

OCEANIC DISTRIBUTION OF *EVADNE* IN THE EASTERN PACIFIC
(CLADOCERA) ¹⁾

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While examining samples from the multiple serial plankton recorder (Longhurst et al., 1966) from the "Eastropac" expeditions, we encountered several stations more than 1000 miles offshore at which abundant cladocerans occurred in the upper mixed layer. Earlier reviews (e.g. Ramner, 1933), and recent general texts on plankton ecology (e.g. Wickstead, 1965) have suggested that cladocerans are, in general, neritic organisms, and since our samples included stations in the South Pacific central gyre, we were prompted to survey, in a rather summary fashion, the nature of the distribution of *Evadne* in the eastern part of the Pacific Ocean.

The samples examined were taken at 1011 stations, of which 927 were from the "Eastropac" expeditions, from the American coast out to about 125°W, while the remaining 84 stations were selected from earlier cruises ("Tethys", "Downwind", "Norpac", "Capricorn", etc.) to give coverage farther to the west, as far as 170°W.

The samples came, for the most part, from simple non-closing nets hauled obliquely towards the surface, mostly with a rather fine (0.3 mm) mesh. Some samples (246) were from surface tows taken with coarser nets (0.5 mm) for special purposes during the "Eastropac" cruises. No attempt was made to quantify the data on *Evadne*, since surface organisms are very irregularly sampled by such techniques as were used. Aliquots were examined of each sample for presence of specimens of *Evadne* and categorized simply as (1) absent, (2) rare (<10 specimens), and (3) abundant (>10 specimens); stations were re-examined from much larger aliquots when the initial data plots indicated negative areas in which, either a priori or because of the distribution of positive samples, we were surprised to find no *Evadne*. Thus, we are confident that the negative areas in our distributions are reasonably correct, summary though our survey was.

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All specimens sorted from the 129 "Eastropac" stations at which *Evadne* occurred were sexed, and females were examined for presence of embryos in the brood pouch; although extremely summary, these data serve to indicate something of the reproductive biology of *Evadne* in the tropical ocean, and are summarized in table I.

Two species were encountered in the samples: specimens having divergent antennal musculature and a terminal spine and which appear to be similar to *Evadne spinifera* Müller, 1868, of the Atlantic, and specimens having parallel

TABLE I
Occurrence of males and of embryo-bearing females in the "Eastropac" samples

		northern hemisphere winter				northern hemisphere summer		
Area (see page 243)		A	B	C	D	A	B	D
Number of stations		32	13	7	14	55	3	2
Number with <i>E. tergestina</i>	♂ ♂	4	—	—	—	4	—	—
Number with <i>E. tergestina</i>	♀ ♀	29	13	7	—	54	3	2
Number of embryos/female	0	169	37	37	—	395	5	4
	1	1	—	—	—	2	—	—
	2	2	—	1	—	4	—	1
	3	12	1	1	—	8	—	—
	4	12	1	5	—	7	—	—
	5	7	3	—	—	—	1	—
	6	—	4	5	—	—	3	—
	7	—	—	—	—	—	1	—
	8	1	—	—	—	—	1	—
Number with <i>E. spinifera</i>	♂ ♂	—	—	—	—	—	—	—
Number with <i>E. spinifera</i>	♀ ♀	6	—	—	14	1	—	—
Number of embryos/female	0	26	—	—	129	1	—	—
	1	—	—	—	1	—	—	—
	2	—	—	—	2	—	—	—
	3	—	—	—	10	—	—	—
	4	—	—	—	5	—	—	—
	5	5	—	—	5	—	—	—
	6	—	—	—	—	—	—	—
	7	—	—	—	1	—	—	—
	8	—	—	—	—	—	—	—

antennal muscles and a rounded posterior profile and which are apparently referable to *Evadne tergestina* Claus, 1877. The second species was much more common than *E. spinifera*, which was restricted to certain areas. No critical examination of the specimens was made, but it is expected that they may not prove to be identical with Atlantic forms.

The apparent distribution of *Evadne* in the samples is indicated in figures 1 to 3, which show, successively, its distribution in the eastern tropical Pacific during the northern hemisphere winter; in the same region during the northern hemisphere summer; and over the whole eastern Pacific, for all seasons combined.

In the eastern tropical Pacific region the major differences in the surface circu-

lation between northern summer and winter conditions are: (1) the extent towards the coast, at around 10°N , of the Equatorial Countercurrent; (2) the extent and strength of the equatorial divergence west of the Galapagos Islands; (3) the direction and strength of the coastal currents off the west coast of Mexico. In addition, the temperature regime and the position of the thermal fronts to the north and south of the tropical regions are, of course, modified by the migration of the meteorological intertropical convergence zone.

The distribution of specimens of *Evadne* in seven samples from the multiple serial plankton sampler indicated that it occurs only in the upper part of the mixed layer in the tropical ocean. Table II shows two typical depth distributions for each species. Typically, *E. tergestina* occurred only in the surface sample, taken usually over a depth range less than the upper 10 m of the water column; *E. spinifera*, in its main area of distribution south of the equator, occurred rather deeper — down to 20 m at one station — as would be expected from the very deep mixed layer in this area. These data indicate, in summary, that *Evadne* in the eastern Pacific is an epiplankter of very shallow distribution.

DISTRIBUTION OF EVADNE TERGESTINA

Northern winter. — Samples from "Eastropac" cruises 11, 12, 13, and 14 which were concurrent during February-March 1967, showed that *E. tergestina* occurred

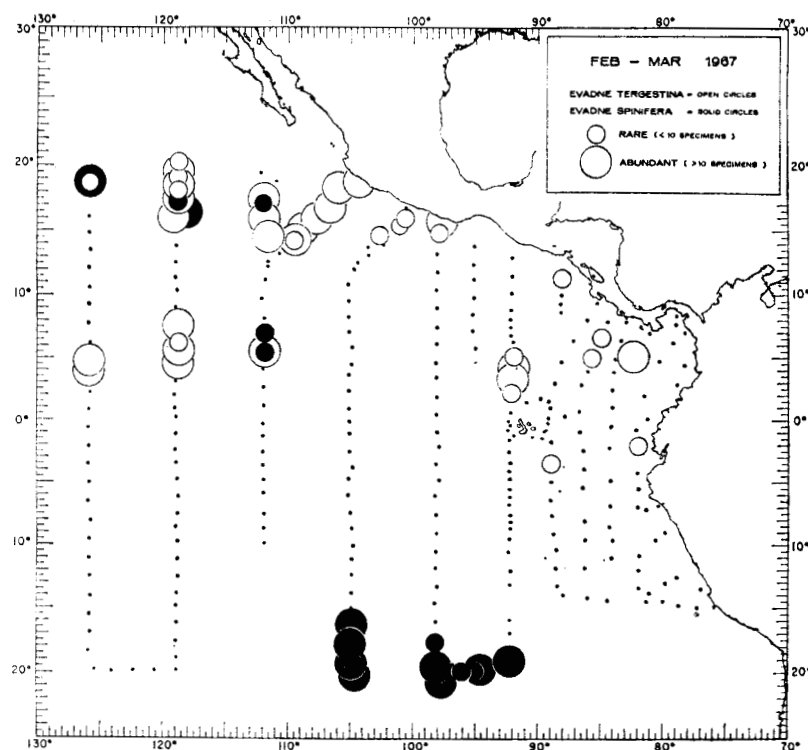


Fig. 1. Distribution of *Evadne* in the eastern tropical Pacific during the northern hemisphere winter.

TABLE II

The vertical distribution of *Evadne* in four typical multiple serial plankton sampler profiles. Numbers of individuals per 100 m³ filtered

Sample	<i>Evadne tergestina</i>				<i>Evadne spinifera</i>			
	12.018		12.244		12.154		12.164	
	Z(m)	No.	Z(m)	No.	Z(m)	No.	Z(m)	No.
1	0	201	0	167	0	548	0	110
2	8	—	10	—	4	92	12	177
3	26	—	20	12	7	27	15	88
4	48	—	35	—	10	—	25	69
5	60	—	45	5	20	—	40	36
6	78	—	60	—	30	—	55	37
7	96	—	75	—	40	—	70	56
8	110	—	80	—	50	—	80	11
9	123	—	95	—	60	—	90	—
10	138	—	110	—	70	—	110	—
11	160	—	120	—	80	—	120	—
12	175	—	135	—	85	—	135	—
13	195	—	140	—	90	—	150	—
14	210	—	155	—	105	—	105	—
15	235	—	165	—	115	—	180	—
16	252	—	180	—	125	—	195	—
17	280	—	195	—	130	—	200	—
18	290	—	205	—	135	—	220	—
19	300	—	220	—	145	—	230	—
20	318	—	230	—	150	—	240	—

in three areas of the eastern tropical Pacific (fig. 1): (A) in a belt along the western coast of Mexico and Guatemala, and extending offshore to 125°W from the latitude of central Mexico at 15 to 20°N; (B) in a zonal belt from 2°N to about 8°N far offshore, isolated from (A), and extending from about 110 to 125°W; and (C) a number of stations westwards and offshore from Ecuador and Columbia forming a less coherent distribution pattern than (A) or (B).

Within (A) most stations were positive for *E. tergestina*; the range of the species here appears to relate to the coastal current along the Central American coast, and to the southwest transport of California Current water from the region to the south of Baja California and off the mouth of the Gulf of California. The "Eastropac" stations do not indicate whether or not *E. tergestina* occurs widely north of 20°N in these longitudes, but it is likely to do so at least to 25°N off the Baja California coast; an earlier cruise (TO-64-1), at which 50 stations were scanned for *Evadne*, showed a concentration of records to the south of the Cape San Lucas Front at 23°N. and only a single occurrence farther to the north, near Punta Eugenio.

About 40% of all samples from region A showed reproductive activity, and males were present in the aliquots examined from four; females carrying three and four embryos dominated, though the number of embryos ranged from 1 to 8.

The isolated tongue of stations lying zonally about 5°N and centered at about 120°W is correlated with an incursion of warmer water from the west, being warmer than 27°C , and representing the eastward end of the Equatorial Counter-Current at a period of the year when it is least well developed in these longitudes. No males were found but embryo-bearing females occurred as frequently as in the region off the west coast of Mexico, although modal numbers of embryos appeared somewhat higher.

Between these two areas in which *E. tergestina* occurs there lies a zone in which no cladocerans were found; the reality of this zone of negative stations is based on scanning more than 70 stations, most of them with a second, confirmatory scan on a large aliquot. The zone may represent the westward flow described by Wyrcki (1965), and recognizable in the "Eastropac" physical data, which appears to originate to the south of the Costa Rica Dome and by which route some Peru Current water may find its way to the northwest.

In the third area, to the west of Costa Rica, Columbia and Ecuador, the positive records are grouped in a few locations and appear to be correlated with the distribution of warmer water; for instance, the fact that there were no records in the Gulf of Panama is probably due to the existence there of upwelling conditions at this season, seen clearly in the surface temperature distribution for February 1967. Thus, the two sets of positive stations at around 5°N are in tongues of warm water extending around the Costa Rica Dome from the coastal region; the record to the south of the Galapagos is in a tongue of warm water extending south around the Ecuadorian frontal region and the record off the Ecuadorian coast is on the warm side of this front.

Four of the samples at approximately 5°N to the west of Costa Rica and the Galapagos Islands included embryo-bearing females carrying high numbers of embryos; neither of the two samples from south of the equator showed evidence of breeding.

Northern summer. — Samples from "Eastropac" cruises 45, 46, and 47 worked during August and September 1967, showed some interesting differences from the winter pattern of distribution. At this season the northern Equatorial Counter-current is well developed and extends in a zonal band across almost the entire region, and this evidently is causative of the very considerable southerly extension of the area west of Mexico which is occupied by *E. tergestina*. The species was widespread, as during the winter period, and all except 8 of the 65 stations within this area were positive for *E. tergestina*; double-checking of samples to the south of this area served only to confirm the distributional boundary at 7 to 10°N . This boundary lies within the Equatorial Countercurrent for most of its length and coincides neither with its northerly nor southerly boundaries as shown by average climatology (Wyrcki, 1965). As during the winter survey, only a very small number of samples contained males, while the percentage with breeding females was about half what it was during the winter survey; the number of embryos

per female (predominantly 3 to 4) was similar to the number during the winter and lower than found in populations in lower latitudes.

The occurrence of positive records in the Gulf of Panama is probably related to the lack of upwelling during these months, and the stations close to the coast which introduce a gap in the continuity of the coastal distribution of the species off Costa Rica are in a region where the Costa Rica Dome induces lowered surface temperatures. Reproduction was active in this season in the Gulf of Panama and along Costa Rica, all samples containing embryo-bearing females; these were again very fecund, ranging from 5 to 8 embryos (mode 6) per female.

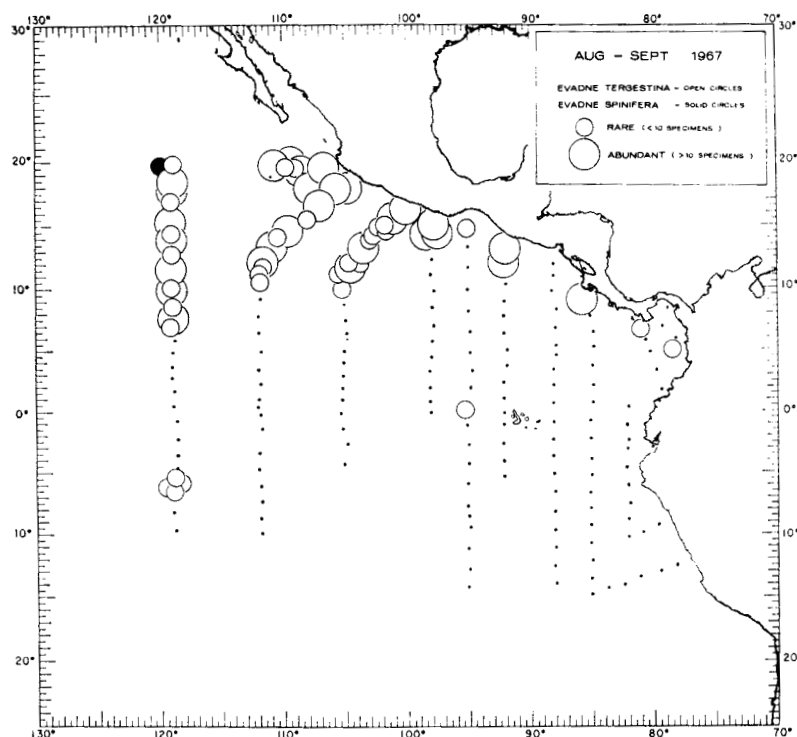


Fig. 2. Distribution of *Evadne* in the eastern tropical Pacific during the northern hemisphere summer.

The most curious occurrence is the single positive station close to the equator at 95°W; this is on the edge of the equatorial divergence, west of the Galapagos Islands in relatively cool water of 23°C and is completely isolated from other records. The positive stations at 5°S of the equator and 120°W are in a tongue or intrusion of warm water, open to the westward and which may represent the South Equatorial Countercurrent. Neither males nor embryo-bearing females occurred in these areas.

Eastern Pacific all seasons. — The data combined from 84 stations from earlier research cruises over the eastern Pacific confirmed that *E. tergestina* is not a neritic

species; however, the "Norpac" samples indicate that the major concentration off the Mexican coast does not extend significantly farther to the west than indicated by the "Eastropac" samples. The "Capricorn", "Downwind", and "Monsoon" samples combine to indicate a region at 20°S and 140 to 160°W in which a high percentage of stations indicated the presence of *E. tergestina*; this is the region of the Society, Tuamota, Cook, and Austral Islands, and it is here that islands are most frequent (albeit still sparse) in the area surveyed by these cruises. The relevance of islands to the oceanic distribution of the species may also be indicated

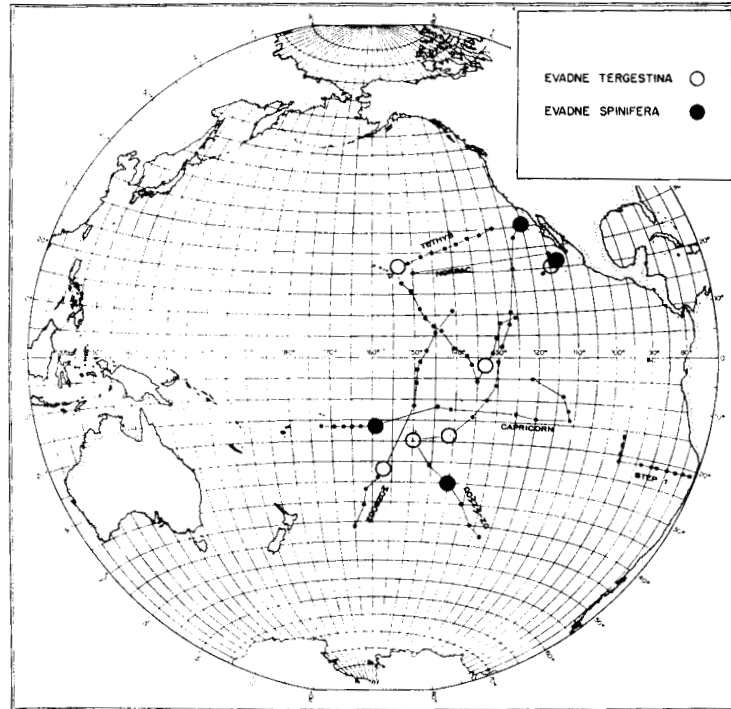


Fig. 3. Distribution of *Evadne* over the whole eastern Pacific, for all seasons combined.

by the other positive records west of the "Eastropac" region: one is just to the northeast of Hawaii, and one rather farther to the north of the Marquesas Islands.

DISTRIBUTION OF EVADNE SPINIFERA

The samples indicated that *E. spinifera* had a distribution quite different from that of *E. tergestina*. During "Eastropac" 11, 12, 13, and 14 in February-March 1967, the sampling lines penetrated southwards through the South Equatorial Current into the northern part of the southern Pacific central gyral water and in this area, at 90 to 110°W and 18 to 20°S, *E. spinifera* occurred in almost all the samples, sometimes abundantly. No specimens of *E. tergestina* were found in this area.

This group of occurrences lies in relatively cool ($<24^{\circ}\text{C}$) water and the location of isotherms from "Eastropac" data and the surface flow vectors of Wyrski (1965) combine to demonstrate that only those station lines which indicated *E. spinifera* distribution penetrated to the region of gyral flow; to the west, the station line at 126°W did not do so and no *Evadne* were found even in its most southerly station, nor were any found in the most southerly stations of cruise 14, off the Peruvian and Chilean coasts.

Otherwise, at two stations in the winter and at one in the summer, *E. spinifera* occurred alongside the more common species. All these occurrences were in the northwestern corner of the "Eastropac" area at around 20°N and 120°W ; the "Norpac" data confirm the occurrence of the species in this region and show it occurring also in North Pacific Central water off San Diego beyond the main stream of the California Current. It was found at only one other station, on "Downwind", in southern gyral water at 120°S 140°W to the southeast of the Austral Islands.

Males were found at only a single station (13.123 at 20°S) where 8 occurred in a sorted sample of 100 individuals. In the northern area off the Mexican coast, females with embryos were found at only a single station in winter and at no stations in the summer survey. However, in the southern area, near 20°S , 50% of the samples contained embryo-bearing females though none included males.

The number of embryos was usually moderate (mode 3) though the range extended to 7 embryos per female. The data from this survey are, of course, only for the southern hemisphere summer and no southern winter data were collected by "Eastropac" from this region, unfortunately.

DISCUSSION

It is remarkable that our records of *E. spinifera* at a group of 14 stations in the South Pacific gyre at about 20°S coincides so precisely with the location of the single previous locality for this species in the eastern Pacific (Ramner, 1933, figure 52). Samples from the Meteor Expedition (Ramner, 1931) and the earlier Plankton-Expedition (Hansen, 1899) had indicated, as summarized by Ramner (1933), that in mid and low latitudes *E. spinifera* occurred both close to the coast and in the open ocean, while *E. tergestina* occurred usually closer to the continents; Ramner's data show mid-ocean distributions of *E. spinifera* in the North Atlantic (Cape Verde Islands to Bermuda), Indian Ocean (5 to 20°S at about 80°E) and Pacific Ocean (noted above, a single station at 17°S 108°W) as well as coastal distributions in all oceans equatorwards of 50° of latitude.

Since Ramner's publication, there have been remarkably few records of ocean-wide distributions of cladocerans, most attention having been given to them in the Mediterranean Sea. Furnestin (1960) and Thiriot (1968) both speak of the neritic character of marine cladoceran distribution, though the former describes *E. spinifera* as the "least neritic" of the species she described.

In the eastern Pacific, Ramner's solitary record of *E. spinifera* has scarcely been added to since the thirties; our data indicate that, in fact, *Evadne* is as widely distributed in this ocean as Ramner showed it to be in the North Atlantic. Moreover, it appears that *E. tergestina*, far from being a neritic species, occurs widely in the great ocean spaces between New Zealand, Polynesia, and the American continent.

Although the evidence is not very clear (so vast is the area), our data suggest that *E. spinifera* in the eastern Pacific is primarily a species of central gyral waters, while *E. tergestina* avoids these water masses and occurs widely but irregularly in warm waters at low latitudes. Such an observation is supported by the data of Thiriot (1968) on three species of *Evadne* in the Mediterranean: he found (1) that *E. tergestina* seems to avoid high concentrations of *E. spinifera* and (2) that *E. spinifera* appears first in the spring and develops large populations in water temperatures of 16 to 21°C, while *E. tergestina* appears only later and has an optimal temperature in excess of 22°C.

Because of his lack of records of *E. spinifera* from the Meteor Expedition in the central South Atlantic, and because of a supposed correlation between its North Atlantic distribution and that of floating *Sargassum* fronds, Rammner (1933) doubted that this was a truly oceanic species. He suggested that the nuchal organ was used for attachment to floating objects in the same manner as in *Sida cristallina* and other fresh-water cladocerans.

We suggest, however, that our data show that at least two species of *Evadne* are members of the oceanic epiplankton, having an ocean-wide distribution in the Indo-Pacific. Moreover, in some oceanic areas at some seasons, both *E. tergestina* and *E. spinifera* occur abundantly and in a high proportion of samples.

RÉSUMÉ

Il est montré, après examen de plus d'un millier d'échantillons de zooplancton de l'Océan Pacifique de l'est, que *Evadne tergestina* et *E. spinifera* sont répandues largement dans l'épiplankton océanique, confirmant ainsi les observations de Rammner pour l'Atlantique Nord. *E. spinifera* vit typiquement dans les régions courants gyroïdes centraux, et *E. tergestina* est répandue plus largement dans les eaux chaudes de la zone tropicale; tous les deux évitent les eaux plus froides des régions d'upwellings même sous l'équateur.

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