta enflata</i>	Di	<i>Tetrochetus</i> sp.	Trunk coelom
		<i>Flaccisagitta enflata</i>	Di	<i>Guschanskiana</i> sp.	Trunk coelom
		<i>Flaccisagitta enflata</i>	Di	<i>Guschanskiana</i> sp.	Trunk coelom
		<i>Mesosagitta minima</i>	Di	<i>Torticaecum</i> type	Trunk coelom
		<i>Eukrohnia hamata</i>	Ce	Tetraphyllidea	Trunk coelom
		<i>Pterosagitta draco</i>	Ce	Tetraphyllidea	Trunk coelom
		<i>Pterosagitta draco</i>	Up	Unidentified parasites	Trunk coelom
		<i>Flaccisagitta enflata</i>	Up	Unidentified parasites	Trunk coelom

References	Area of study	Chaetognath host species	Parasites		
			Type	Taxon	Site of infection
		<i>Serratosagitta pacifica</i>	Up	Unidentified parasites	Trunk coelom
Nagasawa & Marumo (1979)	Suruga Bay, Japan and East China Sea	<i>Aidanosagitta nagae</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Aidanosagitta neglecta</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Aidanosagitta regularis</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Ferosagitta ferox</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Flaccisagitta enflata</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Krohnitta pacifica</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Serratosagitta pacifica</i>	AG	<i>Lankesteria leuckarti</i>	Gut
		<i>Flaccisagitta enflata</i>	Ci	<i>Metaphrya sagittae</i>	Body cavity
		<i>Serratosagitta pacifica</i>	Ci	<i>Metaphrya sagittae</i>	Body cavity
		<i>Zonosagitta nagae</i>	Ci	<i>Metaphrya sagittae</i>	Body cavity
		<i>Aidanosagitta neglecta</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Aidanosagitta regularis</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Ferosagitta ferox</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Flaccisagitta enflata</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Mesosagitta minima</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Serratosagitta pacifica</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Zonosagitta nagae</i>	Di	<i>Monilicaecum</i> type	Body cavity
		<i>Eukrohnia hamata</i>	Ce	Tetraphyllidea	Body cavity
		<i>Flaccisagitta enflata</i>	Ce	Tetraphyllidea	Body cavity
		<i>Pterosagitta draco</i>	Ce	Tetraphyllidea	Body cavity
<i>Serratosagitta pacifica</i>	Ce	Tetraphyllidea	Body cavity		
Shimazu (1979)		<i>Sagitta</i> sp.	AG	<i>Lankesteria leuckarti</i>	Trunk coelom
Shimazu (1982)	Suruga Bay, Japan	<i>Flaccisagitta enflata</i>	Di	<i>Guschanskiana</i> sp.	Trunk coelom
		<i>Caecosagitta macrocephala</i>	Di	<i>Tetrochetus</i> sp.	Trunk coelom
		<i>Flaccisagitta enflata</i>	Di	<i>Tetrochetus</i> sp.	Trunk coelom
		<i>Sagitta</i> sp.	Di	<i>Tetrochetus</i> sp.	Trunk coelom
		<i>Aidanosagitta crassa</i>	Di	Metacercariae I	Trunk coelom
		<i>Caecosagitta</i>	Di	Metacercariae I	Trunk coelom

References	Area of study	Chaetognath host species	Parasites		
			Type	Taxon	Site of infection
		<i>macrocephala</i>			
		<i>Flaccisagitta enflata</i>	Di	Metacercariae I	Trunk coelom
		<i>Flaccisagitta hexaptera</i>	Di	Metacercariae I	Trunk coelom
		<i>Sagitta</i> sp.	Di	Metacercariae I	Trunk coelom
		<i>Aidanosagitta crassa</i>	Di	Metacercariae II	Trunk coelom
		<i>Aidanosagitta crassa</i>	Di	Metacercariae III	Trunk coelom
	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Di	<i>Tergestia</i> sp.	Trunk coelom
	East China Sea	<i>Flaccisagitta enflata</i>	Di	<i>Lecithocladium</i> sp.	Caudal septum
		<i>Zonosagitta nagae</i>	Di	<i>Lecithocladium</i> sp.	Caudal septum
	Suruga Bay, Japan	<i>Flaccisagitta enflata</i>	Di	<i>Lecithocladium</i> sp.	Caudal septum
		Unidentified chaetognath	Di	<i>Parahemiurus</i> sp.	Trunk coelom
	South China Sea	<i>Flaccisagitta enflata</i>	Di	Hemiuridae	Trunk and caudal septum
		<i>Heterokrohnia</i> sp.	Di	Hemiuridae	Trunk and caudal septum
	South China Sea	<i>Flaccisagitta enflata</i>	Ce	<i>Scolex pleuronectis</i>	Trunk coelom
	Japanese Pacific waters	<i>Eukrohnia hamata</i>	Ce	Phyllobothriidae gen. sp.	Trunk coelom
	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Ce	Phyllobothriidae gen. sp.	Trunk coelom
Nagasawa et al. (1984)	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Ba	<i>Flexibacter</i> type	Tegument trunk (external)
	Suruga Bay, Japan	<i>Zonosagitta nagae</i>	Ba	Damage bacteria	Tegument trunk (external)
		<i>Serratosagitta pacifica</i>	Ba	Damage bacteria	Tegument trunk (external)
Nagasawa & Marumo (1984)	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Di	<i>Tergestia</i> sp.	
Nagasawa (1985)	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Ba	Damage bacteria	Tegument trunk (external)
		<i>Sagitta helenae</i>	Ba	Damage bacteria	Tegument trunk (external)
		<i>Zonosagitta nagae</i>	Ba	Damage bacteria	Tegument trunk (external)
		<i>Sagitta helenae</i>	Po	Polychaeta	
Nagasawa et al. (1985)	Tokyo Bay, Japan	<i>Aidanosagitta crassa</i>	Ba	Damage bacteria	Tegument trunk (external)
Horiguchi & Ohtsuka (2001)	Seto Inland Sea, Japan	<i>Aidanosagitta crassa</i>	Dino	<i>Oodinium inlancidicum</i>	Head, caudal septum and fins
Ohtsuka et al. (2004)	Seto Inland Sea, Japan	<i>Aidanosagitta crassa</i>	Ci	<i>Vampyrophrya</i>	Gut

References	Area of study	Chaetognath host species	Parasites		
			Type	Taxon	Site of infection
		<i>Flaccisagitta enflata</i>	Ci	<i>pelagica</i> <i>Vampyrophrya pelagica</i>	Gut
		<i>Zonosagitta bedoti</i>	Ci	<i>Vampyrophrya pelagica</i>	Gut
Lozano-Cobo et al. (2012)	Upper Gulf of California, Mexico	<i>Parasagitta euneritica</i>	Di	<i>Parahemiurus</i> sp.	Gut and trunk coelom
		<i>Parasagitta euneritica</i>	Di	<i>Brachyphallus</i> sp.	Gut and trunk coelom
		<i>Parasagitta euneritica</i>	Di	<i>Hemiurus</i> sp.	Gut and trunk coelom
		<i>Flaccisagitta enflata</i>	Ce	Tetraphyllidea	Gut and trunk coelom
		<i>Parasagitta euneritica</i>	Ce	Tetraphyllidea	Gut and trunk coelom
Lozano-Cobo et al. (2017)	Mexican Central Pacific	<i>Flaccisagitta enflata</i>	A	<i>Corynosoma</i> sp.	Trunk coelom
		<i>Flaccisagitta hexaptera</i>	A	<i>Corynosoma</i> sp.	Head and caudal septum
		<i>Zonosagitta bedoti</i>	A	<i>Corynosoma</i> sp.	Trunk coelom
González-Solís & Gasca (2018)	Gulf of California	<i>Heterokrohnia involucrum</i>	N	<i>Hysterothylacium</i> sp.	Trunk coelom

Table S2. Diagnostic taxonomical characteristics and mean body size (TL = total length and W = width) used to identify each type of epibionts and parasites (28 taxa) observed during the monthly zooplankton time series (1996–1998) collected along the continental shelf of the Mexican Central Pacific

Types of parasites	Reference figures 3 & 4	Size (mm) TL , W	Diagnostic feature	Reference
Cyst	3A-C, 4A-E	0.10, 0.10	Oval shape attached with a glue fluid	No previously reported
Protist sp. 1 (Apicomplexa?)	3H	0.54, 0.07	Elongated cyst	Théodoridès (1989), Leander (2007)
Protist sp. 2	3F	0.06, 0.01	Triangular body shape	
Protist sp. 3 (Ciliata?)	3I	0.07, 0.06	Circular cells similar to <i>Vampyrophrya pelagica</i>	Ohtsuka et al. (2004)
Protist sp. 4 (Dinoflagellate?)	3E	0.15, 0.07	Oval to sigmoid body shape, similar to <i>Blastodinium</i> spp.	Coats et al. (2008)
Protist sp. 5 (Ciliata?)	3D	0.03, 0.03	Spherical to oval shape, similar to <i>Metaphrya sagittae</i>	Ikeda (1917)
Protist sp. 6 (Apicomplexa?)	3G	0.04, 0.02	Oval body shape, similar to Coccidiasina sporozoas	Perkins et al. (2000)
Digenea type 1	3J	0.16, 0.07	Oral and ventral sucker	Yamaguti (1971)
<i>Cercaria owrae</i>	3K, 4F-G	2.10, 0.21	Two posterior cylindric appendages	Dawes (1959)
Accacoelidae sp. 1	3L, 4H	0.32, 0.16	Ventral sucker sessile	Gibson (2002b)
Accacoelidae sp. 2	3M	1.19, 0.09	Ventral sucker on extensible peduncle	Gibson (2002b)
Didymozoidae sp. 1	3N	0.06, 0.05	Contracted specimens	Pozdnyakov & Gibson (2008)
<i>Monilicaecum</i> larva	3O	0.13, 0.04	'Drüsenmagen' present	Pozdnyakov & Gibson (2008)
<i>Paratorticaecum</i> larva	3P	0.27, 0.09	'Drüsenmagen' absent	Pozdnyakov & Gibson (2008)
Hemiuridae sp. 1	3Q, 4I-J	0.43, 0.02	Presence of ecsoma	Gibson (2002a)
<i>Parahemiurus</i> sp.	3R, 4K	0.60, 0.26	Presence of ecsoma, serrated tegument and seminal oval vesicle	Gibson (2002a)
<i>Brachyphallus</i> sp.	3S, 4L	0.38, 0.18	Presence of ecsoma, pit preacetabular and two vitellarium masses slightly indented	Gibson (2002a)
Lepocreadiidae sp.	3T	0.09, 0.07	Body with oval shape. Cuticle slightly spinous. Diffuse	Bray (2005)

Types of parasites	Reference figures 3 & 4	Size (mm) TL , W	Diagnostic feature	Reference
			pigmented band located between both suckers	
Tetraphyllidea sp. 1	3X	0.13, 0.10	Body globular, scolex invaginated, one muscular sucker in each bothridia and one muscular sucker in the middle of the scolex	Shimazu (1978)
Tetraphyllidea sp. 2	3U, 4M	0.33, 0.40	Globular body shape, scolex invaginated, bulbous zone with one muscular sucker, and four thin and elongated bothridia	Shimazu (1978)
Tetraphyllidea sp. 3	3Y, 4N	0.49, 0.42	Globular body shape, scolex invaginated, bulbous zone with four thin and elongated bothridia	Shimazu (1978)
Tetraphyllidea sp. 4	3Z	0.19, 0.18	Globular body shape, scolex invaginated, one muscular sucker in each bothridia	Reimer et al. (1971)
Tetraphyllidea sp. 5	3W	0.51, 0.04	Elongated body shape, segmentation in the middle part of the body. Scolex reduced with bothridia invaginated	Shimazu (1978)
Tetraphyllidea sp. 6	3V	0.73, 0.19	Elongated body shape with the ends of the body truncated and rounded, scolex invaginated and bulbous zone with a elongated bothridia	Shimazu (1978)
<i>Contracaecum</i> sp.	3Ab, 4O-Q	2.68, 0.05	Presence a cephalic tooth between the ventro-lateral lips, presence the intestinal caecum and oesophagus caecum	Hartwich (1975)
<i>Corynosoma</i> sp.	3Ac	0.48, 0.90	Oval body shape and proboscis invaginated	Lozano-Cobo et al. (2017)
Symbiont sp. 1	3Ad	0.26, 0.24	Oval body shape	No previously reported
Symbiont sp. 2	Ae	0.32, 0.19	Oval body shape to elongated	No previously reported

Table S3. NMDS analysis showing the coefficient of determination (r^2) and the Pearson-Kendall (r) correlations with ordination axes for the (A) chaetognath species assemblages (25 sampling months) and (B) parasitized chaetognath species and types of parasites (22 months sampling) as a function of environmental conditions observed during the zooplankton time series (1996–1998) along the continental shelf of the Mexican Central Pacific

Variables	Axis 1			Axis 2		
	r	r^2	tau (τ)	r	r^2	tau (τ)
(A) Chaetognath species						
<i>Aidanosagitta neglecta</i>	0.354	0.125	0.294	-0.2639	0.069	-0.322
<i>Aidanosagitta regularis</i>	-0.410	0.168	-0.339	-0.801	0.642	-0.545
<i>Flaccisagitta enflata</i>	0.592	0.351	0.378	-0.252	0.064	-0.285
<i>Flaccisagitta hexaptera</i>	0.514	0.264	0.292	-0.193	0.037	-0.193
<i>Mesosagitta minima</i>	-0.053	0.003	0.024	-0.713	0.508	0.644
<i>Parasagitta euneritica</i>	-0.565	0.319	-0.417	-0.745	0.555	-0.608
<i>Serratosagitta pacifica</i>	-0.635	0.403	-0.568	-0.606	0.367	-0.553
<i>Serratosagitta pseudoserratodentata</i>	0.210	0.044	0.189	-0.179	0.032	-0.212
<i>Zonosagitta bedoti</i>	0.149	0.022	0.057	-0.636	0.404	-0.367
Environmental conditions						
Thermal Stratification Index (TSI)	-0.9	0.008	-0.047	0.22	0.049	0.073
Temperature at 10m (T10m)	0.119	0.014	0.08	0.118	0.014	0.04
Salinity at 10m (S10m)	0.039	0.002	0.013	-0.245	0.06	-0.133
Mixed Layer Depth (MLD)	-0.191	0.036	0.041	0.312	0.098	0.253
Coastal Upwelling Index (CUI)	0.263	0.069	0.13	-0.506	0.256	-0.29
CUI on sampling day (CUIsam)	-0.55	0.003	-0.057	-0.397	0.158	-0.237
CUI 8 days before sampling (CUIsam-8)	0.7	0.005	0.037	-0.313	0.098	-0.177
(B) Parasitized chaetognath species						
<i>Aidanosagitta regularis</i>	0.305	0.093	0.257	0.108	0.012	0.277
<i>Flaccisagitta enflata</i>	-0.519	0.27	-0.361	0.116	0.013	0.209
<i>Flaccisagitta hexaptera</i>	-0.301	0.9	-0.264	0.138	0.019	0.132
<i>Mesosagitta minima</i>	0.308	0.095	0.244	0.051	0.003	0.158
<i>Parasagitta euneritica</i>	0.321	0.103	0.277	0.079	0.006	0.236
<i>Serratosagitta pacifica</i>	0.018	0.0	0.125	0.183	0.034	0.333
<i>Zonosagitta bedoti</i>	0.574	0.33	0.609	0.266	0.071	0.464
Type of parasites						
Cyst	0.308	0.095	0.438	0.054	0.003	0.072
Protists	0.28	0.001	0.406	0.128	0.016	0.192
Digenea	0.272	0.074	0.372	0.235	0.055	0.492
Cestoda	-0.47	0.221	-0.35	0.038	0.001	-0.033
Acanthocephala	-0.125	0.16	-0.047	-0.015	0.0	-0.171
Nematoda	-0.02	0.0	0.078	-0.075	0.006	-0.183
Unidentified symbionts	-0.179	0.032	-0.051	-0.04	0.002	0.092
Environmental conditions						
Prevalence (P)	0.31	0.096	0.208	0.123	0.015	0.373
Thermal Stratification Index (TSI)	-0.286	0.082	-0.307	0.118	0.014	-0.117
Temperature at 10 m (T10m)	-0.615	0.379	-0.463	0.163	0.026	-0.048
Salinity at 10 m (S10m)	0.476	0.227	0.281	-0.137	0.019	0.022
Mixed Layer Depth (MLD)	-0.246	0.06	-0.277	0.113	0.013	0.057
Coastal Upwelling Index (CUI)	0.266	0.071	0.26	-0.114	0.013	0.017
CUI on sampling day (CUIsam)	0.049	0.002	0.069	-0.062	0.004	0.043
CUI 8 days before sampling (CUIsam-8)	0.345	0.119	0.174	-0.208	0.043	-0.052

Table S4. MRPP analysis for comparison of the abundance assemblages of (A) community structure of chaetognath species and (B) parasitized chaetognath species and type of parasites as a function of significant coefficients of determination calculated in the NMDS analysis. A is a descriptor of within-group homogeneity compared to random expectations ($A = 1 - [\text{observed delta}/\text{expected delta}]$). $A_{\text{max}} = 1$ when all items are identical within groups (delta = 0); $A = 0$ when heterogeneity equals chance expectation, A has a negative value when there is less agreement within station groups than expected by chance. This statistical test generates a p -value to evaluate the likelihood that an observed difference occurred by chance. Significant p -values are shown in bold font

Group of months sampled tested for the following null hypotheses (H_0)	t -statistic	A	p -value
(A) Community structure of chaetognath species			
Semi Mixed period vs. Mixed period vs. Stratified period	0.737	-0.021	0.751
Normal conditions vs. El Niño 1997–98 influence	-1.180	0.0246	0.117
Years sampled: 1996 vs. 1997 vs. 1998	-8.977	0.268	<0.001
Temporal groups defined by NMDS: A_1 vs. A_2 vs. A_3 vs. A_4	-12.010	0.364	<0.001
(B) Parasitized chaetognath species and types of parasites			
Semi Mixed period vs. Mixed period vs. Stratified period	0.312	-0.0096	0.568
Normal conditions vs. El Niño 1997–98 influence	-1.247	0.0269	0.111
Years sampled: 1996 vs. 1997 vs. 1998	-0.318	0.0098	0.324
Temporal groups defined by NMDS: C_1 vs. C_2 vs. C_3 vs. C_4	-5.56	0.2515	<0.001

Table S5. Indicator Species Analysis for (A) community structure of chaetognath species and (B) parasitized chaetognath species and type of parasites in the temporal sampling period, showing only species with significant fidelity ($p < 0.05$) to a specific period. Monte Carlo test of significance of observed maximum indicator value for species is showing the proportion of randomized trials with indicator value equal to or exceeding the observed indicator value, $p = (1 + \text{number of run} \geq \text{observed}) / (1 + \text{number of randomized runs})$. Significant Monte Carlo p -values are shown in bold font

Indicator species	Indicator group	Observed Indicator Value (IV)	Mean	Standard deviation	Monte Carlo p -value
(A) Community structure of chaetognath species					
Semi Mixed period vs. Mixed period vs. Stratified period					
<i>Aidanosagitta neglecta</i>	Mixed period	12.00	15.1	8.24	0.7598
<i>Mesosagitta minima</i>	Mixed period	27.30	31.7	7.30	0.6913
<i>Serratosagitta pseudoserratodentata</i>	Mixed period	11.1	12.0	1.44	1.0000
Normal conditions vs. El Niño 1997–98 influence					
<i>Aidanosagitta neglecta</i>	Normal conditions	17.60	13.9	6.73	0.5329
<i>Mesosagitta minima</i>	Normal conditions	40.70	39.8	8.20	0.4005
<i>Serratosagitta pseudoserratodentata</i>	Normal conditions	5.9	8.0	3.10	1.0000
Years sampled: 1996 vs. 1997 vs. 1998					
<i>Aidanosagitta neglecta</i>	1996 sampled	30.00	15.1	8.23	0.0932
<i>Mesosagitta minima</i>	1996 sampled	45.40	31.8	7.37	0.0505
<i>Serratosagitta pseudoserratodentata</i>	1996 sampled	10.0	12.0	1.79	1.0000
Groups defined by NMDS: A₁ vs. A₂ vs. A₃ vs. A₄					
<i>Aidanosagitta neglecta</i>	A ₁	23.10	15.9	8.89	0.2653
<i>Mesosagitta minima</i>	A ₁	66.40	32.7	8.0	0.0004
<i>Serratosagitta pseudoserratodentata</i>	A ₁	7.7	12.1	4.92	1.0000
(B) Parasitized chaetognath species and type of parasites					
Semi Mixed period vs. Mixed period vs. Stratified period					
<i>Aidanosagitta regularis</i>	Mixed period	7.50	14.4	8.39	1.0000
<i>Flaccisagitta hexaptera</i>	Semi Mixed period	26.70	31.1	7.73	0.6901
<i>Mesosagitta minima</i>	Mixed period	12.50	13.6	1.85	1.0000
<i>Parasagitta euneritica</i>	Mixed period	25.00	14.4	8.40	0.2963
<i>Serratosagitta pacifica</i>	Semi Mixed period	33.30	14.0	8.94	0.0678
<i>Zonosagitta bedoti</i>	Mixed period	25.00	25.9	9.18	0.5471
Cyst	Mixed period	77.30	59.1	13.58	0.1012
Protists	Semi Mixed period	40.00	33.9	12.87	0.3229
Digenea	Mixed period	34.30	39.1	9.33	0.6485
Cestoda	Stratified period	58.20	41.2	9.31	0.0552
Acanthocephala	Semi Mixed period	19.00	19.0	9.18	0.5291
Nematoda	Mixed period	16.70	17.0	8.82	0.5301
Unidentified symbionts	Stratified period	25.00	16.9	7.06	0.3181
Normal conditions vs. El Niño 1997–98 influence					
<i>Aidanosagitta regularis</i>	El Niño 1997–98 influence	7.40	12.9	5.34	1.0000
<i>Flaccisagitta hexaptera</i>	El Niño 1997–98 influence	58.40	37.7	8.62	0.0682
<i>Mesosagitta minima</i>	Normal conditions	6.70	9.0	3.52	1.0000
<i>Parasagitta euneritica</i>	Normal conditions	13.30	13.0	5.47	0.5595
<i>Serratosagitta pacifica</i>	El Niño 1997–98 influence	28.60	13.0	5.00	0.0834
<i>Zonosagitta bedoti</i>	Normal conditions	24.80	29.4	9.16	0.7141
Cyst	Normal conditions	47.60	59.4	11.12	0.8802
Protists	El Niño 1997–98 influence	24.00	33.6	10.65	0.8314

Indicator species	Indicator group	Observed Indicator Value (IV)	Mean	Standard deviation	Monte Carlo <i>p</i> -value
Digenea	El Niño 1997–98 influence	47.10	48.9	9.88	0.4893
Cestoda	El Niño 1997–98 influence	39.00	51.5	9.81	0.9532
Acanthocephala	Normal conditions	11.70	19.1	8.16	1.0000
Nematoda	El Niño 1997–98 influence	23.20	14.9	8.21	0.2204
Unidentified symbionts	El Niño 1997–98 influence	13.60	12.9	5.91	0.3241
Years sampled: 1996 vs. 1997 vs. 1998					
<i>Aidanosagitta regularis</i>	1998 sampled	7.10	14.7	8.38	0.8670
<i>Flaccisagitta hexaptera</i>	1998 sampled	26.40	31.1	8.17	0.8624
<i>Mesosagitta minima</i>	1996 sampled	11.10	13.7	2.30	1.0000
<i>Parasagitta euneritica</i>	1996 sampled	22.20	14.5	8.30	0.3001
<i>Serratosagitta pacifica</i>	1998 sampled	9.00	14.4	8.47	0.7213
<i>Zonosagitta bedoti</i>	1996 sampled	33.10	25.9	9.21	0.2118
Cyst	1996 sampled	55.90	59.6	13.68	0.6379
Protists	1996 sampled	12.30	34.1	12.95	0.9822
Digenea	1996 sampled	47.70	39.1	9.19	0.1662
Cestoda	1996 sampled	37.30	41.6	9.37	0.6261
Nematoda	1998 sampled	25.00	16.9	9.25	0.1826
Acanthocephala	1996 sampled	9.30	19.2	9.05	1.0000
Unidentified symbionts	1997 sampled	13.10	17.0	7.39	0.6593
Groups defined by NMDS: A₁ vs. A₂ vs. A₃ vs. A₄					
<i>Aidanosagitta regularis</i>	A ₁	25.00	23.6	15.59	0.4623
<i>Flaccisagitta hexaptera</i>	A ₂	28.80	33.3	10.40	0.6703
<i>Mesosagitta minima</i>	A ₁	12.50	18.1	14.93	0.5507
<i>Parasagitta euneritica</i>	A ₁	25.00	23.3	15.18	0.4603
<i>Serratosagitta pacifica</i>	A ₁	25.00	23.8	15.84	0.4683
<i>Zonosagitta bedoti</i>	A ₁	100.00	30.0	15.51	0.0002
Cyst	A ₁	79.80	58.5	17.34	0.1388
Protists	A ₁	71.50	36.0	17.45	0.0600
Digenea	A ₁	84.20	39.6	11.70	0.0002
Cestoda	A ₂	57.80	40.6	11.89	0.1094
Acanthocephala	A ₂	21.20	28.0	13.59	0.7405
Nematoda	A ₂	12.30	27.2	14.17	1.0000
Unidentified symbionts	A ₂	8.80	21.8	14.68	1.0000

References for Supplemental Material (Tables S1 and S2)

Bray RA (2005) 45 Family Lepocreadiidae Odhner, 1905, In Jones A, Bray RA, Gibson DI (eds), Keys to the Trematoda, Vol 2, CAB International and Natural History Museum, London, p 545–602

Coats DW, Bachvaroff T, Handy SM, Kim S, Gárate-Lizárraga I, Delwiche CF (2008) Prevalence and phylogeny of parasitic dinoflagellates (Genus *Blastodinium*) infecting copepods in the Gulf of California. *CICIMAR Océánides* 23:67–77

Dawes B (1959) On *Cercaria owrae* (Hutton, 1954) from *Sagitta hexaptera* (d'Orbigny) in the Caribbean Plankton. *J Helminthol* 33:209–222

Gibson DI (2002a) 37 Family Hemiuridae Looss, 1899, p 305–340 In Gibson DI, Jones A, Bray RA (eds), Keys to the Trematoda Volume 1, CAB International and Natural History Museum, London

Gibson DI (2002b) 38 Family Accacoeliidae Odhner, 1911, p 341–347 In Gibson DI, Jones A, Bray RA (eds), Keys to the Trematoda Volume 1, CAB International and Natural History Museum, London

- González-Solís D, Gasca R (2018) First record of the bathy-pelagic chaetognath *Heterokrohnia involucrem* Dawson, 1968 in the Gulf of California and its association with a parasitic Nematode. *Thalassas Int J Mar Sci* 34(1):227–232
- Hartwich G (1975) No. 2 Keys to genera of the Ascaridoidea, p 1–15 In Anderson RC, Chabaud AG, Willmott S (eds), *CIH Keys to the nematode parasites of vertebrates*. Commonwealth Agricultural Bureaux International, Farnham Royal, UK
- Horiguchi T, Ohtsuka S (2001) *Oodinium inlandicum* sp. nov. (Blastodiniales, Dinophyta), a new ectoparasitic dinoflagellate infecting a chaetognath, *Sagitta crassa*. *Plankton Biol Ecol* 48:85–95
- Ikeda I (1917) A new astomatous ciliate, *Metaphrya sagittae*, gen et sp. nov., found in the coelom of *Sagitta*. *The Zoological Society of Japan* 317–324
- Leander BS (2007) Marine gregarines: evolutionary prelude to the apicomplexan radiation? *Trends Parasitol* 24:60–67
- Lozano-Cobo H, Gómez del Prado-Rosas MC, Cota-Meza MS, Pacheco-Chávez M, Sánchez-Velasco L (2012) Helmintos parásitos en chaetognatos en el Alto Golfo de California, México. *Biologist (Lima), Biología y ecología de infecciones parasitarias*. 10(Suppl 2):32. http://sisbib.unmsm.edu.pe/BVRevistas/biologist/v10_sup2/contenido.htm
- Lozano-Cobo H, Gómez-Gutiérrez J, Franco-Gordo MC, Gómez del Prado-Rosas MC (2017) The discovery of acanthocephalans parasitizing chaetognaths. *Acta Parasitol* 62:401–411
- Nagasawa S (1985) Ecological significance of deformed chaetognaths associated with bacteria. *Bull Mar Sci* 37:139–141
- Nagasawa S, Marumo R (1979) Identification of chaetognaths based on the morphological characteristics of hooks. *Mer (Tokyo)* 17:177–188
- Nagasawa S, Marumo R (1984) Feeding habits and copulation of Chaetognath *Sagitta crassa*. *Mer (Tokyo)* 22:8–14
- Nagasawa S, Simidu U, Nemoto T (1984) Bacterial invasion of chaetognaths under laboratory and natural conditions. *J Oceanogr Soc Jpn* 40:327–333
- Nagasawa S, Simidu U, Nemoto T (1985) Scanning electron microscopy investigation of bacteria colonization of the marine copepod *Acartia clausi*. *Mar Biol* 87:61–66
- Ohtsuka S, Hora M, Suzaki T, Arikawa M, Omura G, Yamada K (2004) Morphology and host-specificity of the apostome ciliate *Vampyrophrya pelagica* infecting pelagic copepods in the Seto Inland Sea, Japan. *Mar Ecol Prog Ser* 282:129–142
- Perkins FO, Barta JR, Clopton RE, Pierce MA, Upton SJ (2000) Phylum Apicomplexa, p 190–369 In Lee JJ, Leedale GF, Bradbury P (eds), *An Illustrated guide to the Protozoa: organisms traditionally referred to as protozoa, or newly discovered groups* (2nd edition), Society of Protozoologists, USA

Pozdnyakov SE, Gibson DI (2008) 65 Family Didymozoidae Monticelli, 1888, p 631–734 In Bray RA, Gibson DI, Jones A (eds), Keys to the Trematoda, Volume 3. CAB International and Natural History Museum, London

Reimer LW, Berger C, Hewer B, Lainka H, Rosenthal I, Scharnweber L (1971) On the distribution of larvae of helminths in plankton animals of the North Sea. *Parasitologiya (Leningrand)* 5:542–550

Shimazu T (1978) Some helminth parasites of the Chaetognatha from Suruga Bay, central Japan. *Bull Natl Sci Mus (Jpn) A* 4:105–116

Shimazu T (1979) Some protozoan parasites of the Chaetognatha from Suruga Bay, central Japan. *J Parasitol* 28: 51–55

Shimazu T (1982) Some helminth parasites of marine plankton invertebrates. *J Naganoken Junior Coll* 37:11–29

Théodoridès J (1989) Parasitology of marine zooplankton. *Adv Mar Biol* 25:117–177

Yamaguti S (1971) Synopsis of digenetic trematodes of vertebrates, Parts I and II. Keigaku Publishing, Tokyo